1. College of Agriculture and Environmental Sciences

School of Plant Sciences

Root and Tuber Research Activities

Adaptation Trial of Released Potato Varieties (*Solanum tuberosum* L.) in eastern and western Hararghe (ongoing research activity)

By

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Funded by EIAR Grant

Abstract: *Potato varieties released by different Research Centers in the country along with potato varieties improved by Haramaya University have not been tested in eastern Ethiopia. Therefore, this study was initiated with the objective of studying the agronomic performance of nationally and regionally released potato varieties under eastern Ethiopia conditions. The adaptation trial was laid out in randomized complete block design (RCBD) with three replications at three locations. Ten and six potato varieties released by different Research Centers in the country and by Haramaya University, respectively, along with two local cultivars as a check were planted in 2012/13 cropping season and evaluated for yield and yield components. The result of analysis of variance revealed that mean squares for variety, location as well as variety x location were highly significant indicating varieties are performance is different across locations. The total and marketable tuber yield t/ha ranged from 21.19 to 48.616 and 18.109 to 46.69 t/ha. The best four high yielding varieties were Belete, Gera, Marachere and Bubu in that order indicating most of high yielding varieties were obtained from other centers. The research should have to be repeated once more to make recommendation.*

Introduction

Potato (*Solanum tuberosum* L.) is grown in many countries than any other crop in the world. It is the fourth most important crop after the three cereals viz., maize, rice and wheat (Stephen, 1999). Among the root and tuber crops, potato ranks first which is followed by cassava, sweet potatoes and yam. In the densely populated and intensively cultivated highland areas of Eastern and Central Africa, potato is grown primarily by smallholders, both as a cash crop and an important component of household food security (Lawrence, 2004).

In Ethiopia, potato is grown in four major areas: the central, the eastern, the northwestern and the southern. Together, they cover approximately 83% of the potato farmers (CSA, 2008/2009). Among these, the eastern part of the country, particularly east Hararghe only accounts about 3% of the total number of potato growers (CSA 2008/2009). Majority of the potato farmers in this area produce for the market and there is also some export to Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Mulatu *et al*., 2005b). Potato is also produced in the belg (February to May) and the meher (June to October) seasons. Most farmers grow local potato varieties. However, some farmers in the vicinity of Haramaya University and farmers who are targeted by NGO seed programmes have access to improved varieties (Mulatu *et al.*, 2005a). Despite the use of local varieties, the productivity of potato in this area is equivalent to the productivity in the central area. This might be due to good farm management practices triggered by the farmers' market orientation. Despite eastern and western Hararghe agro-ecologies are agronomic potentials for potato production, potato tuber yield has remained low on farmers' field. Therefore, improved potato varieties released at national and regional level has to be evaluated along with a local check for tuber yield and other agronomic characteristic with a major focus to further enhance potato productivity in the region.

Haramaya University released considerable number of improved potato varieties for eastern Ethiopia. However, agronomic performances of these potato varieties have not been tested in comparison to the other potato varieties released elsewhere in the country. Therefore, searching for genotypes, which can perform better in the region remain important always. The role of geographical location in creating varied genetic material even in the absence of genome differentiation was reported in potato (Hawkes, 1994). The presence of genetic variability is considered to be the prerequisite in any plant breeding program. One of the methods used in searching high yielding and agronomically superior potato varieties for different regions (agro-ecology zones) is testing of improved varieties developed by different research institutes in the country as well as outside the country in the target region. This helps to identify superior varieties which can well perform in the area. Potato varieties developed by different Research Centers in the country have not been tested in eastern Ethiopia. Similarly, the six released potato varieties by Haramaya University also have not been tested for their agronomic performance outside eastern Ethiopia. Therefore, study on all potato varieties released in the country, which are under production for their agronomic performance under eastern and western Hararghe condition is necessary. This helps to identify the best performing released variety (ies) in the region. Therefore, this study was initiated with the objective of studying the agronomic performance of nationally and regionally released potato varieties under eastern Ethiopia conditions.

Materials and Methods

Description of the study site: The field experiment has been carried out at three locations namely; Haramaya, Hirna and Arberkete which are considered the representative potato growing locations of eastern and western Hararghe.

Experimental materials: The experiment will be included 10 varieties of potatoes released by various Research Centers for different agro-ecology of Ethiopia, 6 varieties are released by Haramaya University for eastern Ethiopia and two local varieties (Table 1).

Experimental Design: The experimental was laid out as a Randomized Complete Block Design (RCBD) with two factors (location and varieties) and three replications. The gross plot size was 9 m^2, while the net plot was 2.25 m^2. Spacing between plots and replications were1.5m and 1m, respectively.

Table 1. Potatoes varieties tested

No	Variety	Released year	Breeder/Maintainer center	Recommended Altitude (m.a.s.l.)
1	Araarsaa	2006	Sinnana	2400-3350
2	Batte	-	Local cultivar	-
3	Bedasa	2001	Haramaya University	1700-2400
4	Belete	2010	Holeta/East Africa	1600-2800
5	Bubu	2010	Haramaya University	1700-2000
6	Bulle	2005	Hwassa	1700-2700
7	Chala	2004	Haramaya University	1700-2000
8	Chirro	1998	Haramaya University	1700-2400
9	Gabbisa	2005	Haramaya University	1700-2000
10	Gera	2003	Sheno	2700-3200
11	Gorebela	2002	Sheno	2700-3200
12	Gusa	2002	Adet	2000-2800

13	Gudanie	2006	Holeta	1600-2800
14	Jalenie	2002	Holeta	1600-2800
15	Jarso	-	Local cultivar	-
16	Maracherre	2005	Hwassa	1700-2700
17	Moti	2011	Sinnana	2400-3350
18	Zemen	2001	Haramaya University	1700-2400

Cultural practices: All agronomic practices were applied as per the recommendation made by the Haramaya University for the region. Medium size and well sprouted potato tubers were planted at a spacing of 75 cm between rows and 30cm between plants.

Data collection: Phenological, growth, yield, and yield components parameters of potato were recorded; however for this report a one season trial report only yield and yield components are presented.

Activities Completed

Major activities

1. Agronomic performance of the 16 improved varieties along with two local checks were studied
2. Physicochemical and processing attributes of varieties were studied

In general, the yield potential of improved varieties released by Haramaya University for eastern Ethiopia and other Centers in the country has been evaluated for one season. The evaluation is summarized and presented as follows.

Analysis of variance

The analysis of variance computed for 18 potato genotypes for yield and yield components and three locations is presented in Table 2. The analysis of variance result revealed that the presence of highly significant differences among genotypes for all yield and yield components. Similarly, the mean squares for location and variety x location were highly significant for all yield and yield components. The variation in total yield and yield components of potato genotypes at different locations may be due to differential response of genotypes to growing environment. Yield difference among genotypes is attributed both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype by environment interaction. Yield per unit area is the end product of components of several yield contributing characters which are also highly influenced by environment. The analysis of variance as well as the genotypes yield and yield components performance across the three locations indicated that some of the varieties best suited and performed to all the three locations but some others suited to and performed well in one or two locations. Therefore, assessment of genotype × environment interactions (including end use) is necessary to know which one of many potential new cultivars will be best in target environments and for all uses (Vreugdenhil *et al*., 2007). In selecting and evaluating varieties suitability to one environment or wide adaptability, the researchers need to look beyond total yield to the quality factors that influence the economic value and acceptability of potatoes. For new varieties to be successful with producers and consumers, the standards breeders use to measure such things as “tuber quality” and “marketable yield” should reflect local uses of potatoes, market conditions and consumer preferences. The use of standards that do not reflect local conditions is an important reason that many new “improved” varieties are ignored by farmers (Horton, 1987).

Table 2: Mean squares from ANOVA for nine yield and yield components of 16 potato varieties and two local cultivars tested at Haramaya, Hirna, and Arberkete

Trait	Replication (2)	Variety (17)	Location (2)	Variety x Location (34)	Error (106)
Total tuber yield (t/ha)	3.064^{ns}	396.841**	934.615**	84.343**	1.79
Marketable tuber yield (t/ha)	10.650^{ns}	403.885**	1742.457**	113.993**	6.74
Unmarketable tuber yield (t/ha)	1.325 ^{ns}	8.849**	8.775**	3.812**	0.97
Marketable tuber number per hill	3.746 ^{ns}	403.766**	855.709**	118.296**	3.55
Unmarketable tuber number per hill	3.746 ^{ns}	403.766**	855.709**	118.296**	3.55
Average tuber weight (g)	18.590 ^{ns}	2032.135**	615.731**	221.573**	5.63
Large size tuber number (%)	1.84 ^{ns}	993.030**	468.788**	144.311**	3.53
Medium size tuber number (%)	12.375 ^{ns}	62.068**	700.423**	65.564**	6.73
Small size tuber number (%)	4.859 ^{ns}	944.204**	95.103**	150.77**	7.16

**, * and ns= Significant at P < 0.01, P < 0.05 and non significant, respectively.

Performances of potato genotypes

Potato has substantial amounts of vitamins, minerals, and trace elements and if carefully grown, it gives the highest yield of nourishment per hectare of all basic foodstuffs. Furthermore, the production period of potato is not more than 120 days, enabling optimum use of the available agricultural land (Solomon, 1985). Potatoes produce 54 percent more protein per unit of land area than wheat and 78 percent more than rice. No other food, not even soybean, can match the potato for production of food energy and food value per unit of land area (Stevenson *et al.*, 2001). To exploit the potential of the crop, it is necessary to select varieties that produce highest yield per unit area. This includes selection of varieties suitable or adaptable to specific growing environment of varieties that are adaptable in wide range of environment. This in turn requires testing varieties as many as possible in different growing environments.

Crop yields are customarily measured in physical weight per unit of land area. However, potato farmers, traders, processors and consumers are less concerned with total production than with size of tubers and their quality. Many factors are affecting tuber size such as varietal characteristics, growing season; planting density, amount of fertilizer applied etc. However, in relation to variety, one may conclude that in low yielding crops the average tuber size is generally small, while in high yielding crops the average tuber size tends to be large (Beukema and Vander Zaag, 1979).

The 16 improved varieties and the two local cultivars mean yield and yield components across three locations are presented in Table 3. The genotypes are categorized in to three groups viz., potato varieties (6) released by Haramaya University; potato varieties (10) released by other Research Centers in the country and local cultivars to compare the performance of potato varieties released by Haramaya University with others. In addition, the mean of potato varieties released in recent years and old varieties were compared to asses how much improvement was made in increasing yield and yield components of potato through continuous breeding efforts of researchers.

The lowest total and marketable tuber yield (t/ha) was 21.19 and 18.109 t/ha, respectively, which was produced by the local cultivar, Jarso. The highest was 48.616 and 46.69 t/ha of total tuber and marketable tuber yield, respectively, which was obtained from the recently released (2010) variety named Belete. None of the improved varieties produced less than 32 and 31 t/ha average total tuber and marketable tuber yield, respectively, across locations except Bulle, which produced 27.79 and 24.43 t/ha average total tuber and marketable tuber yield, respectively, which was almost similar to the yield of local cultivar Bette and it is also susceptible to late blight.

The overall mean potato varieties released by Haramaya University exceeded overall mean of potato varieties released by other Centers for total and marketable tuber yield (t/ha), marketable tuber number per hill and in producing large sized tuber in higher proportion, but recorded lower mean values for unmarketable tuber yield (t/ha), unmarketable tuber number per hill, and in producing medium and small sized tubers which is desirable in terms of tuber quality. The local cultivars are producing the lowest yield as well as yield components (Table 3). However, when individual varieties are evaluated, none of potato varieties released by Haramaya University produced the highest total tuber yield and marketable yield (t/ha). Belete produced the highest yield across locations (48.616 & 46.69 t/ha of total tuber and marketable tuber yield), which is followed by Marachere (45.25 & 41.18 t/ha of total tuber and marketable tuber yield) and Gera (44.23 & 41.77 t/ha of total tuber and marketable tuber yield). All potato varieties released by Haramaya University produced higher yield better than other seven potato varieties released by other Centers, among which Bubu (40.49 & 39.62 t/ha of total tuber and marketable tuber yield) & Gabbisa (40.53 & 38.17 t/ha of total tuber and marketable tuber yield) produced considerably higher yield.

Withregard to tuber size, Belete (48.71%) followed by Gera (45.87%), Bubu (45.16%) and Araarsaa (41.78%) produced highest proportion of large sized tubers while Jarso (56.03%), Bulle (51.73%), Marachere (50.02%), Bedasa (46.36%), Bette (46.05%) and Jalenie (44.54%) produced highest proportion of small sized tubers. This result showed that i) considerable number of improved varieties produced small tubers similar to local cultivars and in this regard, potato varieties released by Haramaya University were better than others and ii) breeders in different centers were looking for higher yield and disease resistance and give less attention to tuber size. Similarly, only Belete (99.85g), Araarsaa (77.01g), Bubu (75.71g), and Moti (75.59g) produced tubers with higher average tuber weight while all other improved varieties produced tubers with medium average tuber weight (45 to 72g).

Table 3. Mean performance of 16 potato varieties and two local cultivars for yield and yield components of 16 potato varieties and two local cultivars tested at Haramaya, Hirna, and Arberkete

Variety	TTY(t/ha)	MTY(t/ha)	UMTY(t/ha)	MTN	UMTN	ATW(g)	LTN (%)	MTN (%)	STN (%)
Bubu	40.49	39.62	0.87	9.34	2.67	75.71	45.16	28.95	25.89
Gabbisa	40.53	38.17	2.36	12.33	3.17	62.93	31.3	30.51	38.18
Chala	38.43	38.03	0.4	11.64	4.4	58.09	33.69	33.05	33.25
Bedasa	36.69	33.92	2.77	13.43	4.73	49.3	23.87	29.77	46.36
Zemen	37.34	36.13	1.21	13.54	1.5	64.15	36.33	33.47	30.19
Chirro	37.96	35.1	2.86	9.82	2.1	68.36	37.75	31.05	31.2
Mean of HU varieties	**38.51**	**36.9**	**1.61**	**11.68**	**3.09**	**63.09**	**34.68**	**31.13**	**34.18**
Moti	33.49	31.25	2.24	7.77	1.97	75.59	36.52	29.72	33.76
Belete	48.616	46.69	1.926	8.54	2.5	99.85	48.71	28.48	22.81
Araarsaa	32.75	31.31	1.44	6.97	1.27	77.01	41.78	31.38	26.84
Gudanie	36.64	35.07	1.57	9.93	2.4	63.16	31.63	36.39	31.98
Bulle	27.79	24.43	3.36	8.04	5.57	45.34	19.3	28.97	51.73
Marachere	45.25	41.18	4.07	14.7	4.97	50.38	19.86	30.12	50.02
Gera	44.23	41.77	2.46	13.37	1.7	71.99	45.87	32.53	21.61
Gorebella	35.79	33.82	1.97	9.67	2.64	64.12	33.2	31.99	34.81
Gusa	33.82	33.81	0.01	9.63	3.62	57.82	30.1	30.06	39.84
Jalenie	35.03	31.12	3.91	11.55	5.3	47.63	18.29	37.17	44.54
Mean of other Centers Varieties	**37.34**	**35.05**	**2.29**	**10.02**	**3.19**	**65.29**	**32.53**	**31.68**	**35.79**
Batte	27.17	23.53	3.64	9.54	4.97	43.11	18.35	35.59	46.05
Jarso	21.19	18.109	3.08	7.3	4.8	39.95	14.36	29.61	56.03
Mean of local cultivars	**24.18**	**20.82**	**3.36**	**8.42**	**4.88**	**41.53**	**16.36**	**32.6**	**51.04**
Mean	**36.27**	**34.08**	2.18	**10.39**	**3.35**	**61.92**	**31.45**	**31.6**	**36.95**
SD	**6.64**	**6.97**	1.26	**2.35**	**1.45**	**15.03**	**10.5**	**2.62**	**10.24**

Improved varieties released for growers by different Research Centers and Haramaya University were arbitrary categorized into three groups on the basis of released years as first (6), second (7) and third (3) group which were released from 1998 to 2002 (considered as old), 2003 to 2006 (intermediate) and 2010 and 2011(recent), respectively, to have preliminary information how much improvement was made in yield and yield components and the result is presented in Table 4. Both total and marketable tuber yield (t/ha) were increased ranged from 5.1 to 13.18% and 5.08 to 15.31%, respectively. Unmarketable tuber yield (t/ha) was increasing from the first to intermediate group (starting from 1998 to 2006) but a sharp reduction was observed in potato varieties released recently (2010 & 2011) indicating breeders first effort was to increase total yield and later they were also gave equal attention to increase total and marketable tuber yield as well as reducing unmarketable tuber yield. Marketable and unmarketable tuber number per hill were also reducing in recently released varieties because the average tuber weight and large sized tuber proportion were increasing while medium and small sized tuber proportions were reducing. This indicates that recently, breeders' effort was towards to increasing both total yield and tuber quality rather than focusing only to increase total yield.

The varieties were tested for one season at three locations which may not allow to made recommendation since at least a one season at the same locations yield and yield components data is required. However, as intermediate research result it is possible to forward suggestion and it is also possible to predict the output of the research activity. The research activity should have to repeat once again in the same locations since three varieties are promising in producing higher yield than the recently released variety (Bubu) by Haramaya University. Moreover, one variety (Belete) produced significantly higher yield and tuber quality than Bubu which can be recommended for eastern Ethiopia if the variety is performing the same as it performed in 2012/13 cropping season.

Table 4. Mean performance comparison of improved varieties in relation to year of release

Trait	Mean performance & year of release			Increase or decrease (%)		
	1998 to 2002 **(6)**	2003 to 2006 **(7)**	2010 & 2011 **(3)**	From 1st to 2nd	From 2nd to 3rd	From 1st to 3rd
Total tuber yield (t/ha)	36.11	37.95	40.87	5.10	7.69	13.18
Marketable tuber yield (t/ha)	33.98	35.71	39.19	5.08	9.74	15.31
Unmarketable tuber yield (t/ha)	2.12	2.24	1.68	5.44	-24.96	-20.88
Marketable tuber number per hill	11.27	11.00	8.55	-2.45	-22.29	-24.19
Unmarketable tuber number per hill	3.31	3.35	2.38	1.15	-29.10	-28.29
Average tuber weight (g)	58.56	61.27	83.72	4.62	36.63	42.95
Large size tuber number (%)	29.92	31.92	43.46	6.67	36.17	45.25
Medium size tuber number (%)	32.25	31.85	29.05	-1.25	-8.79	-9.93
Small size tuber number (%)	37.82	36.23	27.49	-4.21	-24.13	-27.33

Activities to be accomplished during the Remaining Project Period

1. The research should be repeated for one more season to make sound and reasonable recommendation.

2. Genotype x environment analysis should be conducted by taking two years and three locations data to identify varieties that are adaptable to specific or multiple locations.

3. Research on physicochemical and processing attributes of the varieties should be done to make final and holestic recommendation.

Problems Encountered

The research activity proposal was presented to National Potato Project annual meeting and approved to be executed, but the budget allocated for Haramaya University Potato Improvement Program was too low to conduct this trial in three locations. In the absence of generous financial and other facilities support of Haramaya University Vice President for Research Affairs office, the experiments could not be conducted. The team would like to appreciate the support given by research office and request further support for repeating the trial for one more season to make recommendation from the research.

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Agronomic Management of Potato Varieties for Higher Productivity in eastern Ethiopia

By

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Funded by EIAR and Miscelaneaous HrU Grants

General Background

Potato has been introduced to Ethiopia in 1859 by a German Botanist called Schimper (Berga *et al*., 1994). The country has about 70% of the available agricultural land suitable for potato production (Gebremedhin *et al*., 2008). Even though, the country is endowed with suitable climatic and edaphic conditions for potato production the national average yield is about 8.2 tons ha^{-1} which is very low as compared to the world's average production of 17.67 tons ha^{-1} (FAO, 2008). The low yield of potato in the country is attributed to factors such as poor agronomic practices, lack of sustainable supply of improved planting material, high cost of seed tubers, disease and pest problem and inadequate storage (Bereke, 1994). The optimizing of plant density is one of the most important agronomic practices of potato production, because it affects seed cost, plant development, yield and quality of the crop (Bussan *et al*., 2007).

The yield of potato is influenced by a number of factors, which include nitrogen, cultivar, seed piece spacing, climatic conditions, and geographic location (Barry *et al*., 1990; Arsenault *et al*., 2001). As plant density increases, there is a marked decrease in plant size and yield per plant. This effect is due to increased inter-plant competition for water, light and nutrients. Plant density in potato affects some of the important plant traits such as total yield, tuber size distribution, and tuber quality (Samuel *et al*., 2004).

Crop production could be increased either by improving the inherent genetic potential of the crop or through application of better agronomic management, such as through the use of optimum plant density and application of fertilizers. It is well known that plant spacing can alter above and below ground biomass accumulation of vegetable crops. Thus, any plant spacing variation could influence biomass accumulation and subsequently tuber number (Santos and Gilreath, 2004). Therefore, it is necessary to conduct research on a number of agronomic management in eastern Ethiopia to improve the productivity of potato varieties. A number of research activities have been conducted as MSc research in 2012/13 cropping season and continued to make sound recommendations.

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Activities conducted under this mega project are presented in four experiments as follows (thesis data should be shortened and presented under each topic….Dr. Wassu promised to summarize the four theses indicated here).

Title: Influence of Integrated Fertilizer application and Tuber Yield of Potato (*Solanum tuberosum* L.) at Haramaya District, Eastern Ethiopia

Result highlight

The experiment used the recently released Bubu potato variety and the treatments include three level of each for Nitrogen, Phosphorous and Manure were applied on time at Haramaya

University. All necessary data were collected analyzed and the thesis research was defended successfully in May 2013.

Title: Influence of Nitrogen Fertilizer and Planting Density on Growth and Yield on Potato at Haramaya, Eastern Ethiopia

Result highlight

The treatments include two level of Nitrogen & five levels of planting density. The treatments have been applied on time. Recently released variety Bubu potato variety was used for the experiment. All necessary data were collected analyzed and the thesis research was defended successfully in May 2013.

Title: Response of Improved and Local Potato (Solanum tuberosum L.) Cultivars to Nitrogen Fertilizer at Haramaya, Eastern Ethiopia

Result highlight

The treatments include four levels of Nitrogen & four cultivars. The treatments have been applied on time. All necessary data were collected analyzed and the thesis research was defended successfully in May 2013.

Title: Fertilizer Requirement Determination for Potato for Lowland Areas (Dire Dawa)

Result highlight

This is the National Potato Research Project research activity given to Haramaya University as responsible Institution. The research activity was taken by one M.Sc. student and it was conducted in 2013 (March to June). All necessary data were collected and analysis of data is in progress.

Problems Encountered

Research activities were handled by MSc students and responsible researcher as major advisor. The research activities were handled and conducted properly and research results submitted by the students. The results showed that the presence of promising management practices that increase yield and quality of potato tubers. However, the research activities were not repeated for the second season to make final recommendation because of lack of technical staff that can handle the experiments since MSc student can not be recruited because of the police that the same title/experiments can not be repeated by students. With this problem the promising management practices that can enhance the production and productivity of the crop left without making recommendation. However, the responsible researcher planned to conduct at least one experiment entitled **“Effect of Plant Spacing on Growth, Tuber Yield, and Size Distribution**

of Potato (*Solanum tuberosum* L.) Varieties in East and West Hararghe" to make sound and reasonable recommendation by conducting the experiment for two years.

Activities to be accomplished during the Remaining Project Period

The research activities conducted for one year will be repeated to make sound and reasonable recommendation. To conduct the research activities it is necessary to assign capable technical staff members that could handle the research activities properly and allocating sufficient budget is necessary.

Maintenance and Enhancement of Potato and Sweet potato Genotypes at Haramaya University (ongoing research activity)

By

Wassu Mohammed Ali

Funded by HrU Grant

Abstract: *Haramaya University maintained hundreds of potato and sweet potato genotypes for decades. The genotypes were used to release improved varieties for ester Ethiopia, used as germplasm deposit for the nation and used for a number of scientific researches. These crops genetic resources will serve the same purpose for unlimited number of years in the future. Therefore, maintenance, characterization, evaluation and documentation of genotypes are necessary. This project objective was to maintain and study the genotypes for the improvement of the crops. More than 300 potato genotypes are maintained through vegetative (seed tuber) propagation and 116 sweet potato accessions are maintained at field. The sweet potato accessions were evaluated for yield using Augmented Design with 19 replications (blocks) in 2012/13 cropping season. The evaluation revealed that the existence of significant variations among accessions which can be exploited for the improvement of the crops. Moreover, 13, 12 and 20 accessions exhibited superiority over the mean of improved check varieties for total storage root yield (t/ha), marketable storage root yield (t/ha) and dry matter content (%), respectively. The total and marketable storage root yield advantages of accessions were as high as 87.66 and 75.58%, respectively. This indicating the need to further study promising accessions in replicated trials and maintains the rest for future use.*

Introduction

Potatoes one of the most important staple food crops in the East and Central Africa region helps in ensuring food insecurity especially in disaster situations. In these regions within a few decades, potato production increased from 2.8 million metric tons in 1998 to about 4.2 million metric tons in 2002 implying a growth rate of nearly 8% per annum. Despite this remarkable growth, yields are low compared to those obtained elsewhere in the World. National yields of potato in the region range from 2.7 t/ha in Kenya to 8.0 t/ha in Ethiopia. The major contributing factors to the low yields have been the use of inferior and/or poorly adapted varieties, high prevalence of diseases and insect pests, poor soils, and unfavorable weather conditions. Shortage of improved seeds or planting materials and inadequate provision of extension services also contributed greatly to the low yields (George and Otim, 2007).

Sweet potato is cultivated in Ethiopia mostly for human consumption and as animal feed. It ranks third after Enset [*Ensete ventricosum* (Wele) Cheesman] and Potato (*Solanum tuberosum* L.) which is one of the most important root crops produced in the country. The total area under production reaches 33,070 hectares and the production is estimated to be over 2,628,539 quintals. (CSA, 2003). According to FAO (2000) and CSA(2005 and 2006) data, the Ethiopian national average storage root yield of sweet potato ranging between 8 to 10 t ha^{-1} .and under experimental field, storage root yields ranging between 30 to 73 t ha^{-1} (Hall and Harmon, 1989; Bhansari and Ashley, 1990).

Germplasm source is a very crucial in variety development and release. In most cases, the richer the source materials and germplasms the more and the best varieties can be developed and released. However, countries in East and Central Africa have different approaches to accelerated release of acceptable varieties. They also follow different approaches on how they can build their source materials and germplasms. Some countries depend entirely on CIP and /or PRAPACE for materials for their breeding programmes, while others generate own crosses using both local and exotic materials. When we consider Ethiopian condition, the Ethiopian Agricultural Research Institution (EARI) has a national mandate to conduct and coordinate research, but institutions of higher education (Universities and Colleges) are also engaged in research on potato and other crops. The organization has a strong collaborative research with international agricultural research centers such as CIP for potatoes and sweet potatoes. The variety development, which involves evaluation, selection, release and registration procedures pass through several stages (George and Otim, 2007). With this strength and mainly depending on CIP for potato germplasm source, the Institution along with Universities such as Haramaya University released considerable number of potato varieties for different regions.

Current knowledge of the distribution of sweet potato genetic resources indicates that maximum diversity of *I. batatas* in northwestern and southern America and Africa. In the same trend as in other major crop plant, the sweet potato genetic resources are facing a high risk of losing significant amount of variation (Zosimo, 1987). Haramaya University emphasizing the importance of intensive collection of sweet potato germplasm and the University maintained 116 sweet potato germplasm from International and National collections for number of years. The germplasm collections not only used by the University but also by the National research. Therefore, it is necessary to maintain these valuable materials for future use.

The presence of genetic variability is considered to be the prerequisite in any plant breeding program. Therefore, maintaining the available potato and sweet potato germplasm is crucial for the success of the two crop improvement. Haramaya University is pioneer in starting potato research in the country and it is also known in maintaining accessions obtained from International Research Centers. The collection that the University maintained was also served as deposit for the national potato research program and a number of potato varieties were released. Therefore, maintaining the collection is necessary for long period for the success of potato improvement. This project was initiated with the objective of maintaining and enhancing potato and sweet potato genotypes and make available for regional and nation research system.

Materials and Methods

Three hundred seventy two potato genotypes (including 27 genotypes under screening trial for heat tolerance and 18 varieties under adaptation trial) have been planted in a non-replicated trial with three rows at Haramaya University. Medium size and well sprouted potato tubers were planted at a spacing of 75 cm between rows and 30cm between plants. All agronomic practices have been applied as per the recommendation made for the crop.

On hundred sixteen sweet potato genotypes were planted in a non-replicated trial at Haramaya University. The genotypes were also planted in separate field using augmented design to evaluate the yield and quality of genotypes. One M.Sc. student superimposed his M.Sc. research with the objective of evaluation, characterization and documenting of agronomic and physicochemical attributes of sweet potato accessions maintained at Haramaya University.

Activities Completed

Maintenance of potato genotypes

Seed tubers of 350 potato genotypes were stored under DLS and have been planted at field in three rows of 12m length. The tubers will be collected at harvest and will be stored for further maintenance and screening.

Maintenance and enhancement of sweet potato genotypes

One hundred fourteen (114) sweet potato accessions and two released varieties (Adu and Berkome) were planted using augmented block design with 19 replications/blocks. The checks were replicated 19 times and 114 entries/tests were not replicated. Twelve vine cuttings per plot were planted at the top of the ridge. Hundred and 30 cm were maintained between rows and plant, respectively. Replanting was done to substitute the dead vine after one week of planting. All plots received recommended cultural practices uniformly. Harvesting was done after 90 % of the sweet potato leaves changed in to yellowish color. From each plot ten (10) plants left the plants grown at both end of the plot were harvested to estimate yield and yield components. In the superimposed research a number of morphological, phenological, growth, yield and yield components as well as physical and chemical attributes were recorded and analyzed, but only yield and yield components data are included in this report since the initial objective of the experiment was to evaluate sweet potato accessions for yield and yield components.

Analysis of variance

Analysis of variance showed that the presence of significant (P < 0.05) differences among accessions for root fresh weight (g/plant), total storage root yield (t/ha), marketable storage root yield (t/ha) and dry matter content (%) while non-significant difference was observed among accessions for unmarketable storage root yield (t/ha) (Table 1). The result indicates that the presence of sufficient variation among genotypes for yield and selection can effected to identify high yielding ones.

Table 1: Mean squares for five yield traits of sweet potato [*Ipomoea batatas* (L.) Lam.] collections on the basis of adjusted means

Trait	Mean squares		
	Replicationn (18)	**Accession (115)**	**Error (18)**
Root fresh weight (g/plant)	55646.28	66130.4*	26267.22
Total storage root yield (t/ha)	20.02	24.79*	9.59
Marketable storage root yield (t/ha)	10.4	15.15*	5.79
Unmarketable storage root yield (t/ha)	8.84	4.67 ns	3.67
Dry matter content (%)	13.01	21.61*	6.16

*, and ** = Significant at P<0.05 and P<0.01, respectively. Number in parenthesis indicates degree of freedom.

Mean performance of accessions

The minimum and maximum root fresh weight (g/plant) was 103 and 1439 with mean of 542.78. Total storage root yield (t/ha) ranged from 2.261 to 28.461 with average yield of 12.025. Marketable storage root yield and unmarketable storage root yield (t/ha) ranged from 0.512 to 22.08 and 0.01 to 13.63, respectively. Similarly accessions exhibited a wide range of dry matter content (%) with minimum and maximum values of 13.23 and 40.22, respectively (Table 2). More interestingly, 15, 13, 12 and 20 accessions were performed better than the mean performance of check varieties Adu and Berkome. This indicates that it is possible to select accessions for higher yield following the breeding procedures in variety development.

Table 2. Mean minimum, maximum values and standard deviation for yield and yield components of 116 sweet potato accessions on the basis of adjusted means

ait	Mean	Minimum	Maximum	SD	No. accessions with yield above Check varieties
Root fresh weight (g/plant)	542.78	103	1439	262.4	15
Total storage root yield (t/ha)	12.025	2.261	28.461	5.178	13
Marketable storage root yield (t/ha)	8.143	0.512	22.08	3.958	12
Unmarketable storage root yield (t/ha)	3.9	0.01	13.63	2.606	34
Dry matter content (%)	24.878	13.275	40.215	5.238	20

The mean marketable storage root yield (t/ha) was 11.77 and the 10 accessions had average yield advantage of 32.49% over the mean of two check varieties which ranged from 6.78 to 87.66% yield advantages (Table 3). These accessions also exhibited average marketable storage root yield advantage of 19.59% over the best performing check variety, Adu with the range of -3.62 to 69.39% while accessions had average marketable storage root yield advantage of 48.45% over other check variety, Berkome with the range of 19.64 to110.26%. Similarly, the 10 accessions exhibited 37.17, 24.37 and 52.91% average total storage root yield advantages over the mean of the two check varieties, Adu and Berkome, respectively. The total yield advantages of each accession over the mean of the two check varieties, Adu and Berkome is presented in Table 3. This indicating that the highest yielding accessions and others which performed better than the mean yield of the two check varieties need to tested along with the released varieties in replicated trial.

Some of the accessions maintained at Haramaya University had desirable attributes better than the released varieties in many of the traits studied which can be exploited in sweet potato improvement program. More interestingly, the variation among accessions and check varieties and characteristics of genotypes for morphology, phenolgy, physical and chemical qualities of storage roots are well studied and documented in the superimposed research thesis.

Table 3. List of 10 accessions total and marketable yield (t/ha) and percentage yield advantages over check varieties on the basis of adjusted means

	Marketable storage yield (t/ha) and accessions advantages over checks			
Accession	Marketable storage root yield (t/ha)	Marketable storage yield advantage over mean of check varieties	Marketable storage yield advantage over Adu variety	Marketable storage yield advantage over Berkome variety
Tis-9465-7	22.088	87.66	69.39	110.26
Tis-82/0602-12	20.888	77.47	60.18	98.84
Tis-70357-7	19.288	63.87	47.91	83.61
CN-1753-5	14.352	21.94	10.06	36.62
Korojo	13.852	17.69	6.23	31.86
CN-1752-9	13.512	14.80	3.62	28.62
Tis-9468-7	13.492	14.63	3.47	28.43
Koka-12	13.032	10.72	-0.06	24.06
Arbaminch	12.872	9.36	-1.29	22.53
Tis-8441-3	12.568	6.78	-3.62	19.64
Adu	**13.039**			
Berkome	**10.505**			
Mean of Checks	**11.77**			
Accession	Total storage root yield (t/ha)	Total storage yield advantage over mean of check varieties	Total storage yield advantage over Adu variety	Total storage yield advantage over Berkome variety
Tis-9465-7	28.461	75.58	59.19	95.716
Koka-12	26.661	64.47	49.12	83.338

Tis-70357-7	24.861	53.37	39.05	70.960
Tis-82/0602-12	23.661	45.97	32.34	62.708
CN-1752-9	22.061	36.10	23.39	51.705
Bacale	20.261	24.99	13.32	39.327
CN-2065-7	20.061	23.76	12.20	37.952
CN-1753-5	19.611	20.98	9.69	34.858
CN-2066-2	19.061	17.59	6.61	31.076
CN-2059-7	17.661	8.95	-1.22	21.448
Adu	**17.879**			
Berkome	**14.542**			
Mean of Checks	**16.21**			

Problems Encountered

1. Potato and sweet potato genotypes were maintained at Haramaya University for decades and used as a germplasm sources for the two crops improvement where a number of improved varieties were released for eastern Ethiopia. Genotypes maintained by the University served also as national germplasm sources and utilized fro a number of scientific researches in the University and will be utilized for the same for the future for unlimited number of years. However, the budget allocated for Haramaya University Potato Improvement Program, particularly for casual labour was too low and it was very difficult to conserve such large number of potato accessions. Budget was not allocated from National Root Crops project for two consecutive budget years for sweet potato improvement as well as for maintenance of genotypes. However, the University allowed a 17 months research budget for both crops. But, maintenance of genotypes and improvement of the crops is uninterrupted breeding research activity; therefore, it is necessary to look for budget source to maintain as well as to use genotypes for the improvement of the two crops.

2. There is a need to characterize, evaluate and document the potato genotypes maintained at Haramaya University as it has been done in sweet potato, but this requires sufficient financial and skilled manpower support. Therefore, it is necessary to allocate both to conduct research on potato genotypes

3. The potato genotypes were maintained by planting recycled seed tubers for many years which leads to disease development (degeneration) which required to be rejuvenated through true potato seed propagation or tissue culture. This again requires sufficient financial and skilled manpower support which can't be effective with the existing technical staff and shortage of budget.

Activities to be accomplished during the Remaining Project Period

1. Grouping of sweet potato genotypes on the basis of 22 traits studied will be conducted to understand the genetic distance of accessions and to group genotypes and identify which are going to be used to improve which desirable traits of the crop.

2. Genetic analysis of sweet potato genotypes will be conducted to generate genetic information that will be utilized to design appropriate breeding methods to improve the crop.

3. Disease reaction of potato genotypes and dormancy period of seed tubers of genotypes will be studied to generate preliminary information which genotype will be used for which cropping system (irrigation, belg and meher).

4. The sweet potato genotypes will be maintained at field and potato genotypes seed tubers will be stored and maintained in DLS.

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Vegetable Crops Research Activities

Screening of Heat Tolerant Potato (*Solanum tuberosum* L.) Genotypes in eastern Ethiopia (ongoing research activity)

By

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Abstract: *Potato improvement research for lowland areas of the country was initiated by Haramaya University and later become a national research activity. The research activity was conducted for one season and discontinued and re-initiated in 2012 with the objective of screening potato genotypes for heat tolerance. The research was conducted at Dire Dawa in 2012/13 cropping season using randomized complete design (RCBD) with three replications. A total of 26 potato genotypes were tested for yield and yield components. Highly significant (P<0.01) difference was observed among genotypes for total tuber yield t/ha, marketable tuber yield t/ha and dry matter content (%). The genotypes yield ranged from 7.4 to 24.3 and 4.44 to 22.52 t/ha for total tuber yield and marketable tuber yield and most of the genotypes registered above the national average yield (>10 t/ha) indicating the possibility of developing potato varieties for lowland areas of the country. The genetic gains calculated for total tuber yield and marketable tuber yield t/ha were 29.48 and 48.49%, respectively, at 5% selection intensity indicating the highest possibility of improving potato yield through selection. The dry matter content which is one of the parameter to estimate the quality of the tubers ranged from 14.89 to 20.96% which is above the minimum and a little below the higher range of potato tubers (13 to 25% dry matter content is the range for potato tubers dry matter content in the world). Generally, the research has proved the possibility of obtaining potato genotypes that can be cultivated in lowland areas of the country and the importance of continuing the research. However, the problem related to conduct the research activity at Dire Dawa need to be solved to be effective in short possible period.*

Introduction

Food security is a key priority for the over 200 million people of Eastern Africa, and this population is envisaged to double by 2030. The need to feed this population puts increasing pressure on the fixed land for food production. This is further aggravated by the increasingly degraded environment and the uncertainties resulting from climate change. Such declining and variable environment requires robust crops adapted to a wide range of agro-ecologies in the region. Cassava, potato and sweet potato are choice crops for such situation and are major food staple crops in the Eastern Africa countries viz., Ethiopia, Kenya, Tanzania, Rwanda and Uganda. Their plasticity to environmental regimes and yield make them the best crops for food and nutrition security in the sub-region (Kyamanywa *et al.*, 2011).

In the tropics and subtropics the major limiting factors for potato production are heat and water stresses. These factors has significant effects on physiology, yield and grade of potato crop .The meteorological elements governing growth, development, production, and quality of potato tubers at a given site are basically air and soil temperatures, solar radiation, photoperiod, soil moisture, and crop water use or evapotranspiration (Midmore, 1992). Adaptation of the potato to the tropics, subtropics, semi-arid and arid conditions has been an important task of breeders, since in vast areas of Africa and Asia, the yield capacity and the high nutritional value of the potato is much needed (Levy, 2000). Therefore, breeders should have to launch research to develop potato varieties which are suitable for stress areas, particularly heat tolerance. Specific cultivars can be possibly bred that are specifically adapted to hot climates, since there are reports indicating the existence of genetic variability for heat tolerance in potato genotypes (Tai *et al*., 1994, Menezes *et al.*, 1999), which could be exploited in breeding programs.

Potato genotypes were introduced in the country at different time by different institutions/organizations, individuals and private companies for different purpose. However, the level of heat tolerance and agronomic performance under specific condition was unknown. It is hypothesized that heat tolerant varieties have good agronomic performance than heat sensitive varieties potato grown under high temperatures condition. Therefore, further investigation with respect to specific location (lowland areas experiencing high temperature) is important. To attain this, it is essential to generate adequate information by studying the agronomic performance of potato genotypes and/or varieties to heat stress tolerance. Therefore, this study was re-initiated with the objective of studying the agronomic performance potato genotypes and varieties under low land conditions of eastern Ethiopia.

Materials and Methods

Location or study site

The field experiment was carried out at lowland agro-ecology of eastern Ethiopia i.e. Dire Dawa in 2012/13 cropping season.

Experimental design and materials

The treatment was comprised five heat tolerant potato varieties, which have been developed elsewhere in the world for low land agro- ecology and other 22 potato genotypes, which have been performed best at Dire Dawa in the past trial.

The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications. The size of the plot was 3 m×3 m. The area of each plot was 9m^2. A distance of 1m between blocks and 1m between plots was maintained. Each plot was consisted of 4 rows of 10 plants.

Cultural practices

Land was prepared according to the recommendation made for the crop. Medium size and well sprouted potato tubers were planted at a spacing of 75 cm between rows and 30cm between plants. Weeding, fertilizer application, cultivation, ridging were done to facilitate root, stolon and tuber growth.

Data collection

Phenological, growth, yield and yield component data were collected and for this report yield and yield component data were analyzed and reported.

Activities Completed

Field trial of potato genotypes in 2012/13 cropping season

Twenty seven potato genotypes including the recently (2011) released potato; Bubu were planted at Dire Dawa during the hottest period (end of June) of the area as it was planned. All agronomic managements were applied and data were collected. One of the planted 27 genotypes was failed to grow under heat stress and the research data collected for 26 genotypes were analyzed and presented below.

Analysis of variance

The analysis of variance computed for seven yield and yield components of potato genotypes grown at Dire Dawa is presented in Table 1. The result revealed that the presence of significant differences among genotypes for total tuber yields t/ha, marketable tuber yield tons/ha, unmarketable tuber number per plant and dry matter content (%). However, non-significant differences among genotypes were observed for unmarketable tuber yield t/ha, tuber number per plant and marketable tuber number per plant. The presence of significant difference among genotypes for most of economic importance traits suggested the existence of variability among potato genotypes which selection can be effected. In addition, the result also suggested to include many potato genotypes as much as possible which may be obtained from local and international collections, since variability to heat stress tolerance is evident from this single trial which only consisted of few potato genotypes. In other words, the more the genotypes tested under heat stress there will be the higher probability of obtaining high yielding heat tolerant genotypes.

Table 1. Mean squares from ANOVA for Seven Yield and Yield Components of 26 Potato Genotypes grown at Dire Dawa, eastern Ethiopia

Trait	Replication (2)	Variety (25)	Error (50)
Total Tuber Yield tons/ha	210.73	56.15**	23.65
Marketable Tuber Yield tons/ha	271.96	66.35**	21.20
Unmarketable Tuber Yield tons/ha	5.785	1.955	1.599
Tuber Number per plant	0.681	2.864	3.546
Marketable Tuber Number per plant	14.865	3.819	2.447
Unmarketable Tuber Number per plant	17.394	2.608*	1.014
Dry matter content (%)	53.229	6.793**	2.307

* & **, Significant at P<0.01 and P<0.05, respectively.

Performances of potato genotypes

Potato can potentially be grown on about 70% of the 10 million ha of arable land in the country (FAO, 2008). There are improved varieties that yield 19 to 38 tons ha^{-1} on farmers' fields (Gebremedhin *et al.,* 2008). The total area cropped with potato in Ethiopia is 59,508.67 ha (CSA, 2011/12) which is very low compared to the existing potential that the crop can be grown on about 70% of the 10 million hectares of arable land in the country and the average yield (8 tones ha^{-1}) is far below the potential (FAO, 2008). The low acreage and yield are attributed to many factors, but lack of high quality seed potatoes and high yielding varieties are the major factors (Lemaga *et al.*, 1994; Endale *et al*., 2008a; Gildemacher *et al.*, 2009a). Particularly high yielding varieties are lacking for lowland areas or there is no report in the country. In this research, total tuber yield was recorded as high as 24.3 t/ha for introduced heat tolerant accession (Vivadial) and as low as 7.4 t/ha for the early introduction of potato genotypes. It was evident the possibility of obtaining average total tuber yield of 12.89 t/ha (Table 2). Only seven genotypes were performing below 10 t/ha and six genotypes were performing above 15 t/ha. The remaining 13 genotypes including Bubu (recently released variety) produced between 10 and 15 t/ha which is more than the national average yield.

Table 2. Mean Performance of 26 Potato Genotypes for Yield and Yield Components Grown at Dire Dawa, eastern Ethiopia

Genotype	TTYt/ha	MTYt/ha	UNMTYt/ha	TN/plant	MTN/plant	UNMTN/plant	DM (%)
CIP-392640-516	13.04	11.25	1.78	7.6	4.73	2.67	18.54
HU19	11.26	7.41	3.85	7.67	3.53	4.13	20.96
HU16	17.18	16	1.19	6.8	5.33	1.47	17.34
Al-100	7.41	4.44	2.97	6.13	2.53	3.6	17.36
CIP-392640-541	15.7	13.33	2.37	8.33	5.07	3.33	17.95
Al-348	13.33	10.96	2.37	5.87	2.87	3	17.26
AL-503	10.37	6.82	3.56	7.33	3	4.33	15.7
CIP-392640-528	15.14	14.52	0.62	5.8	4.4	1.4	17.55
CIP-386029-18c	7.4	4.74	2.67	5.6	2.4	3.2	17.24
AL-209	9.78	6.22	3.56	6.67	2.6	4.07	18.81
CIP-392140-526	21.63	19.85	1.78	7.4	5.27	2.13	17.25
CIP-392640-525	17.78	16	1.78	6.8	5.27	1.53	16.52
Al-269	13.63	10.07	3.55	6.33	3.67	2.67	16.3
CIP-378371-9c	7.4	5.04	2.37	7	2.13	4.87	20.81
Al-119	8.59	6.82	1.78	6.87	3.4	3.47	18.45
CIP-378323-2B	12.77	11.85	0.92	5.53	4.13	1.4	16.65
Al-270	9.33	6.67	2.67	5.6	2.9	2.7	14.89
Vivadial	24.3	22.52	1.78	8.73	6.33	2.4	20.08
CIP-378501-10A	14.52	12.44	2.08	7.47	4.6	2.87	17.8
CIP-391058-506	8	6.22	1.78	5	2.67	2.33	17.52
CIP-391058-520	15.73	13.33	2.4	6.07	4.33	1.73	18.66
CIP-392037-500	13.63	11.56	2.08	7.47	4.47	3	15.92
HU1	13.96	11.85	2.37	7	4.67	2.33	19.17
HU14	11.85	8.89	2.97	6.13	3.6	2.53	16.24
CIP-378371-19	7.7	5.33	2.37	5.07	2.4	3	19.02
Bubu	13.78	12	1.78	5.6	3.5	2.1	18.67
Mean	12.89	10.62	2.28	7	4	3	17.79
LSD (5%)	7.98	7.55	2.07	3	2.57	1.65	2.491
CV (%)	22.1	20.5	20.6	2.4	19.7	19.4	8

TTYt/ha= Total Tuber Yield tons/ha, MTYt/ha= Marketable Tuber Yield tons/ha, UNMTYt/ha= Unmarketable Tuber Yield tons/ha, TN/plant= Tuber Number per plant/hill, MTN/plant= Marketable Tuber Number per plant, UNMTN/plant= Unmarketable Tuber Number per plant and DM (%)=Dry matter content (%)

Regarding the economic importance parameter i.e. marketable tuber yield, genotypes produced 4.44 to 22.52 t/ha with average of 10.62 t/ha, which indicated that the genotypes have a potential of producing more than the average national yield of potato under mid and high altitude agro-ecologies.

Dry matter of potato tubers ranges from about 13 to 37% with an average of 25 %. The other 75% of the potato consists of water. Dry matter increases during the growing season and is highest in the vascular system, intermediate in the cortex and lowest in the pith. The dry mater or 'solids content' of tubers is one of the prime characters used by potato processors to evaluate a crop. Potatoes with high dry matter are most suitable for the manufacture of dehydrated food products and stocks feed and are especially good for the production of fried foods. The dry matter of potato tubers is composed of a number of substances that are either soluble or insoluble in water. Dry matter is particularly significant when frying as the greater the Dry matter the less fat uptake because there is less water for it to replace (Lisi and Leszcy, 1989). In this study the average dry matter of potato was17.79 and with the range of 14.89 to 20.96% which indicated that i) genotypes had not dry matter content below the minimum range for the crop, ii) genotypes had an acceptable dry matter content under heat stress conditions and iii) it is possible to select genotypes that can be used for wide array of end use i.e. for table potato (boiled potato) to French fries.

Genetic gain and heritability

Genotypic and phenotypic coefficient of variation values can be categorized as low (0-10 %), moderate (10- 20%) and high (20 % and above) as proposed by Siva Subramanian and Menon (1973). In this experiment both GCV and PCV values were moderate to high. The estimated phenotypic coefficient of variation was relatively greater than the genotypic coefficient of variation in magnitude for all the traits and the differences between the two were high indicating the more sensitivity of these traits to environmental modifications.

Heritability percentage can be categorized as low (0-30%), moderate (30-60%) and high (60% and above) as demonstrated by Robinson *et al.* (1949). Similarly, genetic advance as per cent mean was categorized as low (0-10%), moderate (10-20%) and high (20% and above) (Johnson *et al*., 1955). In this study, heritability was moderate to total tuber yield t/ha, marketable tuber yield t/ha, unmarketable tuber number per plant and dry matter content. Similarly, the expected genetic advance values or genetic gain was high for total tuber yield and marketable tuber yield t/ha. The observed high genetic advance coupled with moderate heritability is an indication of more additive gene action (Panse, 1957). For these traits which had moderate heritability and high genetic advance, selection may be effective in improving the yield of potato at lowland condition since this indicated the masking effect of environment on the genotypic effect is minimal. Generally, by selecting 5% of the genotypes it is possible to have 29.48% and 48.49% genetic gain of total tuber and marketable yield, respectively, in the genotypes tested (Table 3).

Table 3. Genetic gain and heritability in 26 potato genotypes tested at Dire Dawa

Trait	Range	Mean	σ^2 g	σ^2 p	GCV	PCV	H_2	GA
Total Tuber Yield tons/ha	7.4-24.3	12.89	10.83	34.48	25.53	45.56	31.42	29.48
Marketable Tuber Yield tons/ha	4.44-22.52	10.62	15.05	36.25	36.53	56.69	41.52	48.49
Unmarketable Tuber Yield tons/ha	0.92-3.85	2.28	0.12	1.72	15.11	57.48	6.91	8.18
Tuber Number per plant	5-9	7	0.23	3.78	6.85	27.76	6.09	3.48
Marketable Tuber Number per plant	2-6	4	0.46	2.90	16.91	42.61	15.75	13.82
Unmarketable Tuber Number per plant	1-4	3	0.53	1.55	24.30	41.44	34.38	29.35
Dry matter content (%)	14.89-20.96	17.79	1.50	3.80	6.87	10.96	39.33	8.88

σ^2 g= genotypic variance, σ^2 p= phenotypic variance, GCV= genotypic coefficient of variation, PCV= phenotypic coefficient of variation, H_2= broad sense heritability and GA= genetic advance at 5% selection intensity

Problems Encountered

1. Though, this research activity was assigned to Haramaya University by National Potato Project and the research is one of the major national research activities, the budget allocated for Haramaya University Potato Improvement Program, particularly for casual labour was too low and it was very difficult to conduct the experiment with the budget allocated from the National Potato Project. However, the University Research Affairs office has supported the research and it became possible to conduct the experiment for one season.

2. The research site (Dire Dawa) was in transition to be handover by Dire Dawa University and the workers as well as the management in the site was not settled which became difficult to handle the experiment properly, particularly to apply irrigation on the time schedule. There was also a problem to get sufficient water to irrigate the field.

3. Due to consistent budget shortage and failure to have irrigation water the research activity is not continued in the cool months of Dire Dawa (January to April) to evaluate genotypes potentials in producing yield at different weather condition of the lowland.

Activities to be accomplished during the Remaining Project Period

1. The result obtained from one season yield of few potato genotypes were encouraging and it is also promising to have at least one heat tolerant potato genotype from this trial and if more number of potato genotype are going to be tested the possibility of getting heat tolerant genotypes more than one is at hand. Therefore, it is necessary to allocate sufficient budget to

conduct the experiment in two weather condition (at extreme hot period starting June and relatively cool months starting January) of Dire Dawa.

2. It is necessary to include local potato genotypes which are produced by farmers under irrigation at mid-altitude and other improved varieties which give a higher chance to obtain heat tolerant potato genotypes.

3. Two problems have to be solved to conduct the experiment at Dire Dawa i.e. i) the availability of water for irrigation and ii) to manage the workers as it should have to be since workers are doing worker on their willing, it is difficult to handle experiment which is sensitive to management (on time irrigation application).

4. For long term activity, it better to screen all potato genotypes maintained at Haramaya University for heat tolerance at least for one season which may increase the chance of getting heat tolerance potato genotypes. In addition, it is necessary to introduce heat tolerant genotypes from international research institution through National Potato Research Project.

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Collection and Evaluation of eastern Ethiopia Hot Pepper (*Capsicum* spp.) Genotypes and Adaptation Trial of Released Varieties (ongoing research activity)

By

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Funded by EIAR grant

Abstract: *Hot Pepper (Capsicum spp.) improvement research activity was initiated in 2012 by Haramaya University due to the absence of recommended improved variety and agronomic management for eastern Ethiopia. Keeping in view this problem, the research activity set the following major objectives: i) to test the adaptability of released Capsicum varieties, identify high yielding variety (ies) and to make recommendation for eastern Ethiopia to give solution for the problem within short possible period, ii) to collect, evaluate and characterize farmers Capsicum spp. cultivars for the improvement of the crop in the region for long period solution and iii) to study the nutrient requirement of Capsicum varieties in eastern Ethiopia to enhance the productivity of the crop. The activity was started soon in the same year and 72 genotypes were selected on plant basis evaluation and planted in the field in 2013 for yield evaluation using augmented design. Adaptation trial of improved varieties were conducted in 2012/13* *cropping season in three locations (Haramaya, Hirna and Dire Dawa) of eastern Ethiopia using randomized complete block design (RCBD) with three replications. The varieties were evaluated for yield and yield components where the red pod yield was ranged from 20.23 qt/ha (2.02 tons/ha) to 35 qt/ha (3.5 tons/ha) which is similar to the yield of the crop under research sites reported by different Research Centers. Varieties showed significant differences for all the traits studied and location as well as the variety and location were interacting to influence significantly yield and yield component traits. Moreover, the local cultivar exhibited better yield than the three improved varieties that encouraged in searching high yielding cultivars in the region through collection, evaluation and selection. Mareko Fana was found as high yielder across locations with other desirable traits while three improved varieties (Melka Zala, Mareko Dima and PBC-660) were found to be low yielding, but have desirable fruit characteristics that can be combined with high yielding varieties but lacking these desirable traits through crossing. Though, the research is ongoing and results are reported based a one year data, it suggested continuing research activity on this crop as far as the results are encouraging.*

Introduction

In Ethiopia, Capsicum spice is the most important spice of the country. Kostlan (1913) (as Jansen cited, 1981) called it the National spice of Ethiopia and he stated without Spanish pepper one can not imagine a food. The Ethiopians distinguish three kinds of capsicum spices; 'Karya' the immature green fruits; Berbere', the bulk of the red mature pungent fruits; the same name is also used to indicate a pungent sauce 'Mitmita', the small extremely pungent fruits.

The importance of *Capsicum* for Eastern Ethiopia is not questionable. The fruit can be found on almost every market and the plant is cultivated in the region. Hararghe is one of the main centers of cultivation (Alkamper, 1972 cited by Jansen, 1981). Pepper is the most important spice of the region and used by many people daily. However, the productivity of the crop is very low and as a result there is a tendency by farmers to shift their crop to other high cash value crops such as chat and some other vegetables. Due to its importance used as spice and vegetable, the crop should have to given first research priority in the region. Haramaya University realized the problem and has initiated research project to develop variety for the region. Haramaya University obtained five nationally released *Capsicum* varieties (Marko Fana, Marko Zala, Eshet, PBC-660 (Melka Awaze), Marko Dima) from National Vegetable Research Project and tested in different locations of east Hararghe for yield. But due to some technical problems it is difficult to recommend none of the varieties for growers. Therefore, it is necessary to continue adaptation trial using these varieties along with local check to recommend the most adapted improved variety (ies) for farmers in the region as early as possible.

Hararghe is one of the main centers of cultivation (Alkamper, 1972 cited by Jansen, 1981), which diversity of the crop is expected. Therefore, ccollection, evaluation and selection of farmers *Capsicum* cultivars in Eastern Ethiopia may be one of the preferable breeding methods to improve the crop for the region. Thus collection on plant basis of capsicum plants is necessary in the region.

The commercial production of hybrid *Capsicum* has been successful accomplished using hand-emasculation since the number of seeds produced from a single flower emasculation and pollination are reasonably many. Besides, genetic male-sterility and cytoplasmic male-sterility are also used in commercial hybrid *Capsicum* production. Therefore, it is possible to conduct heterosis breeding using elite (released varieties) to assemble varieties with superior genetic potential for yield, protection against production hazards, and improved quality into a hybrid. The five released varieties which were tested for yield also selfed and selfed seeds are available to make crossing among them. This will allow to produce *Capsicum* hybrids and to test the hybrids superiority over parents. It also allows studying the gene action that controlled *Capsicum* traits that will allow in designing appropriate breeding method(s) to improve this crop.

In Ethiopia *Capsicum* is usually cultivated on rather small plots (100-1000m^2) near the farmers house (Alkamper, 1972 cited by Jansen, 1981). This is done because this culture requires much manual labour and theft can be easier prevented. Moreover, cattle manure can be applied easier, as the cattle are brought near the house at night. If no dung is available, the Ethiopians prefer fallow land for the *Capsicum* crop (Alkamper, 1972 cited by Jansen, 1981). Little is known about the effect of inorganic fertilizers on growth and yield of *Capsicum* spp. in Ethiopian and particularly in Eastern part of the country. The amount of inorganic and/or organic fertilizer to be applied for *Capsicum* variety (ies) should have to be known for each *Capsicum* growing region by conducting fertilizer experiments. Therefore, it is necessary to conduct fertilizer trial to recommend appropriate amount of fertilizer to obtain optimum yield of variety(ies). Due to the above mentioned reasons, this project was reinitiated to fulfill the following objectives.

Objectives

1. To test the adaptability of released *Capsicum* varieties, identify high yielding variety(ies) and to make recommendation for Eastern Ethiopia
2. To collect, evaluate and characterize farmers *Capsicum* spp. cultivars for the improvement of the crop in the region
3. To estimate the extent of heterosis and gene actions involved in the inheritance of desirable traits of *Capsicum* and consequently produce high yielding hybrid (s)
4. To study nutrient requirement of *Capsicum* varieties in Eastern Ethiopia

Materials and Methods

Experimental materials

The adaptation trial of improved varieties will include Marko Fana, Marko Zala, Melka Eshet, PBC-660 (Melka Awaze), Marko Dima along with farmers' variety(ies)/landraces. For the collection, evaluation and selection of local pepper cultivars will be practiced, the collection will be on the basis of single plant selection. About 100 to 125 local collections will be tested along with improved varieties. Fertilizer trial will be conducted using Melka Awaze and Marko Fana. The five improved varieties will be crossed each other in half diallel fashion and F_1 hybrids with their parents will be tested.

Location

The trial will be conducted at Haramaya University Research Station, Hirna testing site, Dire Dawa Tony farm.

Experimental design

1. Adaptation trial would be conducted using randomized block design (RCBD) with three replications, three rows in each plot where each plot allocated for one variety and 30 plants per row.

2. 100-125 local cultivar collections along with the five improved varieties will be evaluated using Augmented design for the first season (screening purpose) and RCBD in the second (after screening) cropping season evaluation.

3. Crossing will be done in half diallel fashion which hybrids (F_1) and parents would be tested using randomized block design (RCBD) with three replications, three rows in each plot where each plot allocated for one parent/hybrid and 30 plants per row.

4. Fertilizer trial will be conducted using randomized block design (RCBD) with three replications arranged in factorial fashion taking 200kg N/ha and 44kg P/ha and 80-120kgN/ha and 44 kg P/ha as maximum and minimum limit, respectively, and two other maximum and minimum amount from these references would be calculated according to standard procedure of fertilizer trials.

4. Identification and scoring diseases will be conducted in all locations with the same design as the genotypes will be planted.

Data collection

Vegetative growth, fruit characteristics and yield traits were recorded, however; only yield and yield component traits are analyzed and presented in this report.

Modification made in materials and methods

All the five improved varieties were not tested in all three locations. This is because; there was scarcity of planting material/seedlings for Marko Dima where this variety was tested at

Haramaya Research site. The number of local collections selected on plant basis was not as proposed (100 to 125), but it was possible to select 72 accessions for final test. This is because of that the variation for fruit characteristics of the collections is not as expected.

Activities Completed

Single plant basis selection of Hararghe *Capsicum* spp. cultivars

Seeds of *Capsicum* spp. cultivars were collected around Hirna in bulk and grown at Haramaya University in 2012/13 cropping season. Selection was practiced on the single plant basis and seventy two *Capsicum* spp. genotypes were selected based on fruit characteristics, plant growth and reaction to diseases (Powdery and Downey mildew). The seeds of selected plants were raised at nursery and planted at field at Haramaya research field in 2013/14 cropping season using augmented design in five blocks which each block consists of 14 new entries and five improved varieties as a check.

Adaptation trial of improved varieties

Mareko Fana, Melka Eshet, Melka Zala, Marko Dima, PBC-660 (Melka Awaze) along with the local cultivar were tested in three locations (Haramaya University, Hirna and Dire Dawa) in 2012/13 cropping season. Marko Dima was not tested at Hirna and Dire Dawa because of scarcity of planting material. The data collected for yield and yield components was subjected to analysis of variance and the result is presented below.

Analysis of variance

The analysis of variance computed for eight yield and yield components of Pepper varieties at three locations revealed that the presence of significant differences among varieties for all the traits except for dry pod weight (g) where varieties and local cultivar didn’t exhibited significant difference (Table 1).

The mean squares calculated for the three locations and for all traits were highly significant ($P<0.01$) which showed that the three locations are varying for the suitability of growing pepper varieties and varieties were also performing differently in different locations. This suggested the need to test varieties as many locations as possible to make recommendation of varieties for growers and it also strongly suggested avoiding recommendation of varieties on the basis of single location test. Significant mean squares for location by variety for all traits except pod size (cm^2) supported the suggestion made earlier since this result indicated that varieties yield and yield components were significantly affected by the interaction of the varieties inherent characteristics and growing environments i.e. the varieties are performing different in different locations.

Table 1. Mean squares from ANOVA for Eight Characters of Pepper Varieties at Three Locations of eastern Ethiopia

Trait	Rep (2)	Loc (2)	Var (4)	Loc x Var (8)	Error (28)
Number of Pods per plant	689.2	8461.4**	588.1*	612.5*	219.7
Dry Pod Weight (g)	2.854	43.917**	0.448	1.514**	1.385
Dry Pod Yield per plant (g)	3150.1	27411.0**	2065.9**	753.2**	746.9
Marketable Dry Pod Yield/ha (qt)	389.4	2642.6**	285.9*	51.9*	106.8
Dry Pod Length (cm)	0.0440	12.2561**	3.2373**	0.9969**	0.8902
Dry Pod Width (cm)	0.02440	0.37881**	1.79436**	0.03840*	0.06577
Pod Size (cm^2)	4.39	340.17**	121.00**	19.67	10.51
Thousand Seeds Weight (g)	0.3609	9.1820**	1.0566*	0.3662*	0.3379

* & **, Significant at P<0.05 and P<0.01, respectively. Rep=replication, Loc=location and Var=variety. Numbers in parenthesis indicated degree of freedom.

Performances of varieties across locations

In Ethiopia, vegetables account only for about 0.95% of the total area under cultivations. Of all the area under vegetables, 68.85% is under red pepper production (CSA, 2011). More than 100,000 tones (annual average) of dry fruit of hot pepper are produced in the country and used for export market with substantial amount consumed locally as spice which exceeds the volume of all other spices put together in the country. However, there is serious shortage of dry fruits both for export and local markets partly due to very low productivity (0.4 t/ha dry fruit yield) of the crop (Fekadu *et al.*, 2008). The dry fruit yield estimate in small farmers' field was about 0.4 t/ha, while the dry fruit yield in experimental plot ranged between 2.5-3 t/ha. This indicates that hot pepper and other vegetable crops need intensive care and management for high return per unit area (Fekadu *et al.*, 2008). The low average yield of near to 0.4 t/ha dry fruit yield in Ethiopia is brought about by lack of adaptable varieties with the existing agro-ecologies which is also true for eastern Ethiopia where there is no single improved variety recommended for cultivation. The mean performance of improved Pepper varieties for yield and yield components at three locations of eastern Ethiopia on the basis of one cropping season adaptation trial is presented in Table 2.

The data presented in Table 2 showed that dry pod yield of varieties ranged from 20.23 quintals or 2.02 tons **(**Melka Zala) to 35 quintals or 3.5 tons/ha (Mareko Fana). The observed yield for varieties was in the same range for dry fruit yield in experimental plots recorded elsewhere in the country which ranged between 2.5 to 3 t/ha (Fekadu *et al.*, 2008). The interesting result in this research was the performance of local cultivar yield which was 28.07 quintals or 2.81 t/ha which was only exceeded by Mareko Fana and Melka Eshet and if it is only considered the local use of 'Karya' the immature green fruits and "Berbere', the bulk of the red mature pungent fruits, it is only exceeded by Mareko Fana since Melka Eshet is a variety released for processing due to its color and oleoresin extraction. The local cultivar included was a mixture of different genotypes collected from western Hararghe (around Hirna) only, which does not represent sufficiently the entire eastern Ethiopia. This showed that the potential and the higher chance of improving yield of this crop in the region through extensive collection, evaluation and selection of local pepper cultivars in the region. This suggestion was in agreement with Alkamper, (1972) cited by Jansen, (1981) who reported that Hararghe is one of the main centers of cultivation where diversity of the crop is expected. Therefore, ccollection, evaluation and selection of farmers *Capsicum* cultivars in eastern Ethiopia are strongly suggested to improve the productivity of the crop in the region. This is because of that the present study result as well as the earlier report clearly showed that the potential of the region local cultivars are not well explored and not exploited. Therefore, the research in this crop is better to focus on the exploitable diversity of the local cultivars of the region rather than depending on improved varieties developed elsewhere in the country.

Table 2. Mean Performance of Pepper Varieties for Yield and Yield Components at Three Locations of eastern Ethiopia

Trait	Location	Mareko Fana	Melka Eshet	Melka Zala	Local	PBC-660	Mean
Number of Pods per plant	Haramaya	59	51	28	41	92	54
	Hirna	13	14	8	9	10	11
	Dire Dawa	21	16	17	13	12	16
	Mean	**31**	**27**	**18**	**21**	**38**	**27**
Dry Pod Weight (g)	Haramaya	2.7	2.51	2.68	2.84	1.32	2.41
	Hirna	4.65	4.56	5.22	5.39	6.51	5.266
	Dire Dawa	2.42	2.16	1.85	2.78	1.8	2.202
	Mean	**3.26**	**3.08**	**3.25**	**3.67**	**3.21**	**3.29**

Dry Pod Yield per plant (g)	Haramaya	152.9	129.6	65.7	115.6	117.9	116.34
	Hirna	58.4	64.3	43	50.7	48	52.88
	Dire Dawa	49.6	35.7	31.1	36.5	22.1	35
	Mean	**86.97**	**76.53**	**46.60**	**67.60**	**62.67**	**68.07**
Marketable Dry Pod Yield/ha (qt)	Haramaya	53.6	47.4	25.4	42.7	44.5	42.72
	Hirna	27.8	30.6	20.5	24.1	22.9	25.18
	Dire Dawa	23.6	17	14.8	17.4	10.5	16.66
	Mean	**35.00**	**31.67**	**20.23**	**28.07**	**25.97**	**28.19**
Dry Pod Length (cm)	Haramaya	10.34	8.91	10.62	10.04	8.43	9.67
	Hirna	7.82	7.46	9.07	8.08	7.54	7.99
	Dire Dawa	7.66	7.66	9.05	8.02	8.79	8.24
	Mean	**8.61**	**8.01**	**9.58**	**8.71**	**8.25**	**8.63**
Dry Pod Width (cm)	Haramaya	2.98	2.64	1.809	2.626	1.826	2.38
	Hirna	2.67	2.613	1.893	2.6	1.727	2.30
	Dire Dawa	2.42	2.06	1.723	2.503	1.647	2.07
	Mean	**2.69**	**2.44**	**1.81**	**2.58**	**1.73**	**2.25**
Pod Size (cm^2)	Haramaya	30.79	23.53	19.19	26.88	15.43	23.16
	Hirna	15.21	16.77	11.42	16.45	9.27	13.82
	Dire Dawa	18.58	15.62	15.62	20.06	14.48	16.87
	Mean	**21.53**	**18.64**	**15.41**	**21.13**	**13.06**	**17.95**
Thousand Seeds Weight (g)	Haramaya	7.64	7.56	6.83	7.417	6.28	7.14
	Hirna	5.63	6.43	6.03	6.333	5.37	5.96
	Dire Dawa	5.67	5.67	5.33	6	5.667	5.67
	Mean	**6.31**	**6.55**	**6.07**	**6.58**	**5.77**	**6.26**

Performances of five varieties and local check at Haramaya

Since Mareko Dima was not tested in two other locations and only evaluated at Haramaya due to scarcity of planting materials (seedlings), it is necessary to conduct separate analysis for Haramaya testing site to evaluate the variety performance. The analysis of variance result is presented in Table 3 and mean performances of six pepper varieties including local check is presented in Table 4. Highly significant (P<0.01) differences were observed among varieties for all the traits except for thousand seeds weight (g) which the mean square for this trait was non-significant. This indicated that the presence of considerable variations among varieties for all traits except thousand seeds weight.

Table 3. Mean squares from ANOVA for Eight Characters of Six Pepper Varieties at Haramaya, eastern Ethiopia

Trait	Replication (2)	Variety (5)	Error (28)
Number of Pods per plant	1626.4	2186.1**	366.6
Dry Pod Weight (g)	0.3825	3.1002**	0.2105
Dry Pod Yield per plant (g)	7632.6	3703.1**	703.3
Marketable Dry Pod Yield/ha (qt)	886.60	413.86**	74.76
Dry Pod Length (cm)	0.955	19.158**	1.420
Dry Pod Width (cm)	0.02064	0.88546**	0.03746
Pod Size (cm^2)	16.06	374.37**	22.31
Thousand Seeds Weight (g)	0.0421	1.3821	0.4823

Mareko Dima was performing lowest dry pod yield per plant (g) and marketable dry pod yield/ha (qt) which was only exceeded Melka Zala with very low differences which showed non-significant differences between these two varieties. The variety also recorded the lowest number of pods per plant. However, this variety recorded extremely highest mean values for dry pod weight (g), dry pod length (cm), dry pod width (cm) and pod size (cm^2). These traits are desirable in developing pepper varieties both for local consumption ('Karya' and "Berbere') and for processing as spice. The thicker and longer the fruit of pepper are preferred by local consumers and processors due to the potential of the fruit to produce high end products. But, as far as the variety is not performing high yield per unit area, it is not possible to recommend for cultivation as a variety since farmers are also looking for higher yield per unit area. However, this variety will be used in crossing program to transfer its desirable characteristics to produce hybrid or variety which combine many number of pods per plant and Mareko Dima desirable fruit characteristics which leads to the hybrid or variety to be high yielding.

Table 4. Mean Performance of Six Pepper Varieties for Yield and Yield Components at Haramaya, eastern Ethiopia

Trait	Mareko Fana	Mareko Dima	Melka Eshet	Melka Zala	Local	PBC-660	Mean
Number of Pods per plant	59.4	14.8	51.1	27.8	40.5	92	47.6
Dry Pod Weight (g)	2.7	4.5	2.51	2.68	2.84	1.32	2.76
Dry Pod Yield per plant (g)	152.9	66.2	129.6	65.7	115.6	117.9	108
Marketable Dry Pod Yield/ha (qt)	53.6	25.6	47.4	25.4	42.7	44.5	39.8
Dry Pod Length (cm)	10.34	15.5	8.91	10.62	10.04	8.43	10.64
Dry Pod Width (cm)	2.976	3.032	2.64	1.809	2.626	1.826	2.485
Pod Size (cm^2)	30.8	47.1	23.5	19.2	26.9	15.4	27.1
Thousand Seeds Weight (g)	7.64	8.22	7.56	6.83	7.42	6.28	7.32

Recommendation and Suggestion for Future Research Directions

Though the research result presented here is based on a one season and three locations data, it has given good information to made some recommendation and suggestion for future research direction in this crop in the region. This can be summarized in short as follows:

1) The yield obtained from all varieties including local cultivar is encouraging since it is similar to yield recorded by other Research Centers for the crop, therefore, it is necessary to test for one more season to identify the best variety and to make recommendation for cultivation in eastern Ethiopia.
2) The yield of local cultivar is near to comparable the best performing improved varieties and exceeded the two Melka Zala and PBC-660 and Mareko Dima when it was evaluated across locations and Haramaya, respectively. Based on this research result as well as the earlier report, it is suggested to conduct collection, evaluation and selection of local cultivars throughout the region to exploit the existing diversity for yield and yield components.

3) Though, Mareko Dima can't be recommended as variety due to its low yielding potential per unit area, it has desirable fruit characteristics that can be transferred through crossing. The same is true to PBC-660 (Melka Awaze) and Melka Zala, which performed lower yield than local cultivar which may not be recommended for cultivation in the region if performed the same in the other cropping season, but they have desirable characteristics of producing extremely highest number of pods per plant and desirable fruit characteristics which can be transferred or combined to other varieties that lack these traits through crossing. In general, varieties have different desirable traits that can be combined through crossing; therefore, crossing of varieties is essential to develop high yielding hybrid or variety which combines all desirable characteristics that will be preferred both by local consumers and processing plants.
4) To develop or recommend improved variety is the first step in improving the productivity of the crop which the full potential of the variety productivity can be expressed and enhanced by providing proper agronomic management, therefore, fertilizer requirement of the crop or variety should be determined as soon as possible by considering major pepper growing areas of the region. For this purpose, this one season research clearly showed that which variety is going to be used in determining fertilizer requirement and other agronomic management. The variety Mareko Fana is performing highest yield across locations and it has also all desirable fruit characteristics. In addition, though, Mareko Fana was released in 1976, it is still the most popular variety grown both by small scale and large farms in the country. This is because, it produce fruit with dark red colour, long, thick skin and pungent as well. Due to its thick skin, colour and pungency, this variety is particularly suited for processing plants of spices as well as preferred by local consumers for both Karya' and "Berbere'. Therefore, it is possible to use this variety for any agronomic management research in the region.

Activities to be accomplished During the Remaining Project Period

1) Crossing among improved varieties should be made as much as possible and hybrids along with parents should be tested

2) Further collection and selection of local cultivars considering major hot pepper growing areas of eastern Ethiopia is necessary to develop varieties for the region which perform better than varieties developed elsewhere

3) Optimum organic and/or inorganic fertilizer rate for maximum yield of pepper should be studied in eastern Ethiopia and other agronomic management practices that maximize the yield of hot pepper also better to be studied as early as possible in the region

4) Major disease, insect pest of this crop better to be studied to suggest control methods

Problems Encountered

The adaptation trial was proposed in 2011 and submitted to grant of Haramaya University fund. The project has been accepted and announced to be funded, however, with lack of proper communication it was not finalized as HU funded project. With the Research office and with other research program support the first season and collection of local cultivars have been accomplished. As new project including collection, evaluation and selection of local cultivars, fertilizer rate determination, adaptation trial of improved varieties and crossing program was proposed for 2012/13 HU research grant and accepted for 17 months period research, but the research activities can't be accomplished with this period except adaptation trial of improved varieties which will be completed in the grant period. Therefore, to complete the research project at least it is necessary to extend for five years and to be funded the same.

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Survey and Variability Study on Morphology and Quality Attributes among Mango (*Mangiferaindica* L.) Cultivars in Eastern Haraghe, Ethiopia

TewodrosBezu (MSc.), Kebede W/Tsadik (PhD) &TamadoTana (PhD)

Abstract: *Mango productionis the dominant in which it covers 35% of the total acreage allotted for fruit production in the eastern parts of the country. However, except limited efforts made by some researchers, detailed scientific study on theexisting mango-ecotypeshaving diverse production and qualitycharacters not yet been carried out .Thus, study was conducted with the objectives of assessing the farmer's production practices and their challenges and to study the variability with regard to tree morphology and physico-chemical attributes of the eco-types fruit in order to identify the superior trees that can have desirable features. Survey using semi-structured questioner and interview, was madewith 90 mango growers selected purposively in the major mango growing areas of eastern hararghe: Error Weldia, Harewe and Bisidimo Leprosy Referral hospital from 2004 to 2005 EC. Moreover, 143 trees having similar ages but different characters were also identified based on the growers experience and naming. The result indicated that, almost all eco-types are seedling in origin derived from very few trees that were introduced from abroad via missionaries and traders. Input shortage (water, fertilizer and pesticide), lack of technologies, pest, postharvest loss and poor marketing were the major problems specified by the growers. Furthermore, around 24 promising eco-types were selected based on physico-chemical attributes of their fruits such as fruit weight, fruit to stone ratio, eating quality, quantity of fiber in fruit and fruit firmness at ripening stage, for further maintenance and study. It was also observed that, some of the trees showed variability though they have similar local naming. Therefore, the promising trees should be urgently maintained and studied further for their other agronomic performances since the intention of the growers had becoming towards other cash crops. Moreover, focus should also be given in improving the production, productivity and marketing of the crop in order to utilize the available and adaptable mango eco-types rather than replacing them with the imported and improved cultivars.*

Background and Justification

Fruit crops play an important role in the national food security. They are generally delicious and highly nutritious (mainly of vitamins and minerals) that can balance cereal-based diets. Fruits supply raw materials for local industries and sources of foreign currency. Moreover, the development of fruit industry will create employment opportunities, particularly for farming communities. In general, the country has great potential and encouraging policy to expand fruit production for fresh market and processing both for domestic and export markets. Besides, fruit crops are friendly to nature, sustain the environment, provide shade, and can easily be incorporated in any agro-forestry programs (MoARD, 2009).

Despite this potential, the area under fruits is very small in Ethiopia and mainly smallholder based. According to the Ministry of Agriculture and Rural Development report , there are about 3 million farmers involved in fruit production with a total area of about 43,500 ha and producing about 261,000 t annually (MoARD, (2005),. However, less than 2% of all the produce is exported (Joosten, 2007). Although the number of farmers growing fruit trees seems high, each farmer grows very few trees of local cultivars which are also poorly managed and are mainly for home consumption. These fruits are typically cultivated to supplement household income from their main crops. The few state farms with about 3,000 ha mainly grow tropical fruits (banana, avocado, mango, orange, and papaya) and are mainly located in the eastern Rift Valley (Siefu, 2003).

According to Wiersinga and Jager(2007),Dire Dawa and Harari (Eastern Ethiopia) are stated as one of the well-known production and supply areas of both fruits and vegetables in Ethiopia in which35% of the total acreage allotted for fruit production is covered by Mango in the eastern parts of the country (according to unpublished Haramaya University Horticulture Department Survey, 1996). Moreover, Ishot (2009) also stated fruit crops produced in Harari People National Regional State by the year 2004/2005 were 30tons on a total land area of 163 ha owned by a total of 5,171 peasant holders. The area occupied by mango was 115 ha while their total production and productivity was 12.2ton and0.1tonha^{-1}, respectively. In general, mango is grown widely and dominantly in the central and lower parts of the Bisidimo and Erer River basins including in the vicinities of the Harar city.

A comparative study made between income from fruit growing and cereals (sorghum and maize) in Hararby TAM Agribusiness (2004) revealed that the annual income from fruit growing such as mango and custard apple was ETB 60,000/ha/yr and over 70,000 for chat based farming, compared to 2,000 for maize and only 1,000 for sorghum.

However, majorities of the mango cultivars are originated from seedlings arising from natural crossing and are not maintained true to type by asexual propagation. Except in research centers and few state farms, no known mango cultivars are produced and most mango trees in Ethiopia are seedlings (not grafted). Seedling mango trees are vigorous, tolerant to some diseases and produce high fruit yield. However, their fruits are not uniform in size, shape and taste; trees have long juvenile period; unmanageable tree size for routine cultural practices; and fruits do not mature at the same time affecting marketing (MoARD, 2009).

Even if the farmer’s livelihood is highly supplemented by the income from their mango trees, (unpublished Haramaya University Horticulture Department Survey, 1997), there is a declining trend in yield and quality of the fruits from the trees. Some of the factors contributing to this include foliar diseases, old age, poor management and seedling originatednature of the trees (Yeshitela and Nessel, 2003). Except the farmer’s traditional naming for identification, the trees are mixed and difficult for identification. On the other hand, owing to the current government policy in export-oriented horticulture, majority of the investors and/or institutions are focusing on importing improved cultivars from abroad even though locally adapted superior cultivars are believed to exist. This may lead to loss of the locally adaptable, good yielding quality cultivars unless timely intervention measures are undertaken.

Objectives

The study was conducted with the following objectives:

- To study about the status of mango production
- Studying the variability of mango trees grown in Eastern Ethiopia based on tree and fruit morphology and fruit quality traits.
- To characterize the trees for further maintenance, multiplication and distribution to the end users.

Materials and Methods

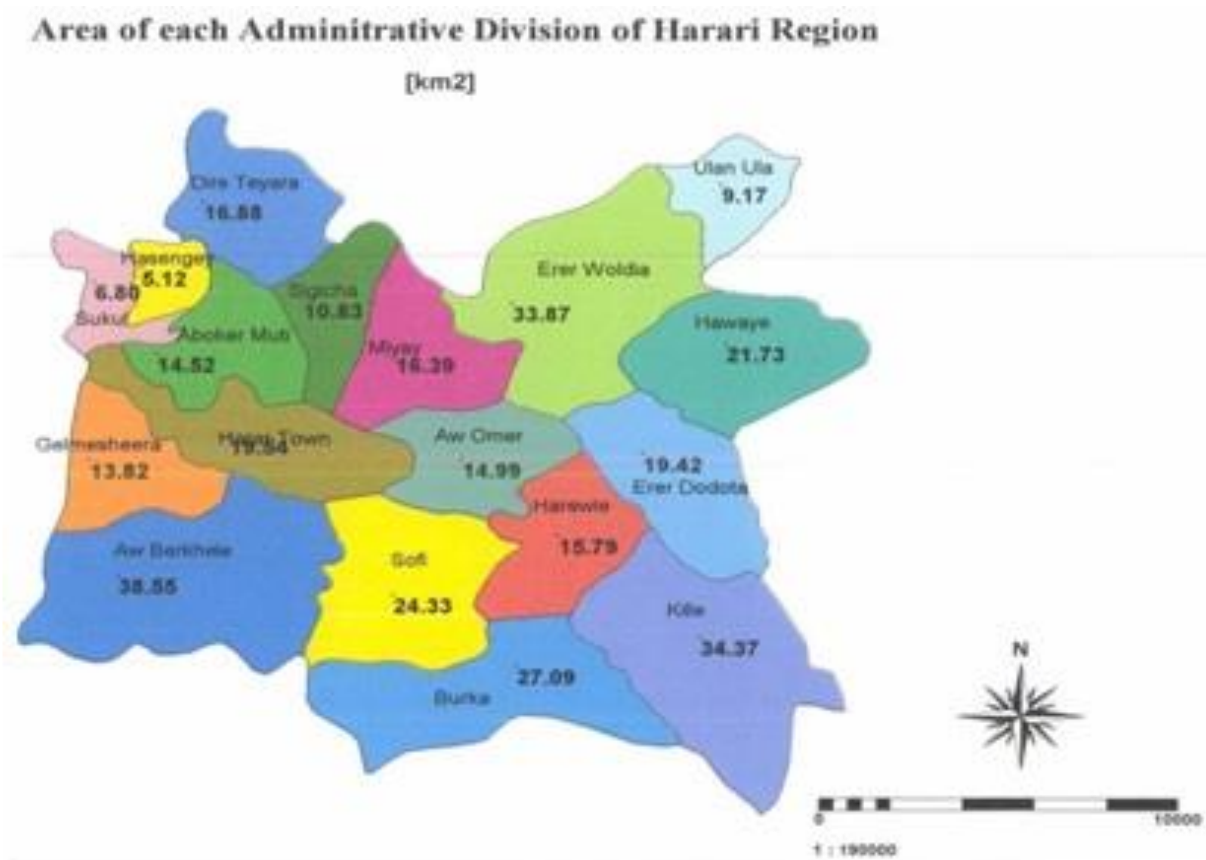
Description of the study area

The study was conducted on the major mango-producing rural *kebeles* of Harari people's regional state, specifically: ErrerWeldia (sub-kebeles: Errer Marko, Ganda Haji, GolaGandaWedia, ItisaBakere, ItisaGoroMaskida, Kona and MelkaHidaGedi), Harewe (sub-kebeles: Agemboy, Bereser, HareweKalu and Nole) and Bisidimo (Bisidimo leprosy referral hospital farm).The region is located in the eastern part of Ethiopia. The totalgeographical area is about 343.21 km^2. It is geographically located between 42.03 –42.16 N latitude and 9.110-9.240 E longitude.

Administratively; the region is divided in six urban and three ruraladministrative *weredas* (main kebeles). These administrative *kebeles* are further divided into 19 sub-kebeles (inurban) and 17 sub-kebeles (in rural). The region is mainly categorized in two agro-ecological zones, i.e. 90% of the land area of the region is estimated to be mid-high land (*weynadega*), between 1400 – 2200 meter above sea level, while the remaining 10% is kola (approximately found below 1500 meter above sea level) (Sultan *et al*., 2011).

The climate of the region is suitable for production of diverse horticultural cropswhere temperature is ranging between 17.1^{o}C-20.2^{o}C throughout the year. The coolest season (18.7^{o}C) is between June and September, and coincides with large rains. The average annual amount of precipitation is about 750-1,000 mm (http://hararconnection.com/hnrs.htm).

In Harari people's regional state, the dominant economic sector is primarily service sector followed by agriculture. The agriculture is mainly relied up on the seasonal rainfall and traditional farming method. The region also known for its fruit production, such as mango, banana, orange, *anona spp*. and guava. (Sultan *et al*., 2011).



Source: Harar Vision Net (2010)

3.2 Studying material identification and sampling methods

The mango trees to be evaluated wereselected purposively after consulting the district (*wereda*) agricultural offices about the location and names of farmers growing locally known mango eco-types. Then, the study was done on total of 40 farmers having at least ten (10) or more mango trees. Interviewwas made with the growersusing semi structuredquestionnaires about the mango production practices, constraints and inparticular the present ecotypes and their specific features. Then, the identified mango eco-types were listed and summarized based on local naming. Finally, 143 treeshaving similar age but different production features as per the growersexperiencewere selectedandtagged for the study. Furthermore, interview and group discussions were also made with the professionals (developmental agents and/or researchers) of the areas about their previous history, means of classifying the existing eco-types and/or over all experiences in relation with the existing eco-types.

Data collected

Both primary and secondary data werecollected to obtain the required information for the study. Accordingly, interview about the general mango production practices, ecotypes and their constraints using semi structured questionnaires; 13 tree morphological variables (trunk circumference, crown diameter, leaf blade length, petiole length, height of matured tree, tree type, crown shape, tree growth habit, foliage density, leaf blade shape, leaf base shape, leaf apex shape and leaf margin) and physico-chemical variables (fruit length, fruit diameter, fruit weight, fruit firmness, stone length, stone width, stone weight, fruit to stone ratio, fruit shape, shape of fruit apex, fruit attractiveness, skin color of ripe fruit, fruit skin surface texture, depth of fruit stalk cavity, fruit neck prominence, fruit beak type, pulp color of ripe fruit, quantity of fiber in pulp; pulp juiciness; pulp aroma, seed shape, eating quality, pulp total soluble solids and pulp titrable acidity of the mango ecotypes were recorded and determined as perthe mango crop descriptors written by IPGRI (2006).

Data analysis

The data collected were summarized and analyzed using descriptive statistics

Results and Discussions

Mango Production Practices and Constraints in Eastern Hararghe

The survey resultrevealed that the majority of mango growershave few mango trees (10-20 trees) originated from seeds of fewintroducedbut unknown cultivars from different countries like Saudi Arabia byMuslims who used to go to Meka, traders and missionaries (Table 1). The responses with regard to the production practices showed the existing mango trees are of 100% seedling originthat could be the reason forthe existing variability among eco-types and also the majority of the ecotypes planted without the recommended spacing and pruning of the trees is not practiced. Due to this fact, the majority of the trees observedwere too crowded, very tall and the undersides of the canopy of the trees arewithout leaves and fruit.Moreover, the majorities (70%) of the growers do not supplement their trees with the required fertilizer but some (26%) apply organic fertilizerssuch as compost and manure. However, the rates of fertilizer application have not yet been determined for the study area.

Regarding the pests and their management, the respondents pointedout the major insect pests like fruit fly (100%),thrips (21%) and termites (10%); and diseases such as powdery mildew (99%) and anthracnose (100%). For the management of the aforementioned pests, cultural practices like smoking for management of thrips especially during flowering and sanitation via removing diseased branches and weedinghave beenthe common methodsusedby the growers due to several factors likeunavailability of pesticide, economical problem and lack of knowledge.

The major production constraint in the study area is water shortage (79%) which is followed by pest problems (78.6%).Lack of knowledge about production practices (nutrition, pruning, pest management etc.) and post-harvest losses were also noted as major problems of the growers.Likewise, absence of good marketing system that could benefit or attract the growers is the additional bottleneck raised (table 2). As a result, the grower reflected their tendency towards cultivation of cashcrops like chat by uprooting the exiting trees.

Table 1: Mango production practices adopted by the farmers in the study area

Variable		**# of respondents**	**%**
Number of trees per farmers			
	10-20	50	71.40
	21-30	12	17.10
	31-40	6	8.60
	>40	9	12.90
Type of planting material			
	seedling	70	100.00
	grafted	0	0.00
Source of planting material			
	local	54	77.14
	imported	16	22.86
Plant spacing			
	recommended	3	4.29
	non-recommended	67	95.71
Pruning			
	yes	19	27.14
	no	51	72.86
Fertilizer application			
	organic	18	25.71
	inorganic	3	4.29
	none	49	70.00
Major pest			
	Insect pest		
	thrips	15	21.43

	fruit fly	70	100.00
	scale	0	0.00
	termite	7	10.00
	others	0	0.00
Diseases			
	powdery mildew	69	98.57
	anthracnose	70	100.00
	others	2	2.86
Pest management practices			
	pesticide	0	0.00
	Cultural (Smoking, cleaning etc.)	70	100.00
	integrated	0	0.00

Table 2: Major production constraints of mango in the study area

Constraints	# of respondents	%
Erratic rainfall (scarcity of irrigation water)	55.00	79.00
Shortage of fertilizer	15.00	21.42
Pest	55.00	78.60
Lack of knowledge & skill	44.00	62.90
Postharvest fruit rot	35.00	50.00
Poor Marketing	9.00	12.90

Mango Eco-types in Eastern Hararghe

Both the tree and fruit characters of the mango ecotypes showed significant variation (table 3 & 4) though some of the eco-types have similar local naming (Table 5). Accordingly, highest variation 80.18% and 91.68% resulted from fruit and stone weight, respectively. This could be due to seedling origin nature of the trees besides other environmental variables. However, among the eco-types examined, 24 trees (table 5) are shortlisted based on major fruit quality variables such as fruit weight, fruit to stone ratio, eating quality, quantity of fiber in fruit and fruit firmness at ripening stage. Moreover, the world standard of TSS (total soluble solute) and TA (titrable acidity) for superior mango cultivars is 15-22 and 0.15-3%, respectively (Yeshitela and Nessel, 2003). And hence, the shortlisted eco-types also fall in the aforementioned standards.

Table 3: Tree morphological characteristics of mango eco-types

Variable	Minimum	Maximum	Mean	Coefficient of Variation
Trunk circumference (cm)	33	420	198.99	37.64
Crown diameter (m)	3.2	28.25	11.02	41.68
Leaf blade length (cm)	3	30.4	17.88	40.55
Petiole length (cm)	2.2	27.00	7.10	93.22
Height of matured tree	1	4	2.8	41.43
Crown shape	1	4	2.76	28.26
Tree growth habit	1	3	2.01	11.94
Foliage density	3	7	4.87	34.09

Table 4: Fruit physicochemical characteristics of the mango eco-types

Variables	Mean	Minimum	Maximum	CV (%)
Fruit length (cm)	8.61	5.32	13.91	19.78
Fruit diameter (cm)	5.89	3.53	9.07	20.40
Fruit weight (g)	294.12	103.1	1140.29	80.18
Fruit Firmness (lb)	3.68	1.61	9.56	38.73
Stone length (cm)	6.92	4.24	11.33	20.11
Stone width (cm)	3.55	1.37	7.37	26.32
Stone weight (g)	67.14	28.63	319.19	91.68
Fruit/stone	5.06	0.66	20.72	48.50
Fruit shape	2.13	1	5	59.46
Shape of fruit apex	2.12	1	3	23.97
Fruit attractiveness	2.86	1	4	24.70
Skin color of ripe fruit	2.53	1	5	35.69
Depth of fruit stalk cavity	0.27	0	2	199.98
Fruit beak type	1.48	1	4	66.66
Pulp color of ripe fruit	4.50	1	8	39.92
Quantity of fiber in pulp	2.71	0	7	79.01
Pulp juiciness	2.29	1	3	28.78
Pulp aroma	1.89	1	3	37.33
Eating quality	6.10	3	9	25.95
Pulp total soluble solids (ºBrix):	3.40	2	5	18.88

Table 5: Shortlisted eco-typesof mango tress based on their desirable fruit physico-chemical characteristics

Tree Code	Local Name	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Weight (g)	Fruit Firmness (lb)	Stone Length (cm)	Stone Width (cm)	Stone Weight (g)	Fruit: Stone	Fruit Shape	Shape of Fruit apex	Fruit Attractiveness
EA1	Amba Ahmed Abdulahi	13.91	9.07	796.25	3.76	11.33	4.75	38.43	20.72	Oblong	Obtuse	Good
HAD4	AmbaAdi	8.73	6.06	977.52	5.61	5.77	2.73	139.83	6.99	Oblong	Obtuse	Excellent
HLI2	AmbaLibaanatoo	7.90	4.37	783.82	4.73	5.05	2.21	193.75	4.05	Oblong	Obtuse	Average
HMAI7	AmbaMaity	11.35	7.90	662.39	5.43	8.50	3.80	209.06	3.17	Oblong	Obtuse	Excellent
AN	AmbaNeguse	12.60	8.13	512.98	6.18	9.78	5.64	54.10	9.48	Oblong	Round	Good
AB1	AmbaBebala	12.57	8.03	452.17	3.65	10.67	5.26	38.00	11.90	Oblong	Round	Excellent
E39.1	AmbaSabid	10.11	7.72	351.75	3.28	7.95	3.94	48.47	7.26	Roundish	Obtuse	Good
HBIS2	AmbaBishaano	8.40	6.58	1094.06	5.67	6.33	3.01	171.71	6.37	Elliptic	Obtuse	Excellent
E39.3	AmbaSabid	9.09	7.03	318.85	2.85	7.54	4.37	41.30	7.72	Roundish	Round	Good
HHU5	Amba Hula	9.60	6.30	1140.29	4.97	5.20	2.22	178.00	6.41	Elliptic	Obtuse	Excellent
HLI4	AmbaLibaanatoo	7.80	5.82	1060.94	5.67	4.93	2.40	251.23	4.22	Roundish	Obtuse	Excellent

AH2	AmabaHarewe	11.25	7.06	378.40	3.51	8.56	3.66	36.77	10.29	Roundish	Acute	Excellent
E24.5	AmabaHarewe	11.80	6.76	330.73	2.04	7.87	3.18	45.37	7.29	Roundish	Acute	Excellent
AN2	AmbaNeguse	11.99	8.20	454.20	4.07	8.46	7.37	64.30	7.06	Oblong	Round	Good
HKU5	AmbaKukurfa	8.63	6.26	1078.30	5.13	5.50	2.31	125.09	8.62	Oblong	Obtuse	Excellent
E22.4	AmbaGuracha	7.62	6.02	175.90	2.25	6.10	3.93	28.63	6.14	Roundish	Round Average	Average
E15.2	AmbaBebala	12.45	8.36	487.30	5.70	9.91	6.15	57.50	8.47	Oblong	Round	Excellent
HNG2	AmbaNeguse	7.65	5.43	1122.80	5.02	6.95	2.88	168.37	6.67	Elliptic	Obtuse	Good
E37.5	AmbaNeguse	11.81	8.38	491.65	3.72	9.29	4.62	60.40	8.14	Oblong	Obtuse	Good
AH3	AmbaHarewe	9.09	6.63	279.02	2.49	7.62	4.09	46.30	6.03	Roundish	Obtuse	Good
E39.4	AmbaSabid	9.32	7.64	263.45	1.90	7.44	3.91	38.57	6.83	Roundish	Acute	Excellent
ES	AmbaSufian	10.87	6.65	361.53	6.12	8.97	3.56	52.80	6.85	Eliptic	Obtuse	Good
E47.5	AmbaUmerAlishoAdi	9.14	6.73	240.58	5.31	7.26	4.08	38.43	6.26	Oblong	Obtuse	Good
E24.4	AmbaHarewe	9.14	7.19	295.50	5.42	7.95	4.75	54.53	5.42	Roundish	Acute	Excellent

Table 5 Cont….

Tree Code	Local name	Skin color of ripe fruit	Fruit skin surface texture	Depth of fruit stalk cavity	Fruit neck prominence	Fruit beak type	Pulp color of ripe fruit	Quantity of fiber in pulp	Pulp juiciness	Pulp aroma	Eating quality	Pulp total soluble solids (^{0}Brix):	Pulp titrable acidity
EA1	Amba Ahmed Abdulahi	Green	Smooth	Absent	Absent	Perceptible	Light yellow	Absent	Very juicy	Strong	Excellent	17.8	0.52
HAD4	Amba Adi	Green with red blush	Smooth	Absent	Absent	Perceptible	Yellow	Absent	Slightly juicy	Mild	V.good	20.5	0.97
HLI2	Amba Libaanatoo	Yellow	Smooth	Absent	Absent	Perceptible	Dark orange	Absent	Very juicy	Strong	Excellent	24.0	1.16
HMAI7	Amba Maity	Green	Smooth	Absent	Absent	Mammiform	Yellow orange	Absent	Very juicy	Strong	Excellent	15.0	1.49
AN	Amba Neguse	Green	Smooth	Absent	Slightly P.	Mammiform	Yellow	Absent	Very Juice	Intermediate	V. good	16.8	1.01
AB1	Amba Bebala	Green	Smooth	Absent	Slightly P.	Mamiform	Orange	Absent	Very juicy	Strong	Excellent	17.0	0.25

E39.1	Amba Sabid	Green	Smooth	Shallow	Absent	Perceptible	Greenish Y.	Absent	Very juicy	Strong	Excellent	18.0	0.64
HBIS2	Amba Bishaano	Greenish yellow	Smooth	Absent	Absent	Perceptible	Yellow	Low	Very juicy	Intermediate	Good	16.0	0.77
E39.3	Amba Sabid	Yellow	Smooth	Shallow	Absent	Perceptible	Light Orange	Absent	Juicy	Strong	Excellent	18.0	0.15
HHU5	Amba Hula	Yellow	Smooth	Absent	Absent	Perceptible	Golden yellow	Absent	Juicy	Mild	Good	11.0	0.87
HLI4	Amba Libaanatoo	Yellow	Smooth	Absent	Absent	Perceptible	Yellow	Low	Very juicy	Strong	V.good	14.0	1.86
AH2	Amaba Harewe	Yellowish O.	Smooth	Absent	Slightly P.	Prominet	Orange	Absent	Very Juicy	Intermediate	V.good	16.5	1.31
E24.5	Amaba Harewe	Yellowish Orange	Smooth	Medium	Absent	Perceptible	Light Orange	Absent	Very Juicy	Intermediate	V.good	17.1	0.23
AN2	Amba Neguse	Green	Smooth	Absent	Absent	Perceptible	Greenish Y.	Absent	Very Juice	Intermediate	V. good	15.8	0.62
HKU5	Amba Kukurfa	Geern with red blush	Smooth	Shallow	Absent	Perceptible	Orange	Low	very juicy	intermediate	Good	17.0	0.87
E22.4	Amba Gurac	Green	Smooth	Absent	Absent	Perceptible	Greenish Y.	Absent	Very Juicy	Strong	Excellent	19.8	0.23

	ha												
E15.2	Amba Bebala	Green	Smo oth	Abse nt	Slightly P.	Prominen t	Light yellow	Intermedi ate	Juicy	Stron g	Excell ent	16.5	0.41
HNG2	Amba Negus e	Green ish yello w	Smo oth	Medi um	Absent	Perceptib le	Yellow orange	Low	Juicy	Inter media te	Good	16.0	0.89
E37.5	Amba Negus e	Green	Smo oth	Shall ow	Absent	Perceptib le	Orange	Low	Very Juicy	Inter media te	V. good	18.0	0.58
AH3	Amba Harew e	Green ish Y.	Smo oth	Shall ow	Absent	Perceptib le	Light Orange	Absent	Very Juicy	Mild	V.goo d	16.0	0.81
E39.4	Ambas abid	Orang e	Smo oth	Shall ow	Absent	Perceptip le	Yellow orange	Absent	Very juicy	Inter media te	V. good	18.0	0.61
ES	Ambas ufian	Yello wish G	Smo oth	Shall ow	Absent	Perceptib le	Light orange	Low	Juicy	Mild	Good	17.0	0.38
E47.5	Amba Umer Alisho Adi	Yello wish G.	Smo oth	Abse nt	Absent	Perceptib le	Yellow orange	Absent	Juicy	Mild	V. good	18.2	0.43
E24.4	Amba Harew e	Yello w	Smo oth	Medi um	Absent	Perceptib le	Light Orange	Low	Very Juicy	Inter media te	V.goo d	16.5	0.50

Table 6. Shortlistedpromising eco-typesof mango based on tree morphological characteristics

Tree Code	Local name	Trunk circumference (cm)	Crown diameter (m)	Leaf blade length (cm)	Petiole length (cm)	Height of matured tree (m)	Tree type	Crown shape	Tree growth habit	Foliage density	Leaf blade shape
EA1	Amba Ahmed Abdulahi	258.00	12.60	20.60	3.90	Very tall	Seedling	Broadly pyramidal	Spreading	Intermediate	Lanceolate
HAD4	AmbaAdi	236.00	14.00	22.80	5.60	Very tall	Seedling	Broadly pyramidal	Spreading	Dense	Lanceolate
HLI2	AmbaLibaanatoo	246.00	8.50	18.70	2.90	Medium	Seedling	Semi circular	Spreading	Sparse	Lanceolate
HMAI7	AmbaMaity	165.00	10.00	25.00	4.40	Very tall	Seedling	Broadly pyramidal	Spreading	Dense	Lanceolate
AN	AmbaNeguse	252.00	17.75	3.00	16.00	Very tall	Seedling	Semi circular	Spreading	Sparse	Lanceolate
AB1	AmbaBebala	214.00	12.60	24.20	4.20	Very tall	Seedling	Oblong	Spreading	Intermediate	Lanceolate
E39.1	AmbaSabid	168.00	11.80	6.20	22.60	Medium	Seedling	Semi circular	Spreading	Sparse	Lanceolate
HBIS2	AmbaBishaano	214.00	9.70	18.00	3.00	Medium	Seedling	Semi-circular	Spreading	Sparse	Lanceolate
E39.3	AmbaSabid	180.00	13.40	4.60	20.60	Medium	Seedling	Semi circular	Dropping	Sparse	Lanceolate
HHU5	Amba	142.00	10.00	21.40	4.00	Tall	Seedlin	Semi	Spreadin	Interme	Lanceolat

	Hula						g	circular	g	diate	e
HLI4	AmbaLibaanatoo	180.00	7.40	23.60	4.80	Tall	Seedling	Oblong	Erect	Dense	Lanceolate
AH2	AmabaHarewe	323.00	28.25	4.40	21.00	Very tall	Seedling	Semi circular	Spreading	Intermediate	Lanceolate
E24.5	AmabaHarewe	198.00	8.30	3.60	21.60	Tall	Seedling	Spherical	Spreading	Intermediate	Lanceolate
AN2	AmbaNeguse	263.00	17.50	3.00	17.60	Very tall	Seedling	Semi circular	Spreading	Sparse	Lanceolate
HKU5	AmbaKukurfa	142.00	9.40	25.10	3.70	Very tall	Seedling	Semi circular	Spreading	Sparse	Lanceolate
E22.4	AmbaGuracha	235.00	13.75	3.80	18.40	Very tall	Seedling	Semi circular	Spreading	Intermediate	Lanceolate
E15.2	AmbaBebala	210.00	17.10	19.20	4.40	Very tall	Seedling	Semi circular	Spreading	Sparse	Lanceolate
HNEGU2	AmbaNeguse	90.00	7.00	30.40	5.40	Medium	Seedling	Semi-circular	Spreading	Dense	Lanceolate

E37.5	AmbaNeguse	187.00	8.00	4.80	22.80	Short	Seedling	Semi circular	Spreading	Intermediate	Lanceolate
AH3	AmbaHarewe	380.00	24.00	4.20	20.00	Very tall	Seedling	Semi circular	Spreading	Sparse	Lanceolate
E39.4	Ambasabid	262.00	18.60	3.60	21.20	Tall	Seedling	Semi circular	Dropping	Sparse	Lanceolate
ES	AmbaSufian	194.00	11.00	19.40	2.90	Medium	Seedling	Semicircular	Spreading	Sparse	Lanceolate
E47.5	AmbaumerAlishoAdi	186.00	14.50	19.50	2.70	Short	Seedling	Semicircular	Spreading	Dense	Lanceolate
E24.4	AmbaHarewe	229.00	11.20	3.20	17.80	Tall	Seedling	Semi circular	Spreading	Intermediate	Lanceolate

Summary and Conclusion

Mango production has a long history in eastern Hararghe and it is the dominant among other fruits in cultivation. There is remarkable variability among the existing mango trees since almost all growers propagate it sexually even though other variables like ecological, edaphic factors and crop husbandry practices could contribute to the variation. The study also revealed the potentials to mango production but the need for serious attention to the existing treeswith regard to husbandry practices and conservation of the potential germplasm. Though, the study showed the shortlistof some promising trees, otherstrees could also serve a vital role for further breeding work. Therefore, maintenance or conservation of at least the shortlisted eco-types in safe place is the urgent activity to be done by the concerned body since the inclination of the growers is shifting to other cash crops and seasonal crops. Moreover, focus should also be given in improving the production, productivity and marketing of the crop in order to utilize the available and adaptable mango eco-types rather than replacing them with the imported and improved cultivars.

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Sorghum Research Program

By

Ketema Belete (PhD)

Funded by EIAR

Introduction

The sorghum research program at Haramaya University (HU) used to have the mandate of developing sorghum technologies (varieties, agronomic and crop protection practices, etc.) for eastern Ethiopia until recently when the Mechara and Fedis Agriculture Research Centers of ORARI (Oromia Agriculture Research Institute) and Jijiga Agriculture Research Center of SoPARI (Somali Agro-pastoral and Agriculture Research Institute) were started. In the 1970s, the Ethiopian Sorghum Improvement Project (ESIP) was started at this institution and coordinated the National Sorghum Research until 1983 when EIAR (Ethiopia Institute of Agricultural Research) the then IAR (Institute of Agricultural Research) started to coordinate the national sorghum research. Currently, the sorghum research at HU is conducting breeding and agronomy activities at the main campus, i.e., at Haramaya, and other sites such as Babile, Fedis and on farmers' field. The activities include the national sorghum breeding trials sent by the National Sorghum Coordinating Center and those initiated by HU staff.

The number of activities during the last few years has been decreasing due to the change in allocating research budget. Previously the needed budget for sorghum research was through EIAR. Currently, the Sorghum Research at HU has been conducting limited number of research activities funded from the University budget.

Breeding ongoing activities

Sorghum Varieties Verification

Introduction

Sorghum variety verification is the last activity before a variety is released to be used by farmers. The main purpose is .to grow the candidate variety on land area of 100m2 at least on two farmers' field where the yield trial has been conducted. In our case, eight experimental sorghum varieties were evaluated as regional variety trial (RVT) on three locations (Haramaya, Kersa and Adele) for two years along with at least one check. Of the eight varieties, three of them (Wegerie-3,Wegerie-5 and Fendisha-5) were identified as candidate varieties for release. The candidate varieties and the standard check (this is a recently released sorghum variety) were sown on equal land area on the same field, side by side. Representative of the NVRC (National Variety Release Committee) could have evaluated the performance of the candidate variety(ies) as compared to the standard check. The NVRC's decision of releasing the candidate varieties will base on evaluating the performance under field condition and the submitted data of the two years at three locations. Therefore the objective of this activity is to verify the performance of three highland sorghum varieties.

Materials and methods

The three best varieties (Wegerie-3,Wegerie-5 and Fendisha-5) and one standard check variety (Chelenko) were grown on campus and at 4 locations (Adele, Haramaya, Hirna and Kersa) on 8 farmers' fields. The plot size for each of the variety was 10 m by 10 m. Standard agronomic practice for sorghum production was used. The three candidate varieties were selected from other experimental varieties based on their average performance at three locations (Adele, Haramaya and Kersa). Standard agronomic practice for sorghum production was used at each location. The varieties were sown at each location at the time farmers sow sorghum.

Highlight

The performance of the varieties at five of the nine sites was poor few weeks after sowing and those at the four sites were promising, but they were also discontinued due to moisture shortage before seed set (Table 1). Thus this activity will be repeated during the coming crop season.

Activities to be accomplished during the remaining project period

The three candidate varieties and the check variety will be sown on campus and at least on six farmers' field. Application will be submitted to the NVRC (National Variety Release Committee). The NVRC team will be invited to evaluate the varieties at appropriate stage of the crop.

Table 1: Summary of the performance

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Specific site</th><th colspan="2">Performance</th></tr>
<tr><th>After sowing</th><th>Final</th></tr>
<tr><td>Haramaya</td><td>On campus</td><td rowspan="4">Good stand establishment and performed well till heading</td><td rowspan="4">Moisture shortage before seed set</td></tr>
<tr><td rowspan="2">Kersa</td><td>Farm 1</td></tr>
<tr><td>Farm 2</td></tr>
<tr><td rowspan="2">Adele</td><td>Farm 3</td></tr>
<tr><td>Farm 4*</td><td>Very poor stand due to flood after germination from the adjacent potato field</td><td rowspan="4">Discontinued due to the stated performance problem after sowing</td></tr>
<tr><td rowspan="2">Hirna</td><td>Farm 5*</td><td>Poor uniform stand establishment. Part of some rows of the same variety has germinated well while others did not</td></tr>
<tr><td>Farm 6*</td><td rowspan="2">Very poor stand establishment</td></tr>
<tr><td>Haramaya</td><td>Farm 7*</td></tr>
</table>

	Farm 8*		

1.2. Preliminary Variety Trial for Highland and Intermediate areas of eastern Ethiopia

Introduction

Preliminary variety trial (PVT) is the second stage of activities in pure line selection of breeding, the first being observation nursery. During the previous year large number of varieties was evaluated in observation nursery at Haramaya (highland location) and Babile (intermediate location). The best varieties (as compared to the check) were selected and evaluated as PVT.

Objectives: To identify high yielding and best performing sorghum varieties for eastern Ethiopia

Materials and methods

The selected varieties from 2012 crop season were evaluated in three PVTs. They are PVT-1 (Shefere set) and PVT-2 (Wegerie set) at Haramaya and PVT-3 at Babile. The list of the varieties is given in Tables 2, 3 and 4. Each of them is originated from the respective location. Randomized complete block design with three replications was used at each location.. The plot size was 3 rows of 5 m length. Standard agronomic practice for sorghum production was used.

Highlight: The initial performance of all the three was good at each location. But the trials at Haramaya were seriously affected by shortage of moisture at heading. This was due to the fact that there was serious drought after sowing at Haramaya. It rained 3 weeks after sowing. Thus PVT-1 and PVT-2 should be repeated. At Babile also it rained late as compared to the previous years, but the early moisture condition was better than that of Haramaya. Some varieties were seriously affected at heading. In some of them flowering was not uniform. We were hoping that there will be some best performing varieties, but the analysis of the data showed that this PVT also has to be repeated.

Table 2. List of sorghum varieties in PVT-1 sown at Haramaya in 2012 crop season

No	Entry Name	No	Entry Name
1	SHEFER RED	7	SHEFERAI RED
2	SEFERAIRED	8	MUYRA 1
3	SEFERA RED	9	MUYRA 2
4	SEFERAI RED	10	CHELENKO
5	SEFERAI RED6	11	LONG MUYRA
6	SHEFERE RED		

Table 3. List of sorghum varieties in PVT-2 sown at Haramaya in 2012 crop season

No	Entry Name	No	Entry Name
1	WOGERAI YELLOW	10	WEGERAI RED
2	WEGERAI YELLOW	11	WOGERAI RED
3	WEGERAI YELLOW	12	WOGERAI WHITE
4	WEGERAI RED	13	WOGERAI RED
5	WEGERAI RED	14	WOGERAI RED
6	WEGERAI YELLOW	15	MUYRA 1
7	WEGERAI RED	16	MUYRA 2
8	WEGERAI WHITE	17	LONG MUYRA
9	WEGERAI RED		

Table 4. List of sorghum varieties in PVT-3 sown at Babile in 2012 crop season

No	Entry Name	No	Entry Name
1	2009 collection # 1	14	2009 collection # 25
2	2009 collection # 3	15	2009 collection # 26
3	2009 collection # 4	16	2009 collection # 27
4	2009 collection # 5	17	2009 collection # 30
5	2009 collection # 7	18	2009 collection # 32
6	2009 collection # 9	19	2009 collection # 33
7	2009 collection # 11	20	2009 collection # 35
8	2009 collection # 12	21	2009 collection # 37
9	2009 collection # 13	22	2009 collection # 39
10	2009 collection # 16	23	IS 9302
11	2009 collection # 19	24	IS9323

12	2009 collection # 21	25	Chame
13	2009 collection # 24		

Activities to be accomplished during the remaining project period

Each of the PVT will be sown at HU sites on campus (PVT-1 and PVT-2) and Babile (PVT-3). At the end of the season the best of each PVT will be advanced to RVT (regional variety trial).

1. Agronomy Activities

Activity to be repeated

On-farm evaluation of some dryland legumes in intercropping with sorghum varieties for management of Striga (Striga spp) in eastern Hararghe.

Introduction

Intercropping legumes in sorghum is one of the crop management practices that can be used to control striga in sorghum production. The intercropped legume will contribute to the improvement of soil fertility, which will reduce the striga damage.

Objectives:

- To identify the appropriate legume(s) for intercropping with sorghum which can reduce ***striga*** emergence and growth and give the highest overall productivity;
- To determine the performance of ***striga*** resistant and susceptible sorghum varieties under the intercropping system and their influence on emergence and growth of ***striga***.

Materials and methods

Two sorghum varieties (*Striga* resistant variety Gubie and *Striga* suseptable variety Teshale) and three dryland legumes (common bean, cowpea and groundnut) were intercropped both between rows and between plants) at Fedis research site for two years. Randomized complete block design with three replications was used. There were 12 treatments. They were: common bean between two rows of Gubie, common bean between two plants of Gubie, common bean between two rows of Teshale , common bean sown between two rows of Gubie, cowpea sown between two plants of Gubie, cowpea sown between two rows of Teshale, cowpea sown between two rows of Teshale, cowpea sown between two rows of Gubie, groundnut sown between two plants of Gubie, groundnut sown between two rows of Teshale, groundnut sown between two rows of Teshale and groundnut sown between two rows of Teshale. 13 (Chiro not sown),12(defended not sown),11(Fedis not sown),10(not sown),09(not sown)

Highlight: The intercropped were sown in 2010/11 and 2011/12 crop season at Fedis research site. The rainfall distribution while the crop was in the field was adequate, thus the condition was not favorable for uniform striga infestation during both years. This made it impossible to collect data related to striga. At the end of 2010/11 crop season, the plan was to analysis the data as regular intercrop, but at the National Sorghum Review it was decided to repeat, because the objectives are on *stiga* management has not met. It has been suggested to repeat the experiment on farmers' fields, because the soil fertility on Fedis research site might not be conducive for striga infestation as that of farmers' fields. The experiment was not conducted during the last crop season because enough land was not found.

Activities to be accomplished during the remaining project period

The trial will be conducted on farmers' field where there is striga infestation.

1.1. Agronomy ongoing

Effects of row spacing on sorghum production

Introduction

Different persons have suggested (during farmers' day and other meetings) the need of using of other row spacing for the early and short sorghum varieties. Because the currently used inter-row spacing of 75 cm and intra-row spacing of 20 cm is mainly for the tall and early maturing sorghum varieties. Therefore the objective of this study is determine the best intera and inter row spacing for short and early maturing sorghum production

Materials and methods: Four inter-row (75, 65, 55 and 45 cm) and two intra-row (15 and 20) spacing were used. Randomized complete block design in 4x2 factorial combination with three replication was used The eight spacing treatment combinations (75x20, 75x15, 65x20, 65x15, 55x20, 55x15, 45x20 and 45x15) were sown at Babile and Fedis experiment stations. Sorghum varieties Teshale and Gubiye were used at Babile and Fedis respectively.

Highlight: There was poor stand establishment at Babile due to moisture problem at sowing. At Fedis the major data of interest, grain yield and biomass showed that the highest and lowest grain yield was due to 55x15 and 75x20 spacing, respectively. Spacing of 45x15 and 75x20 gave the highest and lowest biomass yield, respectively. The one year data at one location showed that the recommended spacing (75x20 cm) gave the lowest grain and biomass yield (Table 5).

Table 5. Grain and biomass yield for spacing trial at Fedis in 2012 crop season

No	Treatment (cm)	Grain yield (kg/ha)	Biomass yield (kg/ha
1	75 x 20	2111 (7)*	4962 (7)
2	75 x 15	2326 (5)	4962 (7)
3	65 x 20	2145 (6)	5222 (6)
4	65 x 15	3162 (3)	5325 (5)
5	55 x 20	3555 (2)	8143 (2)
6	55 x 15	4444 (1)	7610 (4)
7	45 x 20	2666 (4)	8048 (3)
8	45 x 15	3555 (2)	8270 (1)
	LSD		

* Number in the bracket shows ranking

Activities to be accomplished during the remaining project period

The trial will be conducted at least for one more year.

Combating effect of Climate Change on Crop Production in Eastern Ethiopia through Crop Diversification: the case of Pearl Millet

Ketema Belete and Temam Hussien

Funded by HrU Government Research Fund.

Abstract: Use of a crop that can withstand stress environment as opposed to a crop prone to such environment has been advocated as strategy of addressing climate change. The potential pearl millet, a more drought resistant crop than sorghum has been considered in the current study. One season study was conducted with the objectives of determining optimum inter and intra row spacing for pear millet production, and to identify high yielding pearl millet genotypes. Agronomic study consisting of 4 inter- (40, 50, 60 and 70 cm} and 3 intra-row spacing (10, 15 and 20 cm) was conducted for one season at 4 lowland-moisture stress sites, Babile, Bisidimo, Fedis and Dire Dawa. Randomized complete block design with three replications was used. There was severe moisture shortage, therefore limited data was obtained. The grain yield data at

Fedis showed that row spacing of 50 x 20 and 40 x 20 gave significantly the highest grain yield than others. The data for biomass showed that at Fedis the 40x20; at Babile the 50x10 and 40x15; and at Tony Farm 50x20, 40x10, 40x15 and 40x20 spacing gave significantly highest biomass Based on this it can be concluded that spacing of 40x20 is better at Fadis because both the grain yield and biomass yield is significantly the highest. Fourteen pearl millet varieties from ICRISAT and 95 accessions from IBC were used for varieties/accessions identification study. The performance of the varieties at Fedis was better than the other sites. There was significance difference among varieties in terms of biomass and grain yield. The 95 accessions from IBC were evaluated at Tony Farm. The visual agronomic performance evaluation (overall plant aspect) indicates that 33 accessions were performed very well. There is a possibility of identifying potentially best genotype from the 33 accessions.

Introduction

Currently, the change in climate has been one of the challenging factors around the world. Climate change is defined as a long-term shift in the climate of a specific location, region or planet (USDS, 2003). It also refers to general shifts in climate, including temperature, perception, winds, and other factors. Its effect on crop production has been a major concern.

Crop diversification is one of the approaches that have been suggested to tackle the effect of climate change on crop production (Lin, 2011). Increasing the number of crops or varieties of particular crop as compared to a single crop or one variety of a crop, use of crop mixture as compared to sole cropping and use of a crop that can withstand stress environment as opposed to a crop prone to such environment has been advocated as strategy of addressing climate change (Bradshaw, *et.al*, 2004). Sorghum (*sorghum bicolar* (L.) Moench) has been used as the only drought resistant cereal in moisture stress areas of Ethiopia. Its production has been affected due to the recurring drought. Thus use of pearl millet (*Pennisetym glaucum* (L.) R.Brown), a more drought resistant crop has been considered. Research on this crop is not aimed to slow down or deemphasize the sorghum improvement/production in the area. It is just one of the crop diversification strategies that will address the effect of climate change.

Pearl millet is a robust, cross-pollinated, diploid, annual grass, with 2n = 2x = 14 chromosomes. A single plant can easily selfed and cross-pollinated as both male and female. Inbred are usually vigorous and ideally suited for hetrosis breeding (Burton, 1974; Brunken, *et.al.*1977).

It has C_4 photosynthetic pathway and has the highest water use efficiency among the other eight cereals viz rice, wheat, maize, sorghum, rye, triticale, barley and oat (Stoskopf, 1985). It produces 3.64 units of dry matter for every 1000 units of water consumed, compared to the rice which is 1.47 units of dry matter for every 1000 units of consumed water. The reason for such high water use efficiency is believed to be related to fewer stomata or to stomatal closure under conditions of moisture stress even in the middle of the day (Jauhar, 1981). It has several advantages as compared to other cereals including tolerance to drought, heat and leached acid soils with very low clay and organic matter contents. It adapts to drought through the mechanism of avoidance rather than resistant (Reddy, 2006). It has the ability to grow rapidly in response to brief periods of favorable conditions. The crop commonly grows under the most difficult farming conditions such as low soil fertility and limited moisture (Stoskopf, 1985). These traits of pear millet made it a cereal of need in areas where even sorghum, ‘the crop camel’ fails to give yield. It is a crop of choice, currently when the change in climate is of great concern.

It tillers highly freely, compensating well for irregularities and produces 2 to 3 times more heads per plant than sorghum at similar plant population. It is a robust, very rapid growing, erect, bunch-grass, thus when properly managed it will provide quality food and forage besides the grain. It is an extremely variable species, in which culms are solid and pithy 2 to 4 m high (Burton, 1974).

Pear millet germplasm has been collected by the Institute of Biodiversity Conservation (IBC) of Ethiopia and the International Crop Research Institute for Semi Arid Tropics (ICRISAT).

Crop management practices have been developed in other parts of the world. The recommended optimum seed depth for pearl millet is 5-7 cm and 2-3 cm for sandy and heavy soil, respectively. Stoskopf (1985) recommends spacing of 40 cm x 15 cm and seed rate of 3-6 kg/ha under rain fed condition. Inter and intra row spacing of 45-60 cm and 12-20 cm, respectively has also been recommended (Raddy, 2006). Abdirahman (2009) reported yield advantage of 50 x 20 cm as compared to 60 x20 cm under repeated tillage at Jijiga plain. Inter-row spacing of 60 and 70 cm, and intra-row spacing of 10 and 20 cm has been used at ICRISAT (C .T. Hash, personal communication). Application of 80 kg N/ha and 40 kg P2O5/ha has been recommended under dependable adequate moisture and use of fertilizer is not recommended under limited moisture condition (Raddy, 2006).

Pear millet is considered as an excellent alternative for producing grain and forage, particularly in the arid and semi-arid regions of Africa and India. To this effect ICRISAT as identified regional centers at Niger, west Africa and at Kenya, east Africa.

In Ethiopia, even though finger millet (*Eleusine coracana* (L.) Gartn) is a popular millet species, pearl millet is becoming popular in some parts of the country where production of other crops is not dependable due to moisture limitation, such as in Dire Dawa Administrative Region and Somali Regional State (personal communication with farmers and agricultural experts at both regions). The former Millet Research Project at EARO (Ethiopian Agricultural Research Organization) considered pearl millet as an important dry land cereal and varietal development activity was implemented. One variety was released few years ago. However, at present the pearl millet research at EIAR (Ethiopian Institute of Agricultural Research) has been partially discontinued due to manpower.

Development of crop management practices and identification/development of crop variety are the two initial technologies for production of any crop. Therefore this project was proposed with the following two objectives, (a) to determine optimum inter and intra row spacing for pear millet production (b) to identify high yielding (in terms of grain or/and forage), agronomically superior and pest resistance pearl millet genotypes

Materials and Methods

There have been two separate independent activities. The first activity was based on one of the essential crop management practices that is **Determination of inter and intra row spacing** and the second activity was on the first activity in plant breeding or variety development i.e. **Identification of genotypes.**

2.1. Determination of Inter and Intra Row Spacing (Activity 1)

A pear millet variety '*ICMV-221*'/ also called *'Kolla-1'* that have been released by Melkassa Agricultural Research Center was used. The availability of this variety that has been released in Ethiopia made it possible to do this activity. The treatments will be 4 inter-row spacing (40, 50, 60 and 70 cm} and 3 intra-row spacing (10, 15 and 20 cm). Randomized complete block design in factorial with here replication was used.

The study was planned to be conducted at 4 lowland-moisture stress sites, Babile, Bisidimo, Fafan and Melkajebdu. Babile and Fafan are sites of Haramaya University, Bisidimo Hospital and Fafam Agricultural Research Center (FARC), receptively. There was poor crop establishment at Bisidemo due to moister shortage immediately after sowing. Fafan was changed to Fedis, because the budget requested guard was very high. Melkajebdu was replaced by Tony Farm (HU site 7 km in Dire Dawa). The HU site at Fedis was used. Therefore 3 sits (Babile, Fedis and Tony Farm) were used. .

Data were collected on plot and 5 random plants bases following procedure of ICRISAT. The data on plot bases were: days to 50% flowering, days to maturity, lodging percent, panicle weight, biomass yield, grain yield, 1000 kernel weight, harvest index, disease and insect incidence; the data on 5 random plant bases are: plant height,. The data will be analyzed using the procedure of Gomez and Gomez (1984).

2.2. Identification of Genotypes (Activity 2)

Pearl millet genotypes obtained from IBC and ICRISAT were used. This part of the project has 2 sub-activities, (1) plant quarantine and (2) characterization and evaluation under eastern Ethiopia condition.

Plant quarantine

To prevent introduction and spread of disease and pests, the genotypes obtained from ICRISAT were examined thoroughly upon arrival. These genotypes were planted in isolated plots and inspected for any disease and pest not recorded in Ethiopia.

2.2.1. Characterization and evaluation of genotypes

Fifteen genotypes obtained from ICRISAT were evaluated at same sites (Babile, Fedis and Tony Farm) where the spacing activity was conducted. One row plot of 4 m length with inter- and intra-row spacing of 70 and 20 cm were used for each genotype, based on ICRISAT's recommendation. Randomized complete block design with three replication was used.

Ninety five accessions obtained from IBC were evaluated only at Tony Farm, because the amount of seed obtained from IBC was very little to sow it at other sites. One row plot of 4 m length with inter- and intra-row spacing of 70 and 20 cm were used for each genotype, based on ICRISAT's recommendation. Simple lattice design or another design was used. Data was collected on plot bases following procedure of ICRISAT.

Result and Discussion

Determination of Inter and Intra Row Spacing

As it has been stated above Fafan was changed to Fedis, because the budget requested guard was very high. Poor stand establishment at Bisidemo and Babile. At both sites crop emergence was not uniform due to moisture problem. It was replanted at Babile, but not at Bisidemo due to absence of rain. At Babile and Tony farm the performance was good, but it did not seed set due to the serious drought at flowering therefore only biomass yield was collected. At Fedis data on grain and biomass yield was collected.

Table 1 shows that row spacing 50 x 20 and 40 x 20 gave significantly the highest grain yield than others. The data for biomass showed that at Fedis the 40x20; at Babile the 50x10 and 40x15; and at Tony Farm 50x20, 40x10, 40x15 and 40x20 spacing gave significantly highest biomass, indicating that the specified spacings are best a he respective sites. Based on this it can be concluded that spacing of 40x20 is better at Fadis because both the grain yield and biomass yield is significantly the highest. In terms of biomass, it can be concluded that

Table 1: Grain and biomass yield of pearl millet as influenced by spacing

	Grain (kg/ha)	Biomass (kg/ha)		
Spacing (cm)*	Fedis	Fedis	Babile	Dire Dawa
70 x 10	1000	3814	2980	1132
70 x 15	1500	4470	3993	2563
70 x 20	1700	4112	4112	1967
60 x 10	1300	5832	5068	1667
60 x 15	1500	5138	4652	2430
60 x 20	1700	5246	4513	2500
50 x 10	1300	6667	7000	2000
50 x 15	1500	6417	5750	2583
50 x 20	2100	7083	4000	3250
40 x 10	1100	4723	5926	2778
40 x 15	1300	6112	7685	2963
40 x 20	2100	8334*	5741	3611
LSD	300	612	785	963

* Spacing= intra- and inter row spacing (for example 70 x 10 means the intra- and inter row spacing are 70 and 10 cm respectively

Identification of Genotypes

Plant quarantine

Based on various plant quarantine procedures all the 15 genotypes obtained from ICRISAT were found to be healthy. Thus the seed of the genotypes were used for the trials.

Evaluation and characterization of pear millet genotypes

The genotypes used for this activity were of two types: genotypes from ICRISAT and 95 accessions from IBC.

a) Performance of genotypes from ICRISAT

The 14 released genotypes from ICRISAT were sown at Babile, Bicidemo, Fedis & Dire Dawa. Poor stand establishment similar to the spacing trial at Bisidemo and Babile made it impossible to evaluate them at these sites. The crop emergence was not uniform due to moisture problem. At Dire Dawa performance was good but no seed set due to the serious drought at flowering. There could have been good seed set if the trial was sown earlier. The trial was sown in late July due to the quarantine procedure.

The performance of the varieties at Fedis was better than the other sites. Table 3 shows that the difference in days to heading and plant height was not significant. There was significance difference among varieties in terms of biomass and grain yield.

The biomass yield of one variety was significantly higher than the check variety Kola-1. The biomass yield of eight varieties was significantly lower than Kola-1 (Table 3). None of the varieties were significantly higher than Kola- in terms of grain yield, but six of them significantly gave lower yield than the check variety. Both the MARC and ICRISAT staff have informed me the Kola-1 a variety developed by ICRISAT staff and this variety is a selection from those sent this time from IRISAT. This information was not available when this study was proposed.

b) Performance of accessions from IBC.

The 95 accessions from IBC were evaluated at Tony Farm during April to June 2013. Their performance was based on visual evaluation as it is done for observation nursery of any initial activity of introduced breeding material. Each accession was evaluated by two persons (each at each side of a row). Six of the 95 accessions were found to be sorghum rather than sorghum. The overall plant aspect (visual agronomic performance) indicate that less than 10% (33 accessions) were performed good and above, 46% of the accessions were evaluated as fair and poor. There is a possibility of identifying potentially best genotype from those rated as OPA-2 and OPA-3.

Table 2. Some agronomic data for 15 pearl millet varieties grown at Fedis

Variety	Days to heading	Height (cm)	Biomass (kg/ha)	Grain (kg/ha)
IC1	93	164	5714	766
IC2	93	144	4166	417
IC3	90	152	4047	695
IC4	92	161	4404	730
IC5	92	177	6071	536
IC6	87	152	3571	508
IC7	91	163	5118	937
IC9	89	150	5952	913
IC10	91	155	4642	1012
IC11	94	156	4761	663
IC12	91	166	7499	774
IC13	92	160	5237	746
IC14	91	146	3690	643
IC15	93	147	6190	842
Kola-1*	89	158	5714	873
LSD	ns	ns	517	156

[1]

* Check variety released by Melkassa Agricultural Research Center

Table 3. Pear millet accessions evaluated at Tony Farm in 2013

Category	Category description*	Number of accessions*	Identification of accession

		*						
1	Sorghum	6	220150	220163	220172	220175	220192	220197
2	Failed	10	220129	220130	220131	220177	220178	
			220180	220181	220182	220183	229979	
3	OPA-2	9	220147	220158	220169	220188	220189	220209
			220211	220215	223240			
4	OPA-3	24	220136	220137	220140	220145	220146	220148
			220149	220153	220154	220159	220160	220161
			220171	220187	220190	220191	220195	220200
			220201	220208	220214	221726	223213	223239
5	OPA-4	33	219336	219984	219985	220132	220133	220141
			220142	220143	220144	220155	220157	220167
			220168	220170	220176	220184	220185	220186
			220188	220193	220194	220196	220198	220199
			220202	220203	220205	220207	220212	220213
			220218	220219	220221			

6	OPA-5	13	220135	220149	220151	220152	220156	220162
			220165	220166	220173	220206	220210	220216
			220217					
Total		95						

*Sorghum = accessions that were found to be sorghum rather than pearl millet; Faild = accessions that were not evaluated because a daily laborer irrigated them;OPA = over all plant aspect (it is used to evaluate the entries performance) where 1=excellent, 2=very good, 3=good, 4=fair and 5= poor

**Number of accessions under each category (for example 6 of the 95 accessions)

3. Summery and Conclusion

The change in climate has been one of the challenging factors around the world. Crop diversification is one of the approaches that have been suggested to tackle the effect of climate change on crop production. Use of a crop that can withstand stress environment as opposed to a crop prone to such environment has been advocated as strategy of addressing climate change. Sorghum has been used as the only drought resistant cereal in moisture stress areas of Ethiopia. Its production has been affected due to the recurring drought. Thus use of pearl millet a more drought resistant crop has been considered in the current study. There is recommended crop management practice in Ethiopia for this crop and no varieties has been released for the eastern part of Ethiopia.

Development of crop management practices and identification/development of crop variety are the two initial technologies for production of any crop. Therefore this project was proposed with the following two objectives, (a) to determine optimum inter and intra row spacing for pear millet production (b) to identify high yielding (in terms of grain or/and forage), agronomically superior and pest resistance pearl millet genotypes.

Crop management practice experiment consisting of 4 inter-row spacing (40, 50, 60 and 70 cm} and 3 intra-row spacing (10, 15 and 20 cm) was conducted for one season at 4 lowland-moisture stress sites, Babile, Bisidimo, Fedis and Tony Farm/Dire Dawa. Randomized complete block design with three replications was used. The experiment at Bisidemo was discontinued due to poor crop establishment as a result of moisture shortage immediately after sowing. There was also severe moisture shortage at Babile and Dire Dawa/Tony Farm at flowering. The grain yield data at Fedis showed that row spacing of 50 x 20 and 40 x 20 gave significantly the highest grain yield than others. The data for biomass showed that at Fedis the 40x20; at Babile the 50x10 and 40x15; and at Tony Farm 50x20, 40x10, 40x15 and 40x20 spacing gave significantly highest biomass, indicating that the specified spacing are best the respective sites. Based on this it can be concluded that spacing of 40x20 is better at Fadis because both the grain yield and biomass yield is significantly the highest.

Fourteen pearl millet varieties from ICRISAT and 95 accessions from IBC were used for varieties/accessions identification study.

The performance of the varieties at Fedis was better than the other sites. There was significance difference among varieties in terms of biomass and grain yield. The biomass yield of one variety was significantly higher than the check variety Kola-1. The biomass yield of eight varieties was significantly lower than Kola-1. None of the varieties were significantly higher than Kola- in terms of grain yield, but six of them significantly gave lower yield than the check variety.

The 95 accessions from IBC were evaluated at Tony Farm. Their performance was based on visual evaluation as it is done for observation nursery of any initial activity of introduced breeding material. Six of the 95 accessions were found to be sorghum rather than sorghum. The visual agronomic performance evaluation, overall plant aspect (OPA) indicate that less than 10% (33 accessions) were performed good and above, 46% of the accessions were evaluated as fair and poor. There is a possibility of identifying potentially best genotype from the 33 accessions.

Even though the present study is for only one season on limited sites, there is potential for pearl millet. The agronomic potential should be repeated so that crop management practice for production and crop improvement activity will be available.

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Small Cereals Research Program

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Introduction

Ethiopia is one of the largest grain producing countries in Africa, although it is still a food insecure country and a net importer of grain, it is the second largest wheat producer in sub-Saharan Africa, after South Africa. For the crop year of 2011/2012, from the total land allocated for cereal crops, wheat stands in fourth by covering 15.3% of the total areas preceded by Tef, Maize and Sorghum.

Eastern Ethiopia comprises around 3% of the total wheat producing area in the country (CSA, 2012). Compared to world average (3.1 tons/ha) and the country (2.03 ton/ha), the region's productivity lags behind significantly (Harari- 1.1 ton/ha, Eastern Hararghe -1.78 ton/ha, Western Hararghe- 1.86 ton/ha and Somali 2.3 ton/ha) calling for the need for comprehensive approach to increase productivity (FAOSTAT, 2012, CSA,2012).

The low productivity witnessed is attributed to many reasons. One of the reasons is access to improved varieties. A study conducted between 2004 and 2009 revealed that, improved varieties of wheat seeds were used on only 3% of the land under cultivation. The self-pollinating traits of wheat varieties have led to low replacement rates by smallholder farmers as they multiply existing varieties in the field, even when higher yielding varieties exist (Kulumsa ARC, Unpublished Document). Other important factors include growing the crop in marginal lands, disease outbreaks and susceptibility of varieties under use, poor management practices.

The Small cereals Improvement program of Haramaya University has been conducting regional variety trials to develop high yielding, disease resistant, and moisture stress tolerant varieties that also meet the consumers' and market criteria. These variety trials are conducted at Rare-Haramaya University main campus, Hirna research station, Fedis research station and Chinaksen Farmer's Training Center), which represent the different wheat production environments of ast and west Hararghe zones.

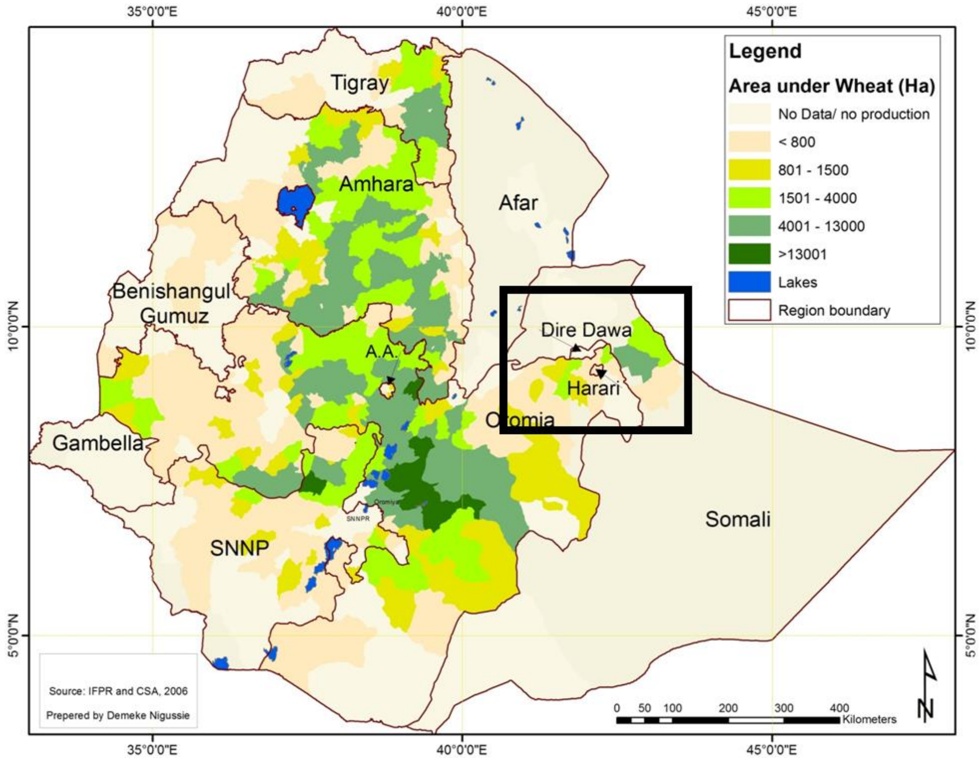

Figure 1Wheat Growing areas in Ethiopia

In the variety development efforts made hitherto, one wheat variety that fulfils the aforementioned breeding objectives has been released.

Objectives

- To develop and promote high yielding, stress tolerant and widely/specifically adapted wheat varieties with their agronomic package to western and eastern Hararghe.

Table 1 Varieties Released by Small Cereals Research Program since 2009

Variety Name	Type	Disease reaction	Seed colour	Days to maturity	Yield (t/ha)		Year Released
					On-station	On-farm	
Qulqulluu	Bread Wheat	Resistant to Yellow, stem and leaf rusts	Red/Brown	~117	2.5-4.4	3.5-4.3	2009

2. Completed Activities

One Adaptation trial of released varieties was completed during the growing season.

Adaptation of wheat varieties in different agro ecologies of Ethiopia

Absract

Twenty one released bread wheat varieties were assessed on farm at four locations: Haramaya (Rare station), Hirna, Chinaksen Farmers Training Center and Fedis with objective to test their adaptability in Eastern Ethiopia. The experimental design used was RCBD with two replications. All parameters showed significant variations (P<0.05) among genotypes and there was also highly significant location and variety location effects (P<0.001)). Mean Separation Analysis showed that no genotype had consistent performance across locations. However, early maturing genotypes Kekeba and Hawi showed higher overall yield performances.

Key words: Adaptation trial, released varieties

Materials and methods

Twenty two Released bread wheat varieties shown below were assessed on station at four locations: Haramaya University Rare station, Hirna substation, Chinaksen Farmers Trainning Center and Fedis. The experimental design was randomized complete block design with two replications.

Data collection and analysis

Parameters like Plant height (PH), Tiller number per plant (TN),Days to maturity (DM), Days to heading (DH), Spike length (SL), Number of spike lets per spike (NS), Kernel number per spike (KS), Grain filling period (GFP),Biological yield (BY), Thousand grain weight (TKW),Grain yield (GY), Hectoliter weight (HLW) (Kg/hl), were collected. Besides, Disease severity and reaction was also recorded.

Twenty one genotypes released from national and regional efforts were used in adaptation trial in 2011 at four locations. Randomized Complete Block Design (RCBD) with two replications was used at each location. The data was analyzed with Proc GLM procedure of the SAS 9.1 software. Combined analyses of variance were performed after homogeneity of error variances were confirmed using Bartlett's test.

Result and Recommendation

Combined analysis of variance over locations has shown significant differences (P<0.05) .05) among genotypes for all parameters The location main effects as well as their interaction were also very highly significant (P<0.001) for all the traits. The location x variety effect was also very highly significant (

Table 2**).**

Table 2. F-values for the various sources of variations of combined ANOVA and their significance levels in Adaptation trial.

Source of variation	df [a]	F- Values					
		DH	DM	PH	HLW	TKW	GY
Variety	20	22.9***	10.15***	4.13***	13.64***	3.42***	1.98*
Location	3	30.58***	35.45**	42.02***	111.17***	360.41***	235.13***
Location x Variety	60	4.45***	5.95***	1.83**	11.75***	5.13***	3.41***
Error	84						
CV (%)		16.42	2.59	5.21	2.74	5.98	16.43

DH- Days to heading; DM-Days to Maturity; PH-Plant Height (cm); HLW- Hectolitre weight (kg/hl); TKW-Thousand Kernel Weight (gm); GY- Grain Yield (kg/ha)

Yield performances of the genotypes across environments

The mean values of some agronomic characters across all environments are given in Table 4**.** Due to very high genotype Vs Environment interaction (

Table 2), no genotype had consistent performance across environments In Fedis, Danda; Hirna, Dinknsh; Chinaksen, ET13-A2 and Rare main station, Kakeba ranked first. As the growing season, 2011 was noted with terminal stress, early maturing varieties, like Kakeba and Hawi seemed to outperform other genotypes in overall performance across environments (Table 3 & Table 4**)**.

Recommendation

The experiment shows clearly that the stations used for the experiments have intrinsic differences amongst themselves and this variation has caused wide variation in performance of the genotypes. Fedis represents moisture stressed environment, Hirna mid altitude with ideal moisture, Chinaksen-terminal moisture stress due to large evapotranspiation and Rare optimum moisture areas, though the year 2012 was noted for terminal moisture stress.

The result affirms that performance of varieties highly depends on the agrecology and as a result proper varietal recommendation should be made on basis of agrecology rather than blanket recommendation. Moreover, as the uncertainty for rainfall is becoming more and more obvious, due to climate change, emphasis should be given breeding for early maturing and phenotypically elastic and resource efficient lines.

Table 3 Mean Yield (kg/ha) Performance of released varieties across test environments.

Variety	Rare	Hirna	Fedis	Chinaksen	Overall mean
Danda	5289.7 ABC	3452.7	3092.6 A	1085.1 H	3230 A BC
Kakaba	5703.6 A	3556.1	2071.9 BCD	2490.7 DBCE	3455.6 A
Hawii	5129.1 ABCD	3699.8	1892.3 GDEF	3128 AB	3462.3 A
Tusie	3537.2 IH	3515.8	2169.7 BCD	2974.7 AB	3049.4 A BC
Pavon-16	4398.2 EFGD	3216.4	2099 BCD	1975.7 DFGE	2922.3 E BC
Et-13a2	3650.3 IGH	2883.3	1488.1 GF	3538.1 A	2889.9 E BC
K6295-4a	4367.4 EFGD	2817.3	2337.3 BCD	2708 DBC	3057.5 A BC
Etbw5483	4795.8 BCD	3144.6	1874.6 GDEF	2090.4 DFCE	2976.4 BC
Etbw-5496	5500.3 AB	2437.3	1805.6 GDEF	1515.2 HFG	2814.6 E C
Digalu	4566.9 ECD	3740.3	1982.6 CDEF	1562.1 HFG	2963 BC
Sofumer	3460.6 IH	2975.7	2564.6 AB	1983.7 DFGE	2746.2 E
Mada-Walabu	3710.5 IFGH	4037.2	2046.3 BCDE	1215.9 HG	2752.5 E

Tay	3481.3 IH	2609	2468.6 BC	1341.4 HFG	2475.1 E
Senkenya	4379.2 EFGD	4118.8	2462.6 BC	1526.1 HFG	3121.6 A BC
Gasay	2974.3 I	3845.2	2444.4 BC	1974.7 DFGE	2809.6 E C
Menze	4520.9 ECD	3605.6	1810.4 GDEF	2865 ABC	3200.5 A BC
Bolo	4454 EFD	3625.7	1387.4 G	2049.4 DFE	2879.1 E BC
Alidoro	4728.3 EBCD	3028.8	1867.7 GDEF	1877.5 HFGE	2875.6 E BC
Dinknesh	3991 EFGH	4253.2	1532.9 GEF	1413.8 HFG	2797.7 E C
Tossa	5646.1 A	3889	2025 CDE	1686.2 HFGE	3311.6 A B
Qulqulluu	4841.8 BCD	3609.6	2113.7 BCD	1499.1 HFG	3016 A BC
LSD	793.59	NS	534.99	804.67	476.69

Table 4 Mean Performance of different parameters released varieties across environments.

Varieties	**Dates to Heading**				**Plant Height**				**Days to Maturity**				**Thousand Kernel Weight) (gm)**				**Hecto litre weight (kg/hl)**			
	F	H	C	R	F	H	C	R	F	H	C	R	F	H	C	R	F	H	C	R
Danda	72	77.	68	75.0	73.9	83.8	81.1	84.4	128	134	132	133	37.3	40.4	38.1	22.5	78.7	77.3	64.6	73.3
Kakaba	64.5	68	59.0	69	71.9	81.0	112	79.5	112	119	110	118	34.3	37.0	41.8	24.3	78.0	76.6	79.8	69.0
Hawii	61.5	64.5	66	65	70.3	77.3	76.6	73.8	113	108	114	121	36.8	48.3	37.9	31.8	92.4	88.7	77.8	72.1
Tusie	68	67	71	67.0	70.5	79.1	78.7	81.2	111	120	109	119	35.0	36.4	38.3	31.8	80.2	79.5	71.5	74.0
pavon-76	65	67	62	61	70.6	81.8	74.5	81.9	106	109	107	111	31.4	41.2	33.9	32.3	75.5	79.8	74.3	65.1
ET-13A2	63.0	65.0	60.5	62.0	69.2	83.8	79.6	86.9	107	104	114	112	33.9	41.4	30.4	31.8	73.1	76.4	67.7	71.5
K6295-4A	64.5	60.0	59.0	59.0	72.7	76.9	75.0	74.1	104	102	101	109	30.9	46.9	33.2	30.3	88.4	76.7	75.6	74.4
ETBW5483	60.5	61.0	60.5	59.5	71.5	85.3	78.4	86.8	106	108	112	84.5	31.2	39.8	40.5	30.8	73.6	91.6	81.2	73.3
ETBW-5496	61.0	66.0	62.5	67.5	72.2	85.3	78.9	85.9	112	118	116	113	28.6	39.5	32.7	28.5	77.7	66.9	73.2	84.4
Digalu	74	76.5	70.0	82	70.6	86.1	83.2	88.1	119	121	124	123	29.2	48.3	36.2	27.1	83.6	75.9	75.8	76.3
sofumer	63.0	63.5	60.5	61.0	70.1	79.6	78.4	77.3	119	115	114	125	37.7	38.6	36.6	27.5	79.4	74.5	73.1	75.1
mada-	67.	61.	62.	63.5	69.	76.	75.	73.	110	114	109	118	35.	45.	39.	26.	76.6	78.	73.	69.7

walabu	5	5	0		8	6	4	4					6	7	3	9		2	2	
Tay	56.0	62.0	61.5	65.5	71.5	78.2	77.0	76.9	110	114	110	119	32.3	40.6	33.2	26.1	77.4	92.7	74.7	69.4
senkenya	68.0	62.5	60.0	65.0	73.1	79.8	79.2	80.9	114	117	112	118	32.0	46.6	33.9	24.0	73.7	75.5	81.6	69.9
Gasay	65.0	60.0	59.0	66.0	71.4	74.0	78.7	75.2	102	105	104	108	39.3	40.3	32.9	24.7	73.6	75.3	73.0	65.5
Menze	68.5	68.0	67.5	69.5	70.7	79.4	78.0	79.2	113	116	112	117.	38.3	42.5	33.8	29.1	84.5	81.1	76.5	70.6
Bolo	66.5	65.5	67.0	70.0	73.5	79.6	53.7	83.4	106	104	109	86.5	28.7	45.1	38.6	29.9	85.9	79.8	78.0	70.2
Alidoro	74	88	78	87	71.3	82.1	77.4	76.8	128	126	138	146	37.7	45.7	39.3	24.7	73.5	75.3	78.4	65.9
dinknesh	60.5	65.0	60.0	66.0	72.4	84.2	74.0	75.4	113	122	114	118	34.4	44.6	38.0	24.6	72.9	80.7	71.7	76.3
Tossa	63.5	60.0	62.5	61.0	71.1	74.9	71.7	71.7	107	109	112	109	34.5	44.3	37.8	29.1	82.4	80.6	78.0	65.5
Qulqulluu	61.0	60.5	61.0	60.0	70.9	76.2	70.7	71.4	107	105	105	112	32.4	43.6	35.5	26.0	77.8	77.1	77.9	80.8

F: Fedis; C: Chinaksen - Hirna, R-Rare, Main research Station.

Ongoing Activities

Durum wheat National Variety trial for optimum and High Moisture areas (11/12)

Twenty durum wheat genotypes were assessed on station Haramaya University main campus Rare station. The experimental design was randomized complete block design with four replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thouhsand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction 6 was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using “SAS” software window version 9.1.

Result and Recommendations

In the trial, analysis of variance showed that all parameters except hectoliter weight showed highly significant (P<0.001) variability among the genotypes (Table 5)

Table 5 F-values for the various sources of variations of ANOVA and their significance levels in Durum wheat National variety trial for optimum and High Moisture areas 11/12

Source of variation	**df** [a]	**F- Values**					
		DH	**DM**	**PH**	**TKW**	**HLW**	**GY**
Variety	**19**	**31.4*****	**116.09*****	**11.579*****	**4.07*****	**1.6 ns**	**3.47*****
rep	**3**	**3.11*****	**3.1125*****	**22.96*****	**2.5**	**1.4**	**1.52**
Error	**57**						
CV (%)		**1.42**	**2.21**	**2.29**	**3.46**	**17.71**	**12.8**

***= significant at 0.1% levels, respectively; ns = non-significant (P>0.05)

DH-Dayst o heading; DM-Days to Maturity, PH- Plant Height; TKW-Thousand Kernel Weight;

HLW-Hectolitre ..gfweight ; GY- Grain Yield

Table 6 Mean yield performance and disease reaction of bread wheat genotypes

Genotype	Yield (kg/ha)	Leaf Rust	Stem Rust
(1)drought tolorate(1/48)off21/2009er(1/48_ off/3/2099	4086.3DE	Tr	5MR-40S
(2)DWSR-ETH/2008	3996.5E	Tr	Tr-10MR
(3)droughtolorate(1/48)off21/2009tolorat(1/24)off1720off 17/2009	4962.6ABC DE	Tr	Tr-10MS
(4)CD08-PANDZ/off/106/2009	4646ABCDE	Tr-10MR	Tr
(5)drought tolorate(1/48)off21/2009tolorat(1/24)off212009	5079.4ABC DE	Tr	0-10R
(6)drought tolorate(1/48)off21/2009tolorate(1/24off19/2009	5054.8ABC DE	Tr-5R	0-10MR
(7)DSP2009-F6 off/1509/2009F4 off/1034/2009	5221.3ABC D	tr-5R	Tr-60S
(8)drought tolorate(1/48)off21/2009off6/2009	4354.8CDE	0-5R	Tr-60S
(9)drought tolorate(1/48)off21/2009tolorate1/24 off1/2009	5064.6ABC DE	Tr-10R	Tr-20S
(10)drought tolorate(1/48)off21/2009off13/2009	5819.8A	Tr-10MS	5MS-40MS
(11)drought tolorate(1/48)off21/2009off44/2009	4884.3ABC DE	Tr	Tr-40MS
(12)DSP2009-F6 off/1509/2009F4 off1336/2009	5720.3AB	Tr-20R	40MS-60S
(13)drought tolorate(1/48)off21/2009off14/2009	5105.1ABC DE	Tr-5MR	20MR-60MS
(14)DSP2009-F6 off/1509/2009	3912.1E	Tr-10MR	Tr-10MR
(15)drought tolorate(1/48)off21/2009	5088.9ABC DE	Tr	10R-40R
hitosa	5424.4ABC	Tr	Tr-50S
kilinto	5099.4ABC DE	Tr-5R	30MR40MS
Ude	4367.6CDE	Tr-5R	20MR-60S
yerer	4523BCDE	Tr	10MR-

Local	4258CDE	10MR-20MS	50MS 20MS-30MS
LSD	1295		

*Tr Trace; MR Moderately Resistant, MS Moderately Susceptible, S, Susceptible

The mean yield of genotypes in the trial is shown in (Table 6)**.** Genotype 10 had performed better from standard checks Ude, Yerer and the local checks. However, the genotype was moderately susceptible to both leaf rust and Stem rust. In relation to disease reaction, genotypes 5, 6 and 3 showed better reactions to the diseases. As the year, especially at Rare Main Station of the University, was noted for Stem rust outbreak, the low severity and resistant reaction observed in the genotypes is promising for future effort to combat this devastating disease (Refer East African Wheat Rust Trap Nursery report).

Durum wheat National Variety trial for optimum and High Moisture areas (12/13)

Materials and Methods

Eighteen durum wheat genotypes were assessed on station Haramaya University main campus Rare station. The experimental design was randomized complete block design with four replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thousand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using “SAS” software window version 9.1

Result and Recommendations

In the trial, analysis of variance showed that all parameters showed highly significant (P<0.001) variability among the genotypes (

Table 7)

Table 7 F-values for the various sources of variations of ANOVA and their significance levels in Durum wheat National variety trial for optimum and High Moisture areas 12/13

Source of variation	**df** [a]	**F- Values**					
		DH	**DM**	**PH**	**TKW**	**HLW**	**GH**
Variety	17	20.75***	16.95***	140.80***	6.89***	13.04***	3.68***
rep	3	2.43*	1.02	0.98	2.22	2.42	0.10
Error	51						
CV (%)		1.48	1.07	2.13	6.2	3.9	19.2

The mean yield of genotypes in the trial is shown in
Table 8. Genotype 3 and 6 , had performed better from standard checks Ude, Yerer and the local checks. However, no statistical difference was observed with the genotype and standard check hitosa. The severity of infection by leaf rust and stem rust was also moderate for the two genotypes. Genotype 11 had statistically comparable yield but more advantageous as it has only trace infection from both diseases. The three genotypes have a potential for future use in Eastern Ethiopia. If the National program does not release them, they need to be included in Regional trials.

Table 8 Mean grain yield (kg/ha) and disease reaction/severity of genotypes

,Genotypes	**Yield (kg/ha)**	**Leaf Rust**	**Stem Rust**
(1)IDON-MD-2009-off/12/2009	5231.2 C	Tr -5R	5MR-10MR
(2)IDON-MD-2009-off/34/2009	5571.1 BC	Tr -5R	Tr
(3)IDON-MD-2009-off/53/2009	6254.92A	5MR-10R	20R
(4)DSP2009-off.2h.22-meh.1h.26	5144.9 CD	Tr-5MR	20S
(5)DSP2009-off.F4.1h.783-meh.4h.259	5702.2 ABC	Tr	5R-20MS
(6)DSP2009-off.F4.1h.785-meh.2h.226	6462.8 A	Tr-10R	10MR-20MS
(7)DSP2009-F6/off/1508/2009	4928.9 CD	Tr-5MR	20MS-20MR
(8)IDON-MD-2009off/25/2009	5159.9 C	0-5R	TR-10MR

,Genotypes	**Yield (kg/ha)**	**Leaf Rust**	**Stem Rust**
(9)DSP2009-off.F4.1H.378-meh.4h.187	4610.5 E	TR-5MR	TR-5MR
(10)DSP2009-off.F4.3h.639-meh.1h.240	4272.8 DE	TR-5R	20MR
(11)DSP2009-offf4.2h.712-MEH.1H.248	6010.9 AB	TR	TR
(12)DSP2009-offF4.2H.735-meh.2h.251	3484.3 F	0-5R	TR-5R
(13)DSP2009-F4.3H.976-meh.2h.292	4202.9 DE	TR-5MR	5R-30MS
Hitosa	5835.7 AB	TR-5MS	TR-20MS
Mangudo	5081.25 CD	TR-5MR	5MR-30MR
Ude	4636.52 CDE	TR-5MR	30S
Yerer	4065.63 E	TR	10MS-20R
Local	3155.6 F	10MS-20R	40MS-60S
LCD	810		

Bread Wheat National Variety Trial for Optimum Area- Set I 11/12-

Materials and Methods

Seventeen bread wheat genotypes were assessed on station at Haramaya University main campus Rare station. The experimental design was randomized complete block design with four replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thouhsand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using “SAS” software window version 9.1.

Result and Recommendations

In the trial, analysis of variance showed that all parameters showed highly significant (P<0.001) variability among the genotypes(Table 9).

Table 9 F-values for the various sources of variations of ANOVA and their significance levels in Durum wheat National variety trial Set I 11/12

Source of variation	df	DH	DM	PH	TKW`	HLW	Yield
		F- Values					
Variety	16	21.56***	17.42***	40.47***	20.7***	5.29***	6.04***
rep	3	2.43*	1.02	0.98	2.22	2.42	0.101
Error	48						
CV (%)		1.48	1.07	2.13	6.2	3.9	19.182

The mean yield of genotypes in the trial is shown in
Table 10. ETB 5879 (5276 kg/ha) performed significantly higher than the check danda' (4426kg/ha) and Digelu (4224 kg/ha).
The genotype showed better reaction against the rust diseases.(10R for leaf rust and Tr for stem rust) It is a potential genotype to be selected for regional variety trials if the same is not selected at national level.

Table 10 Mean grain yield (kg/ha) and disease reaction/severity of genotypes of NVT SET-I 2011/12

Genotype	Yield (kg/ha)	Leaf Rust	Stem Rust
Danda'a	4422.6 BCDE	TR-5R	TR-5R
ETB5956	4272.6 CDE	0-30R	TR
ETB5957	4039.4DEF	0-5R	Tr
ETB5958	3776.1 EF	0	Tr-30R
ETB5961	2732.1 G	Tr-20MR	Tr-5R

Genotype	Yield (kg/ha)	Leaf Rust	Stem Rust
ETB 5998	5087 AB	0-20R	5MR-10MR
ETB5800	4249.1 CDE	Tr-10R	0-30MS
ETB5825	5072.1 AB	Tr-30MS	Tr-5R
ETB5826	4799.6 AB	Tr-20MR	0-5R
ETB5827	4253.3 CDE	Tr-10MR	tr
ETB5850	4975.5 ABC	Tr-10MR	0-Tr
ETB5875	3434.1 FG	0-5MR	0-20MS
ETB5879	5276 A	10R	Tr
ETB5890	4234.8 CDE	0-30ms	10MR-30R
ETB5899	4485.1BCDE	0-5MR	Tr-5mr
ETB5900	4196.9 DEF	10MR-40MR	0-5R
Digelu	4224.1 CDE	5R-10MR	10MR

Bread Wheat National Variety Trial for Optimum Area- Set IV-12-

Materials and Methods

Twenty two bread wheat genotypes were assessed on station at Haramaya University main campus Rare station. The experimental design was randomized complete block design with four replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thousand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using “SAS” software window version 9.1.

Results and Recommendation

In the trial, analysis of variance showed that all parameters showed highly significant (P<0.001) variability among the genotypes Table 11.

Table 11F-values for the various sources of variations of ANOVA and their significance levels in Bread Wheat National Variety Trial for Optimum Area- Set IV-12

Source of variation	**df**	**F- Values**					
		DH	**DM**	**PH**	**TKW**	**HLW**	**GY**
Variety	21	55.98***	20.26***	20.9***	11.48***	3.3***	10.94***
Rep	3	0.67	5.37***	1.15	2	7.01***	1.51
Error	63						
CV (%)		1.01	0.93	3.51	4.53	7.09	7.73

The mean yield of genotypes in the trial is shown in Table 12. ETB 6773 (5335.2 kg/ha) outperformed the standard checks Danda'(4648.5 kg/ha) and Digelu. (4537.9 kg/ha) However, the genotype was susceptible to leaf rust (40S-60S). The next performing genotype ETBW 6777 has showed promising performance (4989 kg/ha) and disease reaction, though statistically no significant difference was observed with the standard check.

Table 12 Mean Yield performance of Bread Wheat National Variety Trial for Optimum Area- Set IV-12

Genotype	**Yield (kg/ha)**	**Leaf Rust**	**Stem Rust**
dandaa	4648.5 BC	Tr-20MR	Tr-5mr
ETBW 6770	3961.6 EGH	Tr-10MR	10MR
ETBW 6771	3456.3 IK	Tr-5R	Tr-5R
ETBW 6772	4188.6DEG	5MS-30MS	5MR-10MR
ETBW 6773	5335.3 A	40S-60S	Tr-5R
ETBW 6774	3814.4 GHI	Tr-5MS	Tr-5MR
ETBW 6775	4311.8CDE	Tr	Tr
ETBW 6776	4020 EGH	Tr-60MS	Tr-10MS

ETBW 6777	4989 AB	5R-20R	5MS-10MR
ETBW 6778	3793.1 GHI	Tr-20MS	Tr-5MS
ETBW 6779	4484 CD	40MS-80MS	20S-40S
ETBW 6780	3611.8 HIK	Tr-5MR	Tr-10MR
ETBW 6781	3362.6 K	20S-40S	5MR-10R
ETBW 6782	3913.8 GH	Tr-20ms	Tr
ETBW 6783	3316.5 K	Tr-10MR	Tr
ETBW 6784	3911.8 HIK	10MR-20MS	Tr-5ms
ETBW 6785	3395.4 IK	20s-60s	Tr-20MS
ETBW 6786	4341 CDE	Tr-10r	Tr-5MS
ETBW 6787	4276.5 CDE	Tr-5R	Tr
ETBW 6788	4025.9 EGH	Tr-20MS	Tr
ETBW 6789	4261.5 CDE	Tr-40MS	40S-60S
Digelu	4537.9 CD	5MS-20MS	5MS-20MS

Bread Wheat preliminary Variety Trial 11/12 Set I

Material and methods

Twenty four bread wheat genotypes were assessed on station at Haramaya University main campus Rare station. The experimental design was randomized complete block design with three replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thousand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using "SAS" software window version 9.1.

Results and Recommendation

In the trial, analysis of variance showed that all parameters showed highly significant (P<0.01) variability among the genotypes (Table 13)

Table 13 F-values for the various sources of variations of ANOVA and their significance levels in **Bread Wheat Pre-National Variety Trial for Optimum Area 11/12- Set I**

Source of variation	df	F- Values					
		DH	DM	PH	TKW	HLW	GY
Variety	23	12.92***	15.02***	17.29***	35.2***	2.65**	10.34***
rep	2	0.07	1.89	4.72***	4.95**	2.5	2.42
Error	46						
CV (%)		1.35	0.96	2.82	3.11	6.49	9.12

Table 14 Mean yield performance and Disease reaction of genotypes inNPVT 11/12 Set I

Genotype	Yield	LR	SR
danda'a	4433 CDEF	Tr	Tr
ETBW6432	3849.8 FGHJ	Tr-5MR	5ms-10ms
ETBW6434	4304.5 DEFG	Tr	Tr-10S
ETBW6435	4794.3 CD	Tr	Tr-5ms
ETBW6440	5838.2 A	Tr	Tr-5ms
ETBW6463	3487.HJK	Tr-5mr	10s-30s
ETBW6468	4347 DEF	Tr	10 MR
ETBW6469	5004 BC	TR-20S	Tr-5MR
ETBW6477	3913.7 FGH	Tr	Tr-20S

Genotype	Yield	LR	SR
ETBW6479	4283.8 EDFG	Tr	10 MR
ETBW6481	3570 HJK	Tr	Tr
ETBW6482	5441 AB	40S-60S	Tr-5R
ETBW6483	3195.8 K	Tr-5MS	Tr-5MR
ETBW6486	3416.2 JK	Tr	Tr
ETBW6490	3221.5K	Tr-20MS	Tr-5MS
ETBW6491	4039.7 EFGH	Tr-5mr	10s-30s
ETBW6493	3710.2 GHJK	Tr	10 MR
ETBW6499	4468.5 CDEF	Tr-60MS	Tr-10MS
ETBW6500	3954 FGH	5R-20R	5MS-10MR
ETBW6501	4081 EFGH	Tr-10R	0-30MS
ETBW6505	4644 CDE	Tr-30MS	Tr-5R
ETBW6509	4743.77 CD	Tr-20MS	Tr
ETBW6544	3096.3 K	Tr-40MS	40S-60S
digalu	4894.7 BCD	5MS-20MS	5MS-20MS

Bread Wheat preliminary Variety Trial 11/12 Set II

Materials and Methods

Twenty four bread wheat genotypes were assessed on station at Haramaya University main campus Rare station. The experimental design was randomized complete block design with three replications.

Data collection and analysis

Parameters like Days to Heading (DH), Days to maturity (DM), Plant Height (PH), Thousand Kernel Weight (TKW), Hectoliter weight (HLW) (Kg/hl), Grain yield (GY) were collected. Besides, Disease severity and reaction was recorded for Stem Rust, Leaf Rust and Yellow Rust.

To reveal the total variability present within the genotypes in randomized complete block design, analysis of variance was computed for all the characters as per Gomez and Gomez (1984) using “SAS” software window version 9.1.

Results and Recommendation

All parameters showed significant variability among genotypes (P<0.001) (Table 15)

Table 15 F-values for the various sources of variations of ANOVA and their significance levels in Bread Wheat Pre-National Variety Trial for Optimum Area 11/12- Set II

Source of variation	df	**AllF Values**					
		DH	DM	PH	TKW	HLW	GY
Variety	23	65.62***	43.11***	22.13***	27.54***	10.73***	7.34***
rep	2	5.73***	0.61	0.73	0.82	10.36***	0.99
Error	46						
CV (%)		0.72	0.64	6.35	6.35	3.92	10.21

The mean yield of genotypes in the trial is shown in Table 16. ETB 6465 (5904.2 kg/ha) out-performed the standard checks Danda’ (4671.5 kg/ha) and Digelu. (4418.9 kg/ha) The genotype was also relatively free from Leaf rust and stem rust. The genotype, if not included in National Variety Trial, will be tested for the region.

Table 16 Mean yield performance and disease reactions of genotypes included in NPVT 11/12 Set I

Genotype	**Yield (kg/ha)**	**LR**	**SR**
Danda'a	4671.5BCDE	Tr-5mr	0
ETB 6197	4263.8GFDE	10MS-30ms	Tr
ETB 6202	3424.7HI	5MS-10MS	5MR-10mr
ETB 6206	3470.2HI	tr	Tr
ETB 6209	3969.7GFHE	20MR-40mr	Tr
ETB 6236	5191AB	tr	40MS-60ms

Genotype	Yield (kg/ha)	LR	SR
ETB 6240	4318.3GFDE	10MS-20ms	Tr
ETB 6251	3693.2GFHI	tr	5MS-10ms
ETB 6253	4845.7CBD	tr	5r
ETB 6261	3866.3GFHI	20mr-30mr	Tr
ETB 6264	5069.3CB	5S-10s	10s-40s
ETB 6266	3233I	tr	Tr-5r
ETB 6270	3904.8GFHI	0-10ms	Tr
ETB 6456	3702.8GFHI	Tr-20r	Tr-20ms
ETB 6457	4332.2GFDE	tr	20ms
ETB 6460	4867.8CBD	tr	Tr
ETB 6461	4055GFHE	50ms-60ms	30ms-40s
ETB 6462	5364.8AB	Tr-20s	Tr-20ms
ETB 6465	5904A	Tr	Tr-10r
ETB 6526	4689.2CBDE	0-10mr	Tr
ETB 6528	4642.8CBDE	Tr	Tr-10s
ETB 6670	4896.8CBD	20S-40s	10r
ETB 6692	5185.3AB	Tr-20r	Tr
Digelu	4418.3CFDE	Tr-5mr	Tr-5ms

Wheat stem rust surveillance in eastern Ethiopia

Introduction

Climate change, in terms of rising temperatures, and the timing and increasing variability of rainfall, is contributing to the spread and severity of rust diseases. Emerging races of rust are showing adaptations to extreme temperatures not seen before. Scientists around the globe are working on monitoring and surveillance (close watch) of stem and stripe rusts to ensure rapid detection and reporting so farmers, policymakers, and agricultural research centers can respond more quickly to initial outbreaks.

To combat the problem of wheat rusts, farmers in rust prone regions need to adopt new varieties of wheat that have durable resistance to both stem and stripe rusts. New rust resistant varieties are in the pipeline at international and national agricultural research centers. Breeders are selecting for other important characteristics including improved yield performance, drought tolerance, and regional suitability.

Country preparedness for outbreaks of wheat rusts involves such issues as the availability of resistant varieties that are known to and accepted by farmers, the availability of sufficient quality seeds of new varieties for farmers to use, and the availability, accessibility and affordability of effective fungicides and capacity of farmers to use them.

In most cases, the bottleneck to getting resistant varieties into the field in time to protect local harvests is local capacity and the ability of national programs to rapidly multiply seeds and deliver them to market. Improving country capacity requires long-term planning, funding, and getting farmers involved earlier in the variety selection process. There is need for enhancing in-country capacity of the breeding, seed and extension systems to continuously ensure that **new, highly productive and genetically diverse resistant varieties are available and accepted by farmers** to meet the challenges of changing rust virulence. Coordination and timely information sharing among all the stakeholders -- from surveillance and plant protection officers, to wheat breeders, seed system and extension agents, and farmers is key.

Tracking Wheat Rust Pathogens

Directed, optimized mitigation of the threat of stem and yellow rusts to resource poor farmers cannot be achieved without vigilant monitoring of the incidence and nature of stem rust in countries thought to be Ug99-free today, and in those where Ug99 is already established. The stark fact is that today, we do not know how far Ug99 or its derivates have migrated. Lack of this knowledge impedes resolution and adoption of appropriate national and international policies, investments, and strategies in plant protection, plant breeding, seed systems, and research on the stem rust pathogen. It is insufficient to predict the pathways by which the Ug99 lineage will migrate, since mutation and sexual recombination (especially in East Africa and Central Asia where the alternate host is endemic) will spawn new variants; variants whose characteristics may dictate changes in gene deployment strategies in both the choice of gene combinations used by breeders, and in the distribution and retirement of varieties by national seed sectors. Such variants can arise anywhere, not just East Africa.

Currently, however, no framework exists for acquiring and sharing data on incidence, severity, and genetic composition of stem rust infections in the developing world. Likewise, there is no singular source of information on the spatial and temporal distribution of wheat (or wheat varieties) in these regions through the course of a year. Combined, these deficiencies preclude directed, efficient action by scientists and policy makers tasked with mitigating the threat to cereal production posed by wheat stem rust.

Field Surveys

It is to be recalled that Haramaya University is a team member of the National Wheat Rusts Surveillance Project. The University is mandated to make surveys in the major wheat growing regions of eastern Ethiopia and report to the coordinator at Ambo Plant Protection Research Centre. Accordingly, surveys of wheat fields were carried out in East and West Hararghe zones' major wheat growing areas from 7 to 15 November 2011 to check status of wheat rusts with emphasis on stem rust.

The field survey was carried out along the following survey routes:

- Haramaya→Kersa→Lange→Kullubi→Chelenko→Kobo→Dedder→Karamekela→Harawacha→Mole→Masa→Mesela→Hirna
- Hirna→Bedessa→Wachu→Harar
- Harar→Kurfachelle→Gurawa→Harar
- Harar→Kombolcha→Jarso
- Harar→Jijiga→Chinaksen→Haramaya

Survey Methodology

Surveys were carried out along the main roads and wheat fields were observed at intervals of approximately 15 to 20 kms. Geographic locations, approximate sizes of fields and wheat growth stages were first recorded. Following this, plants were inspected for symptoms of wheat rusts (stem/black, leaf/brown and yellow/stripe rusts) by walking in a zigzag manner starting from one to the other side of each field. Disease incidence (proportion of plants infected expressed as percentage of the total plants assessed) was determined on 100 plants/field that were scored as either diseased. Disease severity (percentage of plant part infected) was recorded using the Modified Cobb Scale on 10 randomly selected plants per field.

Results

The surveyed areas were situated between 09°02.229´ to 09°32.061´ N latitude and 040°54. 436´ to 042°44.457´ E longitude (Table 1). The altitude of the surveyed areas ranged from 1664 to 2739 masl. In the majority of the surveyed fields, wheat plants were between growth stages 7 and 9 (grain dough to ripening stages) on the growth stage scale suggested by Zadoks and co-workers (Zadoks et al., 1974). The approximate sizes of the surveyed fields ranged from 0.1 to 0.5 hectares. Atotal of 57 fields were observed, but data was recorded from 43 fields only.

Stem and leaf rusts were not encountered in all the fields inspected except traces of leaf rust on three cultivars in the East African Disease Trap Nursery. Yellow rust was encountered in fields located at ≥2400 masl with severities ranging from trace to 40S particularly on the improved variety named Kubsa (HAR 1685). The absence of stem and leaf rusts and low severity of yellow rust could be attributed to unfavourable environmental conditions. Several reports have indicated that wheat rust diseases are severe only in years when conditions are unusually favourable, susceptible varieties are grown, cultural practices are altered, or when the above conditions occur in combination. The range of temperatures that favour the development of stem, leaf and yellow rusts are 15-30°C, 15-25°C, and 10-15°C, respectively. According to earlier reports, under Ethiopian conditions, the rusts infect wheat late in the season, but if favourable conditions prevail and susceptible varieties are grown, early infections are possible. In general, during the 2011/2012 main crop season, the weather particularly the relatively dry condition that prevailed during the season seems to have been unfavourable and suppressed rust development. In the future, the rust infections need to be correlated with the weather data particularly temperature, moisture and relative humidity.

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East Africa Wheat Rusts Trap Nursery (EAWRTN)

This nursery was previously (2007-2010) known as Ethiopian Wheat Rusts Trap Nursery (EWRTN). But it was upgraded to East Africa Wheat Rusts Trap Nursery (EAWRTN) by incorporating additional test materials and three East African countries, i.e., Kenya, Tanzania and Uganda became participants in this program as of the 2011 crop season. The main objective of the EAWRTN is to **monitor prevailing virulences of the pathogens causing leaf, stem and yellow rusts and effectiveness resistance genes.**

This nursery included 146 entries grouped into four sets:

Set I: 45 commercial varieties,

Set II: 17 yellow rust differentials (to be grown in yellow rust hot spot areas),

Set III: 42 stem rust differentials (to be grown in stem rust hot spot areas), and

Set IV: 42 leaf rust differentials (to be grown in leaf rust hot spot areas),.

Set II consisting of 17 yellow rust differentials was not grown at the Haramaya University because this site is not considered hot spot for yellow rust.

During the 2011 main crop season, EAWRTN was planted on the Haramaya University Main Campus Research Site traditionally known as *Rare*. Each entry was planted in two rows of one meter long and 20 cm apart. Diseases were recorded using the Modified Cobb Scale which has two parameters: disease severity (percentage of rust infection of the plant) and plant response to infection (type of infection).

The disease severity was expressed as percent (ranging from 0 to 100) of rust infection of the plant. The numbers are always multiples of five, i.e., 0, Tr (trace level), 5, 10, 15,…..95, 100, N (when the plant is completely dead). The infection types were expressed as follows: 0 = Immune,

R = Resistant, MR = Moderately Resistant, MR-MS = Both Moderately Resistant and Moderately Susceptible but the MR frequency is higher in the plant, MS = Moderately Susceptible and S = Susceptible. Disease records included both the severity and the type of infection (host response) as shown in the examples given below:

- TrR: Trace level of % rust infection with resistant plant response,
- 10MR: 10% of rust coverage (severity) and moderately resistant host response,
- 40S: 40% of rust coverage (severity) and susceptible host response

Results

A. Effectiveness of commercial varieties in controlling the three rusts

Seventeen (38%) of the commercial varieties were immune from leaf, stem and yellow rusts. However, when individual rust is considered, 56% of the commercial varieties were immune and 44% showed traces of infection to leaf rust. Eighty percent of these varieties were immune while 20% showed traces of stem rust infections. Similarly, 69% of these varieties were free and 31% indicated trace yellow rust infections. The virulence of the three rusts on the commercial varieties was very low during the 2011 main crop season. It seems that the commercial varieties were effective in controlling the three rusts. However, a one year's data cannot be conclusive. The study must be repeated in the 2012 crop season for proper conclusion.

B. **Prevailing virulence of the pathogen causing leaf, stem and yellow rusts**

When virulence of the pathogens causing leaf, stem and yellow rusts were considered, only trace infections of the three rusts were detected. Due to this the data was insufficient to draw conclusions.

Table 17: Wheat rusts distribution in the major wheat growing areas of Hararghe in 2011

No.	District	Location Name	Altitude (m)	Latitude	Longitude	Stem rust		Leaf rust		Yellow rust	
						Incidence	Severity	Incidence	Severity	Incidence	Severity
1.	Chinaksen	Almale	1980	09°29.441’	042°38.796’	0	0	0	0	0	0
2.	Chinaksen	Yugyug	2008	09°32.061’	042°32.223’	0	0	0	0	0	0
3.	Chiro	Arberekete	2264	09° 02.223’	040°54.436’	0	0	0	0	0	0
4.	Deder	Obi	2406	09° 18.852’	041°25.963’	0	0	0	0	0	0
5.	Deder	Chafégurmu	2425	09°17.400’	041°23.307’	0	0	0	0	0	0
6.	Deder	Waltebudim	2554	09° 16.468’	041°21.161’	0	0	0	0	0	0
7.	Deder	Lemenwattaha	2739	09° 12.525’	041°20.268’	0	0	0	0	0	0
8.	Diretayara	Hasangey	2060	09 ° 20.863’	042 ° 06.620’	0	0	0	0	0	0
9.	Gurawa	Aradayaya	2494	09°12.027’	041°47.298’	0	0	0	0	100	40S
10.	Gurawa	Hulajeneta	2485	09°09.885’	041°47.459’	0	0	0	0	100	20S
11.	Gurawa	Hulajeneta	2490	09°08.891’	041°48.827’	0	0	0	0	100	20S
12.	Haramaya	Haramaya Univ.	2031	09 ° 25.178’	042 ° 02.199’	0	0	3	tr	0	0
13.	Jarso	Ifajalala	2495	09°29.210’	042°12.878’	0	0	0	0	0	0

14.	Jarso	Ararsa	2556	09º29.292’	042º14.878’	0	0	0	0	0	0
15.	Jarso	Afugug	2538	09º29.731’	042º18.170’	0	0	0	0	0	0
16.	Jarso	Afugug	2535	09º27.340’	042º14.502’	0	0	0	0	1	tr
17.	Jarso	Afugug	2534	09º29.276’	042º14.094’	0	0	0	0	2	tr
18.	Jarso	Galtakke	2491	09º29.196’	042º12.850’	0	0	0	0	1	tr
19.	Jijiga	Umerjey	1736	09º24.237’	042º44.457’	0	0	0	0	0	0
20.	Jijiga	Wataharta	1740	09º24.457’	042º44.138’	0	0	0	0	0	0
21.	Jijiga	Sugdug	1664	09º07.015’	042º 04.865’	0	0	0	0	0	0
22.	Kersa	Metekoma	2133	09º26.856’	041º50.320’	0	0	0	0	0	0
23.	Kersa	Yabetaleucha	2133	09º26.858’	041º50.322’	0	0	0	0	0	0
24.	Kersa	Lencha	2019	09º26.433’	041º46.507’	0	0	0	0	0	0
25.	Kersa	Unidentified	2128	09º26.870’	041º50.022’	0	0	0	0	0	0
26.	Kombolcha	Tula	2186	09º23.853’	042º06.439’	0	0	0	0	0	0
27.	Kombolcha	Waramohammed	2447	09º29.004’	042º12.461’	0	0	0	0	0	0
28.	Kombolcha	Waramohammed	2452	09º28.999’	042º12.458’	0	0	0	0	0	0
29.	Kurfacele	Jirubalina	2405	09º14.055’	041º48.818’	0	0	0	0	0	0
30.	Kurfacele	Odagudina	2519	09º12.495’	041º48.830’	0	0	0	0	0	0
31.	Kurfacele	Jirubelina	2397	09º14.052’	041º48.802’	0	0	0	0	0	0

32.	Kurfacele	Rasajenata	2491	09º12.402’	041º48.049’	0	0	0	0	0	0
33.	Melkabelo	Burkanegaya	2630	09º 10.291’	041º18.387’	0	0	0	0	0	0
34.	Melkabelo	Odabelina	2421	09º 13.879’	041º48.731’	0	0	0	0	0	0
35.	Mesala	Bahabiftu	2436	09º 07.682’	041º13.388’	0	0	0	0	0	0
36.	Mesala	Lubudekeb	2341	09º 04.520’	041º09.705’	0	0	0	0	0	0
37.	Mesala	Burka	2169	09º 04.778’	041º08.856’	0	0	0	0	0	0
38.	Meta	Hawibilisuma	2313	09º26.405’	041º42.609’	0	0	0	0	0	0
39.	Meta	Chelenkolola	2142	09º24.954’	041º37.030’	0	0	0	0	0	0
40.	Meta	Dursitubilisuma	2239	09º24.612’	041º35.862’	0	0	0	0	0	0
41.	Tullo	Odabalena	1797	09º13.108’	041º06.483’	0	0	0	0	0	0
42.	Tullo	Odanegaya	1818	09º13.151’	041º06.430’	0	0	0	0	0	0
43.	Tullo	Tarkanfata	2207	09º10.955’	041º03.236’	0	0	0	0	0	0

Note: Observations were made in 57 fields. But in 14 fields we did not record the geographic location; we simply took note of the presence/absence of rusts.

Acknowledgment

The activities mentioned are funded by EAAPP.Ethiopia.

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Wheat stem rust surveillance in eastern Ethiopia

By

Prof. Temam Hussien

During the 2011/2012 main crop season, the following research activities were undertaken: Wheat stem rust surveillance in eastern Ethiopia, and the Ethiopian Wheat Rust Trap Nursery.

Introduction

Climate change, in terms of rising temperatures, and the timing and increasing variability of rainfall, is contributing to the spread and severity of rust diseases. Emerging races of rust are showing adaptations to extreme temperatures not seen before. Scientists around the globe are working on monitoring and surveillance (close watch) of stem and stripe rusts to ensure rapid detection and reporting so farmers, policymakers, and agricultural research centers can respond more quickly to initial outbreaks.

To combat the problem of wheat rusts, farmers in rust prone regions need to adopt new varieties of wheat that have durable resistance to both stem and stripe rusts. New rust resistant varieties are in the pipeline at international and national agricultural research centers. Breeders are selecting for other important characteristics including improved yield performance, drought tolerance, and regional suitability.

Country preparedness for outbreaks of wheat rusts involves such issues as the availability of resistant varieties that are known to and accepted by farmers, the availability of sufficient quality seeds of new varieties for farmers to use, and the availability, accessibility and affordability of effective fungicides and capacity of farmers to use them.

In most cases, the bottleneck to getting resistant varieties into the field in time to protect local harvests is local capacity and the ability of national programs to rapidly multiply seeds and deliver them to market. Improving country capacity requires long-term planning, funding, and getting farmers involved earlier in the variety selection process. There is need for enhancing in-country capacity of the breeding, seed and extension systems to continuously ensure that **new, highly productive and genetically diverse resistant varieties are available and accepted by farmers** to meet the challenges of changing rust virulence. Coordination and timely information sharing among all the stakeholders -- from surveillance and plant protection officers, to wheat breeders, seed system and extension agents, and farmers -- is key.

Tracking Wheat Rust Pathogens

Directed, optimized mitigation of the threat of stem and yellow rusts to resource poor farmers cannot be achieved without vigilant monitoring of the incidence and nature of stem rust in countries thought to be Ug99-free today, and in those where Ug99 is already established. The stark fact is that today, we do not know how far Ug99 or its derivates have migrated. Lack of this knowledge impedes resolution and adoption of appropriate national and international policies, investments, and strategies in plant protection, plant breeding, seed systems, and research on the stem rust pathogen. It is insufficient to predict the pathways by which the Ug99 lineage will migrate, since mutation and sexual recombination (especially in East Africa and Central Asia where the alternate host is endemic) will spawn new variants; variants whose characteristics may dictate changes in gene deployment strategies in both the choice of gene combinations used by breeders, and in the distribution and retirement of varieties by national seed sectors. Such variants can arise anywhere, not just East Africa.

Currently, however, no framework exists for acquiring and sharing data on incidence, severity, and genetic composition of stem rust infections in the developing world. Likewise, there is no singular source of information on the spatial and temporal distribution of wheat (or wheat varieties) in these regions through the course of a year. Combined, these deficiencies preclude directed, efficient action by scientists and policy makers tasked with mitigating the threat to cereal production posed by wheat stem rust.

Field Surveys

It is to be recalled that Haramaya University is a team member of the National Wheat Rusts Surveillance Project. The University is mandated to make surveys in the major wheat growing regions of eastern Ethiopia and report to the coordinator at Ambo Plant Protection Research Centre. Accordingly, surveys of wheat fields were carried out in East and West Hararghe zones' major wheat growing areas from 7 to 15 November 2011 to check status of wheat rusts with emphasis on stem rust.

The field survey was carried out along the following survey routes:

- Haramaya→Kersa→Lange→Kullubi→Chelenko→Kobo→Dedder→Karamekela→Harawacha→Mole→Masa→Mesela→Hirna
- Hirna→Bedessa→Wachu→Harar
- Harar→Kurfachelle→Gurawa→Harar
- Harar→Kombolcha→Jarso
- Harar→Jijiga→Chinaksen→Haramaya

Survey Methodology

Surveys were carried out along the main roads and wheat fields were observed at intervals of approximately 15 to 20 kms. Geographic locations, approximate sizes of fields and wheat growth stages were first recorded. Following this, plants were inspected for symptoms of wheat rusts (stem/black, leaf/brown and yellow/stripe rusts) by walking in a zigzag manner starting from one to the other side of each field. Disease incidence (proportion of plants infected expressed as percentage of the total plants assessed) was determined on 100 plants/field that were scored as either diseased. Disease severity (percentage of plant part infected) was recorded using the Modified Cobb Scale on 10 randomly selected plants per field.

Results

The surveyed areas were situated between 09°02.229´ to 09°32.061´ N latitude and 040°54. 436´ to 042°44.457´ E longitude (Table 1). The altitude of the surveyed areas ranged from 1664 to 2739 masl. In the majority of the surveyed fields, wheat plants were between growth stages 7 and 9 (grain dough to ripening stages) on the growth stage scale suggested by Zadoks and co-workers (Zadoks et al., 1974). The approximate sizes of the surveyed fields ranged from 0.1 to 0.5 hectares. Atotal of 57 fields were observed, but data was recorded from 43 fields only.

Stem and leaf rusts were not encountered in all the fields inspected except traces of leaf rust on three cultivars in the East African Disease Trap Nursery. Yellow rust was encountered in fields located at ≥2400 masl with severities ranging from trace to 40S particularly on the improved variety named Kubsa (HAR 1685). The absence of stem and leaf rusts and low severity of yellow rust could be attributed to unfavourable environmental conditions. Several reports have indicated that wheat rust diseases are severe only in years when conditions are unusually favourable, susceptible varieties are grown, cultural practices are altered, or when the above conditions occur in combination. The range of temperatures that favour the development of stem, leaf and yellow rusts are 15-30°C, 15-25°C, and 10-15°C, respectively. According to earlier reports, under Ethiopian conditions, the rusts infect wheat late in the season, but if favourable conditions prevail and susceptible varieties are grown, early infections are possible. In general, during the

2011/2012 main crop season, the weather particularly the relatively dry condition that prevailed during the season seems to have been unfavourable and suppressed rust development. In the future, the rust infections need to be correlated with the weather data particularly temperature, moisture and relative humidity.

East Africa Wheat Rusts Trap Nursery (EAWRTN)

This nursery was previously (2007-2010) known as Ethiopian Wheat Rusts Trap Nursery (EWRTN). But it was upgraded to East Africa Wheat Rusts Trap Nursery (EAWRTN) by incorporating additional test materials and three East African countries, i.e., Kenya, Tanzania and Uganda became participants in this program as of the 2011 crop season. The main objective of the EAWRTN is to **monitor prevailing virulences of the pathogens causing leaf, stem and yellow rusts and effectiveness resistance genes.**

This nursery included 146 entries grouped into four sets:

Set I: 45 commercial varieties,

Set II: 17 yellow rust differentials (to be grown in yellow rust hot spot areas),

Set III: 42 stem rust differentials (to be grown in stem rust hot spot areas), and

Set IV: 42 leaf rust differentials (to be grown in leaf rust hot spot areas),

Set II consisting of 17 yellow rust differentials was not grown at the Haramaya University because this site is not considered hot spot for yellow rust.

During the 2011 main crop season, EAWRTN was planted on the Haramaya University Main Campus Research Site traditionally known as *Rare*. Each entry was planted in two rows of one meter long and 20 cm apart. Diseases were recorded using the Modified Cobb Scale which has two parameters: disease severity (percentage of rust infection of the plant) and plant response to infection (type of infection).

The disease severity was expressed as percent (ranging from 0 to 100) of rust infection of the plant. The numbers are always multiples of five, i.e., 0, Tr (trace level), 5, 10, 15,…..95, 100, N (when the plant is completely dead). The infection types were expressed as follows: 0 = Immune,

R = Resistant, MR = Moderately Resistant, MR-MS = Both Moderately Resistant and Moderately Susceptible but the MR frequency is higher in the plant, MS = Moderately Susceptible and S = Susceptible. Disease records included both the severity and the type of infection (host response) as shown in the examples given below:

- TrR: Trace level of % rust infection with resistant plant response,
- 10MR: 10% of rust coverage (severity) and moderately resistant host response,

- 40S: 40% of rust coverage (severity) and susceptible host response

Results

Effectiveness of commercial varieties in controlling the three rusts

Seventeen (38%) of the commercial varieties were immune from leaf, stem and yellow rusts. However, when individual rust is considered, 56% of the commercial varieties were immune and 44% showed traces of infection to leaf rust. Eighty percent of these varieties were immune while 20% showed traces of stem rust infections. Similarly, 69% of these varieties were free and 31% indicated trace yellow rust infections. The virulence of the three rusts on the commercial varieties was very low during the 2011 main crop season. It seems that the commercial varieties were effective in controlling the three rusts. However, a one year's data cannot be conclusive. The study must be repeated in the 2012 crop season for proper conclusion.

Prevailing virulence of the pathogen causing leaf, stem and yellow rusts

When virulence of the pathogens causing leaf, stem and yellow rusts were considered, only trace infections of the three rusts were detected. Due to this the data was insufficient to draw conclusions.

Table 1: Wheat rusts distribution in the major wheat growing areas of Hararghe in 2011

No.	District	Location Name	Altitude (m)	Latitude	Longitude	Stem rust		Leaf rust		Yellow rust	
						Incidence	Severity	Incidence	Severity	Incidence	Severity
44.	Chinaksen	Almale	1980	09^{o}29.441’	042^{o}38.796’	0	0	0	0	0	0
45.	Chinaksen	Yugyug	2008	09^{o}32.061’	042^{o}32.223’	0	0	0	0	0	0
46.	Chiro	Arberekete	2264	09^o 02.223’	040^{o}54.436’	0	0	0	0	0	0
47.	Deder	Obi	2406	09^o 18.852’	041^{o}25.963’	0	0	0	0	0	0
48.	Deder	Chafégurmu	2425	09^{o}17.400’	041^{o}23.307’	0	0	0	0	0	0
49.	Deder	Waltebudim	2554	09^o 16.468’	041^{o}21.161’	0	0	0	0	0	0
50.	Deder	Lemenwattaha	2739	09^o 12.525’	041^{o}20.268’	0	0	0	0	0	0
51.	Diretayara	Hasangey	2060	09 ^{o} 20.863’	042 ^{o} 06.620’	0	0	0	0	0	0
52.	Gurawa	Aradayaya	2494	09^{o}12.027’	041^{o}47.298’	0	0	0	0	100	40S
53.	Gurawa	Hulajeneta	2485	09^{o}09.885’	041^{o}47.459’	0	0	0	0	100	20S
54.	Gurawa	Hulajeneta	2490	09^{o}08.891’	041^{o}48.827’	0	0	0	0	100	20S
55.	Haramaya	Haramaya Univ.	2031	09 ^{o} 25.178’	042 ^{o} 02.199’	0	0	3	tr	0	0
56.	Jarso	Ifajalala	2495	09^{o}29.210’	042^{o}12.878’	0	0	0	0	0	0

57.	Jarso	Ararsa	2556	09º29.292'	042º14.878'	0	0	0	0	0	0
58.	Jarso	Afugug	2538	09º29.731'	042º18.170'	0	0	0	0	0	0
59.	Jarso	Afugug	2535	09º27.340'	042º14.502'	0	0	0	0	1	tr
60.	Jarso	Afugug	2534	09º29.276'	042º14.094'	0	0	0	0	2	tr
61.	Jarso	Galtakke	2491	09º29.196'	042º12.850'	0	0	0	0	1	tr
62.	Jijiga	Umerjey	1736	09º24.237'	042º44.457'	0	0	0	0	0	0
63.	Jijiga	Wataharta	1740	09º24.457'	042º44.138'	0	0	0	0	0	0
64.	Jijiga	Sugdug	1664	09º07.015'	042º 04.865'	0	0	0	0	0	0
65.	Kersa	Metekoma	2133	09º26.856'	041º50.320'	0	0	0	0	0	0
66.	Kersa	Yabetaleucha	2133	09º26.858'	041º50.322'	0	0	0	0	0	0
67.	Kersa	Lencha	2019	09º26.433'	041º46.507'	0	0	0	0	0	0
68.	Kersa	Unidentified	2128	09º26.870'	041º50.022'	0	0	0	0	0	0
69.	Kombolcha	Tula	2186	09º23.853'	042º06.439'	0	0	0	0	0	0
70.	Kombolcha	Waramohammed	2447	09º29.004'	042º12.461'	0	0	0	0	0	0
71.	Kombolcha	Waramohammed	2452	09º28.999'	042º12.458'	0	0	0	0	0	0
72.	Kurfacele	Jirubalina	2405	09º14.055'	041º48.818'	0	0	0	0	0	0
73.	Kurfacele	Odagudina	2519	09º12.495'	041º48.830'	0	0	0	0	0	0

74.	Kurfacele	Jirubelina	2397	09º14.052’	041º48.802’	0	0	0	0	0	0
75.	Kurfacele	Rasajenata	2491	09º12.402’	041º48.049’	0	0	0	0	0	0
76.	Melkabelo	Burkanegaya	2630	09º 10.291’	041º18.387’	0	0	0	0	0	0
77.	Melkabelo	Odabelina	2421	09º 13.879’	041º48.731’	0	0	0	0	0	0
78.	Mesala	Bahabiftu	2436	09º 07.682’	041º13.388’	0	0	0	0	0	0
79.	Mesala	Lubudekeb	2341	09º 04.520’	041º09.705’	0	0	0	0	0	0
80.	Mesala	Burka	2169	09º 04.778’	041º08.856’	0	0	0	0	0	0
81.	Meta	Hawibilisuma	2313	09º26.405’	041º42.609’	0	0	0	0	0	0
82.	Meta	Chelenkolola	2142	09º24.954’	041º37.030’	0	0	0	0	0	0
83.	Meta	Dursitubilisuma	2239	09º24.612’	041º35.862’	0	0	0	0	0	0
84.	Tullo	Odabalena	1797	09º13.108’	041º06.483’	0	0	0	0	0	0
85.	Tullo	Odanegaya	1818	09º13.151’	041º06.430’	0	0	0	0	0	0
86.	Tullo	Tarkanfata	2207	09º10.955’	041º03.236’	0	0	0	0	0	0

Note: Observations were made in 57 fields. But in 14 fields we did not record the geographic location; we simply took note of the presence/absence of rusts.

Improvement of Highland Pulse Crops Research in Eastern Ethiopia

By

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Abstract

A field experiments were conducted during the 2012 main cropping season under rain fed conditions at Haramaya, Hirna, Arbarakate and Fedis locations, eastern Ethiopia. The objectives of the experiment were to develop and promote high yielding, stress tolerant and widely/specifically adapted faba bean, field pea, chick pea, lentil and fenugreek varieties with desirable agronomic and quality traits for Eastern Ethiopia and to renew, increase, and maintain true to type breeder seeds of released varieties of faba bean (Gachena) and field pea (Meti) and make available for basic seed production. The experiments included Lentil National Variety Trial as completed project in 2012 cropping season, faba bean national variety trial, faba bean regional variety trial, field pea national variety trial, chickpea national variety trials (both dessi and kabulli types), fenugreek regional variety trial as on-going projects in a factorial combination in randomized complete block design replicated four times in case of faba bean, field pea, and lentil, whereas three times in case of fenugreek. Despite its completed and on-going activities, the program also proposed about four new activities (Lentil National Variety Trial, Faba bean Regional Preliminary Variety Trial, Field pea Regional Preliminary Variety Trial and Fenugreek Regional Preliminary Variety Trial) to conduct at four different locations (Haramaya, Hirna, Arbarakate and Fedis) in the 2013 cropping season. For field pea, Lentil and chickpea (desi and kabuli types) national varieties trials, the mean squares of the genotypes were highly significant for seed yield, pods per plant, and seeds per pod and hundred seed weight traits. From completed experiment,two superior varieties in terms of varies traits will be further tested and multiplied and distributed for the farmers under the Eastern and Western Hararghe. Likewise, for both Dessi and Kabuli types of chickpea National Varieties Trials, the most out-yielded varieties with yield and related traits will be multiplied and distributed to the users/farmers through the University. In the case of Faba bean Regional Variety Trial, results indicated that genotype ***EK-01012-1-3*** *gave the highest yield at all experimental locations (Haramaya, Hirna and Arbarakate), whereas the lowest seed yield was recorded from* ***EK-01024-1-2*** *(1622.6 kg/ha) and* ***EK-01024-1-1*** *(1526.6 kg/ha), at Haramaya and Arbarakate, respectively. Nevertheless, for Fenugreek Regional Variety Trial, the highest seed yield was obtained from* ***FG-coll-23906-1*** *both at Haramaya and at Hirna, whereas at Fedis the maximum seed yield was obtained from* ***Fg-coll-212656****.*

Key words: Faba bean, Field pea, Chick pea, Lentil and Fenugreek

INTRODUCTION

Among the pulses, faba bean, field pea, chickpea, lentil, and fenugreek are categorized as highland pulses and grown in the cooler highlands. The crops are the major pulses crops grown in the highlands (1800-3000 m.a.s.l) of Ethiopia where the need of chilling temperature is satisfied. The crops take the largest share of the area and production of the pulses grown in Ethiopia.

These crops contribute to smallholder income, as a higher-value crop than cereals, and to diet, as a cost-effective source of protein that accounts for approximately 15% of protein intake (IFPRI 2010). Moreover, pulses offer natural soil maintenance benefits through nitrogen-fixing, which improves yields of cereals through crop rotation, and can also result in savings for smallholder farmers from less fertilizer use.

Despite the importance of the crops in Eastern Ethiopia, their productivities are constrained by different abiotic and biotic factors like moisture stress, severity of different fungal and bacterial diseases. In addition to these, low adoption rate of improved varieties, non-availability of quality seed of improved cultivars, unawareness of farmers about the improved varieties and technologies, and limited use of modern agronomic practices and production inputs (Amare and Adamu, 1994) are the major factors that limit highland pulses production.

Therefore, the highland pulse crops research of Haramaya University has been conducting with the following objectives.

- ✓ To develop and promote high yielding, stress tolerant and widely/specifically adapted faba bean, field pea, chick pea, lentil and fenugreek varieties with desirable agronomic and quality traits for western and eastern Hararghe
- ✓ To renew and conserve breeding materials, to increase and maintain true to type breeder seeds of released faba bean and field pea varieties and make available for basic seed production

1. Completed project in 2012

One set of National Variety trial, Lentil Nationa Variety Trial (L-NVT), was conducted at Haramaya for three years (2010 -2012) in eastern Ethiopia. The results are presented as following.

Lentil National Variety Trial

Materials and Methods

Sixteen genotypes have been evaluated along with two standard checks (Alemaya & Derash) at Haramaya for three years (2010- 2012) in RCB design with four replications. Field plot techniques, field performance evaluation, data collection and data analysis were conducted as per the recommendation.

Summary of Results

Analysis of variance has shown highly significant ($p \leq 0.05$) differences among varieties for grain yield, days to flowering, days to maturity, root rots, rust, powdery mildew, plant height, biomass and 100 seed weight(Table 7).

The overall mean values across years for all abovementioned characters are shown in **Table1**. Variety **EL-142 X R-186-3** gave the highest seed yield (2862.19kg/ha), 100 seed weight (5.05g) as well as biomass (6718.80 kg/ha) among the evaluated varieties. This was followed by **FLIP 2004-50L**which gave (2414.38 kg/ha), (4.43g) and (6093.80kg/ha) of seed yield, 100 seed weight and biomass, in that order. In contrast, the lowest seed yield (1264.38 kg/ha), 100 seed weight (2.53g) and biomass (2500.00kg/ha) were recorded from R**-186 X FLIP 86-38L-10**. Despite its high yielder, **EL-142 X R-186-3** was the best in overall performance and resistance to major diseases common in eastern Ethiopia like rust, root rots and wilt among others, based on the field evaluation. The varieties **EL-142 X R-186-3, FLIP 2004-50L, FLIP 2006-20L** and **Cechol X R-186-8-**1 had better average yield performances than the standard checks and other varieties in the trial.

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Table 1: Mean performance of Lentil National Variety Trial at Haramaya during 2012/13 main cropping season

Variety Name	DF	DM	PM	R.rot	Rust	Wilt	PH (m)	BM (kgha-1)	HSW	SY (kgha-1)
X2002S-161-20	57.75	99.75	1.00	1.13	3.00	1.13	38.55	3750.00	3.30	1368.75
ILL-8008 X ILL-6025-5	58.50	103.25	1.00	0.75	1.00	1.00	41.75	4375.00	3.73	1457.19
FLIP 2006-20L	59.50	105.00	3.00	0.00	0.19	0.00	45.05	5625.00	4.28	1972.50
FLIP 2004-50L	59.75	106.00	3.00	0.00	0.00	0.00	45.65	6093.80	4.43	2414.38
Exotic#2 DZ/2008 AK	56.25	96.00	1.00	3.00	4.50	3.00	34.35	3125.00	2.88	1291.88
FLIP 97-16L	57.75	101.50	1.00	0.88	1.00	1.00	40.85	4062.50	3.50	1398.13
Chekol X R-186-2	57.75	96.75	1.00	3.00	3.00	3.00	36.35	3125.00	3.05	1310.63
R-186 X FLIP 86-38L-10	56.25	95.00	1.00	0.00	5.00	3.00	31.55	2500.00	2.53	1264.38
R-186 X FLIP 86-38L-24	59.25	104.25	3.00	0.44	1.00	0.19	43.75	5000.00	4.10	1714.38
ILL-358 X ILL-2573-2	57.50	98.75	3.00	1.50	3.00	1.50	37.80	3750.00	3.23	1345.00
Cechol X R-186-8-1	59.25	105.00	3.00	0.03	0.81	0.00	44.40	5000.00	4.15	1864.06
R-186 X FLIP 86-38L-4	58.75	101.50	1.00	0.75	1.00	1.00	41.25	4375.00	3.63	1407.81
EL-142 X R-186-3	59.75	107.50	3.00	0.00	0.00	0.00	47.85	6718.80	5.05	2862.19
Alemaya	57.25	97.25	1.00	3.00	3.00	2.63	37.30	3750.00	3.13	1325.31
Derash	58.00	100.75	1.00	1.00	1.13	1.00	39.65	3750.00	3.43	1383.75
X2002S-161-20	58.50	103.25	2.50	0.63	1.00	0.81	42.90	5000.00	3.90	1529.06
Mean	58.23	101.34	1.66	1.01	1.79	1.20	40.56	4375.01	3.64	1619.34
LSD(0.05)	1.12	0.86	0.36	0.12	0.38	0.30	0.64	395.30	0.12	77.87
CV (%)	1.35	0.60	14.55	6.21	15.06	17.79	1.11	6.34	2.37	3.38

DF= Date of 50% flowering, DM = Date of 90% physiological Maturity, PM= Powdery mildew, PH= Plant height in cm, PPP= Number of pods per plant, SPP= Number of seeds per pod, HSW= Hundred seed weight in gram, SY= Seed yield in kg/ha

Recommendation

EL-142 X R-186-3, FLIP 2004-50L and FLIP 2006-20L varieties are recommended for further verification based on field performance and average grain yield under multiplications to meet the national variety release criteria (DUS) in national variety trial

2. Ongoing projects

Background

Two regional variety trials and three national variety trials, representing three crops (Faba bean, Chick pea and Fenugreek) were conducted at four locations (Haramaya, Hirna, Albarakate and Fedis) in Eastern Ethiopia. All of these activities were started in the 2012 main cropping season with the objective to develop and promote high yielding, stress tolerant and widely/specifically adapted varieties with desirable agronomic and quality traits for western and eastern Hararghe. All of these experiments will anticipate completing in 2013/14. The summaries of results for each trial are separately presented in the following sections.

Experiment 1. Faba Bean Regional Variety Trial

Materials and Methods

Fifteen different faba bean genotypes, which promoted from Faba bean Regional Preliminary Variety Trial in 2011 were conducted along with their standard (Gachena) at three locations (Haramaya, Hirna, Albarakate) during the 2012 main cropping season . The treatments were arranged factorially and were laid out in randomized complete block design with four replications. All the necessary agronomic practice was maintained as per the recommendation.

Summary of Results

Analysis of variance shown that significant differences were observed for 100 seed weight and seed yield among the tested entries.

Genotype **EK-01012-1-3** gave the highest seed yield (2730.3kg/ha) and (3407 kg/ha) at Haramaya and Alrbarakate, respectively. This was followed by **EK-01012-1-3** (2679.9 kg/ha) and **EK-00126-4** (3279.4kg/ha), in that order at both locations. In the other hand, the lowest seed yield was obtained from **EK-01024-1-2** (1622.6 kg/ha) and **EK-01024-1-1** (1526.6 kg/ha), at Haramaya and Arbarakate, respectively. At Hirna maximum seed yield was obtained from **EK-LSS02009-2** (2341kg/ha) which was at par with **EK-LSS02022-1** (2038 kg/ha) and **EK-01024-1-2** (2028 kg/ha), whereas the lowest seed yield was recorded from E**K-01001-10-5** (1156.1kg/ha) with over all mean of 2069.47kg/ha (**Table 2**). The standard check, Gachena, was ranked seventh among fifteen tested genotypes in yield performance.

Table 2: Mean grain yield (kgha-1) of genotypes in regional faba bean variety trial at three locations in 2012 main cropping season

Genotype	Haramaya	Hirna	Arbarakate	Mean
EK-01001-8-1	2470.70	1856.90	3263.30	2530.30
EK-01001-10-5	1901.00	1156.10	3151.30	2069.47
EK-01021-4-1	2032.30	1554.00	2754.10	2113.47
EK-020005-1-1	2290.50	1412.50	2883.40	2195.47
EK-LS01006-1	2224.90	1565.20	3195.20	2328.43
EK-01012-1-3	2679.90	1506.20	3232.30	2472.80
EK-01012-1-3	2730.30	1864.60	3407.00	2667.30
EK-00126-4	1650.80	2012.10	3279.40	2314.10
EK-LSS02009-2	2260.00	2341.00	2715.60	2438.87
EK-LSS02022-1	2262.40	2038.00	2683.10	2327.83
EK-01004-2-1	2371.80	1595.50	2200.80	2056.03
EK-01024-1-1	1927.50	1706.90	1526.60	1720.33
EK-01024-1-2	1622.60	2028.00	1900.30	1850.30
EK-01021-4-1	2332.80	1643.40	2007.70	1994.63
Gachena	2183.60	2047.80	2712.50	2314.63
Mean	2196.07	1755.21	2727.51	2226.26
LSD(0.05)	ns	ns	ns	ns
CV (%)	22.5083	28.0610	35.399	28.6561

Work plan

The materials will be further evaluated for yield and related traits in the upcoming cropping season

Experiment-2: Faba bean National Variety Trial- Large seeded for wide Adaptation

Material and Methods

Thirteen large seeded genotypes of faba bean from Kulumsa Agricultural Research Center along with the standard checks, *Dosha and Tumsa*, were used. The materials were laid in RCBD with four replications at Haramaya University research station. All the cultural practices for the experiment were used as per the recommendation of the testing site. Field and laboratory data were collected and subjected to analysis of variance using SAS software (SAS, 1996).

Summary of results

The analysis of variance and mean agronomic performance of the genotypes is presented in **Table 3**. The variety main effect was significant for days to maturity and biomass, while it was insignificant for most of the measured traits.

Dosha gave highest seed yield (2074.1 kg/ha) followed by **EK02017-3** (1684.1 kg/ha) and the minimum was obtained from **EH06006-6** (1211.3kg/ha). The varieties **Dosha**, **EK02017-3**,

EH06007-2, EK02016-1 and **EH06007-1** had better average yield performances than the standard check Tumsa as well as other varieties in the trial **(Table 3).** The highest 100 seed weight was recorded from **EK02019-2** (831.4g) which was at par with 100 seed weight recorded from **EH06007-1** (811.90g), **Dosha** (811.40g), whereas the minimum 100 seed weight was recorded from **EH00053-1** (595.1).

Work plan

Since it is on-going the experiment, the materials will be further evaluated for yield and yield contributed traits for one additional cropping season

Experiment-3. Faba bean breeder seed maintenance

One regionally released faba bean variety, *Gachena*, from Haramaya University were purified and maintained in plot size of 10m x 10m in isolated field. The activity has been conducted at Haramaya University research station during the 2012 main cropping season. All the necessary agronomic practice including rouging of the off-types was performed to maintain the genetic purity of the breeder seed.

Summary of Results

Some parameters was recorded and presented in **Table 4**. The genetic purity of the variety was maintained by distance isolation and discarding the off-type. 198.00 kg of purified breeder seed was produced.

Work plan

Further purification and maintenance will continue and the produced seed will be delivered to the seed unit of the University for further Production of pre-basic and/or basic seed.

Table 3: Mean performance of Faba bean National Variety Trial (Large Seeded trial) at Haramaya during 2012/13 main cropping season

Trt. Name	DF	DM	Rust	PH(cm)	PPP	SPP	STD	TSW	SY(kgha^{-1})
Dosha	51.75	101.50	4.00	127.00	4.45	3.32	73.28	811.40	2074.10
EH00100-2	53.50	98.25	3.50	121.70	4.75	3.35	82.34	775.70	1461.80
EH00053-1	50.50	96.75	4.00	116.95	4.48	3.91	72.97	595.10	1242.30
EK02017-3	54.75	97.25	3.50	132.25	4.95	3.81	79.53	725.70	1491.20
EK02017-3	53.00	96.25	4.00	121.90	4.88	3.47	78.75	743.40	1684.10
EK02019-2	53.00	97.00	3.50	127.00	5.70	3.56	82.66	755.30	1454.20
EH00100-3	55.25	96.50	4.00	124.10	5.45	3.51	82.19	777.40	1486.50
EK02018-1	54.75	98.00	3.50	132.20	5.45	3.04	82.81	704.80	1363.90
EK02018-3	52.00	98.75	4.00	122.55	4.53	4.07	74.38	758.70	1475.90
EK02016-1	53.75	102.00	4.50	125.10	5.20	3.43	72.66	728.00	1581.70
EK02006-2	53.75	101.25	3.00	132.55	5.18	3.45	74.84	785.60	1240.60
EH06007-1	52.00	100.75	4.00	122.80	6.60	3.55	70.78	811.90	1529.90
EH06006-6	52.50	98.75	3.50	120.00	6.25	3.94	83.44	749.60	1211.30

EH06007-2	53.75	98.25	3.00	121.05	5.55	3.31	69.84	774.00	1588.40
Tumsa	54.50	98.75	3.00	135.75	5.43	3.38	83.75	831.40	1358.20
Mean	53.25	98.67	3.67	125.53	5.26	3.54	77.61	755.20	1482.94
LSD(0.05)	3.60	3.22	1.50	16.27	1.97	0.87	14.19	134.39	668.79
CV (%)	4.73	2.28	28.62	9.08	26.23	17.27	12.81	12.47	31.60

DF= Date of 50% flowering, DM = Date of 90% physiological Maturity, PH= Plant height, in cm, PPP= Number of pods per plant, SPP= Number of seeds per pod, STD= Stand count in percentage, TSW= Thousand seed weight in gram, SY= Seed yield in kg/ha

Table 4: Mean Performance a released Faba bean variety (*Gachena)* over 2012 cropping season at Haramaya

Range	DF	DM	CS	Rust	PH	PPP	Spp	SPPl	TSW	SYLD
Mean	56.0	100.2	3.96	4.5	132.30	13.10	2.85	36.30	582.60	198.00
Max	59.0	105.0	5.00	5.00	149.00	18.30	3.75	62.00		
Min	53.0	88.0	3.00	3.5	120.40	7.6	1.92	22.00		

DF= Days to flowering, DM= Days to Maturity, CS= Chocolate spot, PH= Plant Height, PPP= Pods per plant, Spp= Seeds per pod, Spp= Seeds per plant, TSW- 1000 seed weight, SYLD= Seed yield

Experiment 4: Field pea National Variety Trial

Material and Methods

Fifteen field pea genotypes from Kulumsa Agricultural Research Center along with the standard checks, **Burkitu and Letu**, were used. The materials were laid in RCBD with four replications at Haramaya University research station in the 2012/13 main cropping season. All the cultural practices for the experiment were used as per the recommendation of the testing site. Field and laboratory data were collected and subjected to analysis of variance using SAS software (SAS, 1996).

Summary of results

Analysis of variance has shown highly significant ($p \leq 0.05$) differences among varieties for days flowering, powdery mildew, plant height, pods per plant, seeds per pod, seed yield and 1000 seed weight (**Table 8**)

The mean days flowering, powdery mildew, plant height, pods per plant, seeds per pod, seed yield and 1000 seed weight are given in **Table 5**.

Table 5: Mean performance of 15 Field pea National Variety Trial at Haramaya during 2012/13 main cropping season

Variety	DF	DM	PM	PH (m)	PPP	SPP	SY (kgha^{-1})	TSW
Burkitu	59.25	97.00	3.00	1.33	8.69	4.45	1041.70	165.55
EH 05027-2	58.00	95.75	5.00	1.49	9.83	5.50	1649.50	182.88
EH 05024-4	59.75	96.50	4.00	1.49	6.99	3.68	818.80	156.04
EH 05034-1	60.75	95.25	3.00	1.68	8.04	6.23	2063.10	202.75
EH 05050-1	63.50	95.00	3.00	1.43	6.38	4.90	1218.70	171.00
EH 05048-3	60.25	96.00	2.00	1.58	8.21	5.75	1539.30	190.03
EH 04052-1	61.00	97.25	2.50	1.73	7.95	5.43	1367.10	183.31
EH 05031-1	59.25	98.00	1.00	1.55	9.77	4.45	1092.60	166.02
EH 05016-4	61.00	97.75	4.50	1.56	7.74	4.15	993.10	161.05
EH 05024-3	60.75	97.25	3.00	1.46	9.43	4.28	999.80	163.57
EH 05029-2	64.50	98.50	1.00	1.63	7.38	5.10	1466.80	177.35
EH 05014-5	61.75	97.00	3.00	1.55	10.05	6.55	2637.00	208.81
EH 04027-1	60.25	97.00	3.00	1.59	9.78	5.43	1776.40	188.78
EH 04048-1	60.75	98.25	3.50	1.50	10.60	6.30	2134.80	201.22
Letu	61.25	97.00	5.00	1.62	6.88	3.88	903.00	157.15
Mean	60.80	96.90	3.10	1.54	8.51	5.07	1446.78	178.37
LSD	2.17	2.78	0.88	0.21	1.05	0.93	607.05	18.25
CV (%)	2.50	2.00	20.07	9.56	8.67	12.88	29.40	7.17

DF= Date of 50% flowering, DM = Date of 90% physiological Maturity, PM= Powdery-mildew PH= Plant height, in cm, PPP= Number of pods per plant, SPP= Number of seeds per pod, TSW= Thousand seed weight in gram, SY= Seed yield in kg/ha

Variety **EH 05014-5** gave the highest pods per plant(10.05), seeds per pod (6.55), seed yield(2637.00 kg/ha) and 1000 seed weight(208.81g), whereas the lowest was recorded from **EH 05024-4** for pods per plant(6.99), seeds per pod(3068), seed yield(818.80kg/ha) and 1000 seed weight(156.04g) which had in parity with standard check Letu. Nevertheless, the highest powdery mildew was also observed on **EH 05024-4**). This might be one of the reasons why this variety showed less performance in seed yield and other yield contributed traits.

Work plan

Since it is on-going the experiment, the materials will be further evaluated for yield and yield contributed traits for one additional cropping season

Experiment-5: ***Field pea Breeder seed Maintenance and Multiplication***

Material and Methods

One regionally released field pea variety, *Meti*, were maintained in a plot size of 10m x 10m at Haramaya University research station during the 2012 main cropping season. All the necessary agronomic practice including close supervision of the experimental plot and rouging the off-type was performed. All the management practices were given as per the recommendations to maintain the genetic purity of the variety *Meti*.

Summary of Results

Some parameter for the crop was recorded and presented in **Table 6**. The purity of the variety was maintained by discarding the off-type and 112.00 kg of breeder seed was produced from the plot with its thousand seed weight of 232.44g.

Work plan

Further purification and maintenance will continue and the produced seed will be delivered to the seed unit of the University for further Production of pre-basic or basic seed

Table 6: Mean Performance a released Field variety (*Meti*) over 2012 cropping season at Haramaya

Range	DF	DM	Blight	PM	PH	PPP	Spp	SPPl	TSW	SYLD
Mean	54.5	90.58	4.00	3.5	162.00	8.12	6.85	36.00	232.44	112.00
Max	57.5	95.0	5.00	5.00	189.88	18.00	7.80	72.21		
Min	50.6	83.0	3.00	3.00	125.00	3.00	3.25	14.00		

DF= Days to flowering, DM= Days to Maturity, PM= Powdery mildew, PH= Plant Height, PPP= Pods per plant, Spp= Seeds per pod, Spp= Seeds per plant, TSW- 1000 seed weight, SYLD= Seed yield

Table 7: Mean square values of ANOVA for Days to flowering, Days to maturity, Root rots,Rust, Powdery mildew, Plant height, Biomass (kg ha-1) , 100 seed weight (g) ,and Seed yield (kg ha-1) of Lentil National Variety Trial at Haramaya in 2012 cropping season

Source of variation	DF	Days to flowering	Days to maturity	Root rots	Rust	Powdery mildew	Plant height	Biomass	100 seed weight	Seed yield
Replication	3	1.4739	0.854	0.0228	0.1289	0.062	2.671	21158	0.0672	19251.86
Genotype	15	5.015**	58.229**	8.3155**	9.866**	3.729**	77.91**	5195312.5**	1.693**	828551.40**
Error	45	0.618	0.3652	0.0067	0.0726	0.062	0.203	77039.9	0.00746	2989.69
CV (%)		1.35	0.60	6.21	15.06	14.55	1.11	6.34	2.37	3.38

** = significant at P≤0.01, *= significant at P ≤0.05, CV = coefficient of variation

Table 8: Mean square values of ANOVA for Days to flowering, Days to maturity, Powdery mildew, Plant height, Pods per plan, Seeds per pod , (kg ha-1) , 1000 seed weight (g) ,and Seed yield (kg ha-1) of Field pea National Variety Trial at Haramaya in 2012 cropping season

Source of variation	DF	Days to flowering	Days to maturity	Powdery mildew	Plant height	Pods per plant	Seeds per pod	1000 seed weight	Seed yield
Replication	3	1.466	19.84	0.2444	0.016	0.1338	0.523	237.530	49023.94
Genotype	14	10.435**	4.35**	5.885714**	0.042**	7.022**	3.3107**	1192.11148**	1106288.32**
Error	42	2.311	3.784	0.387	0.0218	0.5454	0.4262	163.60296	180966.84
CV (%)		2.50	2.00	20.07	9.56	8.67	12.88	7.17	29.40

** = significant at P≤0.01, *= significant at P ≤0.05, CV = coefficient of variation

Experiment 6: Chickpea National Variety Trial- ***Dessi Type***

Material and Methods

Seventeen chickpea genotypes were conducted along with two standards, *Minjar* and *Natoli*, and a local check at Haramaya University research station during 2012/13 main cropping season. The materials were laid in RCBD with four replications and all the necessary agronomic practice was maintained as per the recommendation.

Summary of results

Significant variation in stand count, grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height, biomass, 100 seed weight and root rots between selections were observed (**Table 12**). Accordingly, variety **DZ-2012-CK-0034** gave the highest stand count (93.75%), pods per plant(83.1), biomass (6458.30kg/ha), 100 seed weight (32.40g) and seed yield (2296.09 kg/ha), while **local check** gave the lowest stand count (69%), pods per plant (32.85), biomass (3750.00kg/ha), 100 seed weight (12.50g) and seed yield (773.96 kg/ha) among tested varieties (**Table 9**).

Work plan

Since the experiment will have one extra season for its completion, further evaluation for yield and yield contributing traits is undergoing.

Table 9: Mean performance of Chick pea National Variety Trial-Desi type at Haramaya during 2012/13 main cropping season

Variety Name	DF	DM	Wilt	PH (m)	PPP	SPP	SDT	BM (kgha^{-1})	HSW	SY (kgha^{-1})
DZ-2012-CK-0030	42.75	107.00	1.00	34.25	45.15	1.64	93.25	5729.20	23.25	1527.19
DZ-2012-CK-0038	41.00	106.50	1.00	32.50	39.85	1.70	86.25	5104.20	21.25	1229.90
DZ-2012-CK-0032	40.75	105.50	1.00	30.20	35.25	1.70	80.50	4375.00	19.10	919.69
DZ-2012-CK-0037	44.00	109.00	1.00	36.85	57.90	1.53	88.75	6041.70	27.68	1899.58
DZ-2012-CK-0027	45.00	109.00	1.00	38.30	60.60	1.58	90.75	6250.00	28.45	1988.23
DZ-2012-CK-0034	46.50	111.75	0.75	45.15	83.10	1.42	93.50	6458.30	32.43	2296.09
Local check	40.00	104.50	1.00	28.55	32.85	1.67	69.00	3750.00	12.50	773.96
DZ-2012-CK-0028	45.50	109.25	0.50	39.90	70.45	1.47	92.75	6458.30	29.90	2085.94
DZ-2012-CK-0033	41.00	106.50	0.75	31.15	36.85	1.72	85.50	4687.50	19.80	1021.46
DZ-2012-CK-0040	42.00	107.00	1.00	33.50	42.83	1.67	87.50	5625.00	22.23	1388.44
MINJAR	42.00	106.50	1.00	32.90	40.95	1.69	93.50	5520.80	21.65	1303.65
DZ-2012-CK-0036	42.00	107.00	1.00	34.05	43.90	1.67	88.25	5625.00	22.75	1462.08
DZ-2012-CK-0031	43.00	107.75	0.75	34.90	49.75	1.57	87.00	5729.20	24.82	1635.83
NATOLI	41.00	106.50	1.00	31.80	38.10	1.74	93.75	4583.30	20.55	1146.04
DZ-2012-CK-0039	43.50	108.00	1.00	35.55	51.35	1.59	91.50	6041.70	25.75	1678.33
DZ-2012-CK-0029	43.00	107.00	1.00	34.60	47.20	1.60	89.50	5729.20	23.65	1577.50
DZ-2012-CK-0035	44.00	108.00	1.00	36.15	55.35	1.54	93.25	6041.70	26.48	1798.13
Mean	42.76	107.46	0.93	34.72	48.91	1.62	88.50	5514.71	23.66	1513.65
LSD	0.38	0.76	0.37	1.91	3.74	0.03	6.40	363.06	1.12	42.29
CV (%)	0.63	0.50	27.8	3.87	5.37	1.52	5.09	4.63	3.33	1.97

DF= Date of 50% flowering, DM = Date of 90% physiological Maturity, PH= Plant height, in cm, PPP= Number of pods per plant, SPP= Number of seeds per pod, STD= Stand count in percentage, BM= Biomass in kg/ha, HSW= Hundred seed weight in gram, SY= Seed yield in kg/ha

Experiment 7: Chickpea National Variety Trial- *Kabuli Type*

Material and Methods

Seventeen chick pea varieties were planted along with three standards, *Arerti*, *Habru*,and *Ejere* checks at Haramaya University research station in the 2012/13 main cropping season. The materials were laid in RCBD with four replications and all the necessary agronomic practice were maintained as per the recommendations.

Summary of Result

Significant differences were observed among varieties for stand count, grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height, biomass and 100 seed weight (**Table 13**).

Among the tested varieties, **DZ-2012-CK-0004** was earliest in days to maturity (97.5 days) but gave lowest100 seed weight (26.63g) next to **DZ-2012-CK-0011** (20.83g) and **DZ-2012-CK-0002** (25.3g). On the other hand, the maturity (102.75 days) of **DZ-2012-CK-0011** was delayed which was statistically in parity with the DZ**-2012-CK-0003** (102.25 days).

The highest plant height(40.55m), pods per plan (46.59), seeds per pod(2.0), biomass (6479.17kg/ha), 100 seed weight(35.18g), seed yield (2084.69kg/ha) and harvest index (32.18%) were recorded from material **DZ-2012-CK-0001**, while the lowest result for aforementioned traits were observed from **DZ-2012-CK-0011** as shown in **Table 10**.

Work plan

Since the experiment will have one extra season for its completion, further evaluation for yield and yield contributing traits is necessary

Table 10: Mean performance of Chick pea National Variety Trial-Kabuli type at Haramaya during 2012/13 main cropping season

Treatment Name	DF	DM	PH (m)	PPP	SPP	BM (hgha^{-1})	HSW	SY (hgha^{-1})	HI (%)
DZ-2012-CK-0007	49.25	100.75	37.55	38.58	1.21	5000.00	28.53	1090.00	21.80
Habru	46.00	99.50	34.95	41.46	1.62	5833.33	31.55	1508.44	25.86
DZ-2012-CK-0003	48.50	102.25	38.70	40.80	1.50	5416.67	30.58	1301.56	24.03
DZ-2012-CK-0011	46.75	102.75	38.70	29.76	1.00	4583.33	20.83	609.13	13.29
DZ-2012-CK-0001	46.25	100.00	40.55	46.59	2.00	6479.17	35.18	2084.69	32.18
DZ-2012-CK-0002	47.00	102.75	36.85	31.25	1.00	4583.33	25.30	828.02	18.07
DZ-2012-CK-0013	47.00	101.50	38.95	40.28	1.50	5416.67	30.32	1250.34	23.08
DZ-2012-CK-0005	47.25	101.00	38.75	40.00	1.50	5416.67	29.98	1168.96	21.58
DZ-10-4	47.25	101.75	38.70	41.02	1.55	5552.08	30.91	1375.31	24.78
DZ-2012-CK-0008	47.00	99.75	35.40	42.00	1.75	5833.33	31.85	1627.82	27.91
DZ-2012-CK-0004	46.00	97.50	38.40	33.30	1.00	4895.83	26.63	887.27	18.14
DZ-2012-CK-0012	46.25	99.00	38.95	43.35	1.81	6145.83	32.53	1800.31	29.30
Arerti	48.25	100.75	36.25	39.39	1.49	5135.42	29.54	1112.81	21.67
DZ-2012-CK-0010	46.25	99.75	35.85	36.47	1.25	5000.00	28.21	965.21	19.30
DZ-2012-CK-0006	47.25	100.25	35.90	38.40	1.36	5000.00	29.13	1062.29	21.25
DZ-2012-CK-0009	46.25	98.50	37.45	35.08	1.19	5000.00	27.48	941.98	18.83
Ejere	47.50	101.50	37.05	44.75	2.00	6250.00	33.45	1904.38	30.47
Mean	47.06	100.54	37.59	38.97	1.45	5384.80	29.53	1265.80	23.03
LSD (0.05)	2.61	4.51	3.95	0.78	0.08	121.46	2.13	62.42	1.42
CV (%)	3.90	3.16	7.40	1.40	3.83	1.59	5.07	3.47	4.34

DF= Date of 50% flowering, DM = Date of 90% physiological Maturity, PH= Plant height, in cm, PPP= Number of pods per plant, SPP= Number of seeds per pod, BM= Biomass in kg/ha, HSW= Hundred seed weight in gram, SY= Seed yield in kg/ha, HI= Harvest Index in percentage

Experiment 8: Fenugreek Regional Variety Trial

Twenty-five, different fenugreek genotypes promoted from "Fenugreek Preliminary Regional Variety Trial" in 2011, were evaluated along with the standard (Chala) in triple lattice design at three locations (Haramaya, Hirna and Fedis) in the 2012/13 main cropping season

Summary of Results

Significant variation in seed yield was observed among tested traits at all locations (Haramaya, Hirna and Fedis)**.**

Table 11: Mean grain yield (kgha-1) of genotypes in regional fenugreek variety trial at three locations in 2012 main cropping season

Genotypes	Haramaya	Hirna	Fedis	Mean
Fgcoll53008	2055.8	444	434	977.93
Fg coll 53097	1752.1	1017	499.6	1089.57
Fgcoll5317	2060	664	433.3	1052.43
Fgcoll239065	1622.9	573	345.8	847.23
Fgcoll239066	1384.6	589	325.8	766.47
Fgcoll239068	2273.8	815	316.7	1135.17
Fgcoll53002	1952.5	404	317.5	891.33
Fgcoll53023	2311	899.2	275	1161.73
Fgcoll212877	2125.2	500	220	948.40
Fgcoll230883	1120	330	222	557.33
Fgcoll53078	1826.7	821	228	958.57
Fgcoll53079	1464.2	572.9	232	756.37
Fgcoll205176	2335.8	505	277.9	1039.57
Fgcoll207356	2194.6	814	207	1071.87
Fgcoll207365	1182.5	786	284.6	751.03
Fgcoll207367	1568.3	1359.2	646.3	1191.27
Fgcoll212777	1662.5	1079	417.5	1053.00
Fgcoll239061	2632.8	1685.8	611.3	1643.30
Fgcoll239063	1400.4	628	321.7	783.37
Fgcoll239064	698.3	618	335	550.43
Fgcoll212656	1597.5	864.2	985	1148.90
Fgcoll213117	1934.6	552	557.9	1014.83
Fgcoll53085	1896.3	642	205	914.43
Fgcoll232195	1597.5	504	766.3	955.93
Chala	984.9	1041	776.3	934.07
Mean	1745.39	748.29	409.66	967.78
LSD(0.05)	917.54	619.52	376.15	637.74
CV (%)	32.0218	50.4037	55.9119	46.11

Material **FG-coll-23906-1** gave significantly the highest average seed yield 2632.8kg/ha and 1685.8kg/ha at Haramaya and Hirna, respectively. It was followed by **FG-coll-205176** (2335.8 kg/ha) at haramaya and **Fg-coll-207367** (1359.2 kg/ha) at Hirna. The lowest seed yield was obtained from **Fg-coll-239064** (698.3kg/ha) at Haramaya and from **Fg-coll-230883** (330kg/ha) at Hirna. At Fedis, **Fg-coll-212656** (985 kg/ha) gave the highest seed yield while the lowest seed yield was recorded from **Fg-coll-53085** (205 kg/ha).

Work plan

The materials will be further evaluated for yield and related traits in the upcoming cropping season

Table 12: Mean square values of ANOVA for Days to flowering, Days to maturity, Stand count, Plant height, Pods per plan, Seeds per pod , Biomass (kg ha-1) , 100 seed weight (g) ,and Seed yield (kg ha-1) of Chick pea National Variety Trial- Desi type at Haramaya in 2012 cropping season

Source of variation	DF	Days to flowering	Days to maturity	Stand count	Plant height	Pods per plant	Seeds per pod	Biomass	100 seed weight	Seed yield
Replication	3	0.352	1.1519	19.235	5.46	33.108	0.000751	27233.12	4.367	21464.70
Genotype	16	13.233**	11.909**	154.37**	61.48**	707.497**	0.03361**	2362579.15**	87.82**	715353.95**
Error	48	0.0716	0.2873	20.27	1.80	6.90	0.00060	65210.55	0.619	884.91
CV (%)		0.63	0.50	5.09	3.87	5.37	1.52	4.63	3.33	1.97

** = significant at P≤0.01, *= significant at P ≤0.05, CV = coefficient of variation

Table 13: Mean square values of ANOVA for Days to flowering, Days to maturity, Stand count, Plant height, Pods per plan, Seeds per pod , Biomass (kg ha-1) , 100 seed weight (g) ,and Seed yield (kg ha-1) of Chick pea National Variety Trial- Kabuli type at Haramaya in 2012 cropping season.

Source of variation	DF	Days to flowering	Days to maturity	Stand count	Plant height	Pods per plant	Seeds per pod	Biomass	100 seed weight	Seed yield
Replication	3	2.470	1.70	410.52	29.53	2.529	0.0064	36288.13	5.92	20582.74
Genotype	16	3.391NS	8.69NS	97.8511NS	9.615NS	83.72**	0.41386**	1284259.47**	44.687**	20582.74**
Error	48	3.376	10.096	108.123	7.736	0.298	0.003	7298.69	2.2379	1927.57
CV (%)		3.90	3.16	14.89	7.40	1.40	3.83	1.59	5.07	3.47

** = significant at P≤0.01, * = significant at P≤0.05, NS= not significant, CV = coefficient of variation

3. New Projects Proposed for 2013

Background

The 2013/14 research activities include those projects that were promoted from preliminary observation nursery in 2012 and that has been sent from EIAR for 2013/14 main cropping season research. Accordingly, sixteen faba bean and field varieties and twenty five genotypes of fenugreek, that have shown superior performance as compared to their standard checks have been identified from the completed observation nursery of faba bean, field pea and fenugreek in the 2012/13 cropping season and sixteen verities of Lentil from DARC are under progress at four locations. The general and specific objectives of activities as well as their separate methodologies with further information are presented as following.

Objectives

General Objective

Increasing highland pulses productivity and production and thereby contribute to enhanced food security and poverty reduction in the eastern part of the country.

Specific objective

To develop and promote high yielding, stress tolerant and widely/specifically adapted faba bean, field pea, Lentil and fenugreek varieties with desirable agronomic and quality traits for western and eastern Hararghe.

Methodology

Activity 1: Faba bean Regional Preliminary Variety Trial

Sixteen faba bean genotypes, which promoted from faba bean observation nursery, will be evaluated along with their standard (Gachena) at Haramaya in the 2013/14 main cropping season. The experimental design will be RCB with 4 replications with plot size of 4 rows of 4m long with 40 and 10 cm inter and intra row spacing. The middle two harvestable rows will be used for data collection. Materials found to be superior to the standard check in grain yield, reaction to diseases and other important traits will be advanced to faba bean regional variety trial

Responsible persons: Nano Alemu, Mekuanent Belay, Alem Eshetu, Birhanu Lelisa, Sisay Zargew and Baker Challo

Duration: one year (2013/14)

Expected output: at least eight candidate accessions will be identified for verification by 2014

Budget: 20,000 Birr

Activity-2: Field pea Regional Preliminary Variety Trial

Sixteen field pea genotypes which promoted from observation nursery will be evaluated along with their standard check (Meti) in RCB with 4 replications at Haramaya in the

2013/14 main cropping season for one year. The plot size will be four raw of 2m long with 20cm inter row spacing. The middle 2 harvestable rows will be used for data collection. Materials found to be superior to the standard check in grain yield, reaction to diseases and other important traits will be advanced to the field pea regional variety trial by 2014.

Responsible persons: Nano Alemu, Mekuanent Belay, Alem Eshetu, Birhanu Lelisa, Sisay Zargew and Baker Challo

Duration: one year (2013/14)

Expected output: at least eight candidate accessions will be identified for verification by 2014

Budget: 20,000 Birr

Activity 3: Fenugreek Regional Preliminary Variety Trial

Twenty five different fenugreek genotypes promoted from the fenugreek observation nursery will be evaluated along with the standard check (Chala). The experiment will be laid in RCB design with 4 replications at three loctions (Haramaya, Hirna and fedis) in the 2013/14 main cropping season for one year. The plot size will be 4 raw of 4m long 20cm inter row spacing and the middle two harvestable rows will be used for data collection. Materials found to be superior to the standard check in grain yield, reaction to diseases and other important traits will be advanced to fenugreek regional variety trial by 2014

Responsible persons: Nano Alemu, Mekuanent Belay, Alem Eshetu, Birhanu Lelisa, Sisay Zargew and Baker Challo

Duration: one year (2013/14)

Expected output: at least fifteen candidate genotypes will be identified for verification by 2014

Budget: 40,000 Birr

Activity 4. Lentil National Variety Trial

Sixteen genotypes from Debre Zeit Agricultural Research Center will be evaluated along with standard checks (**Alemaya** & **Derash**) at Haramaya for two years (2013 and 2014) cropping season. Field plot techniques will be carried out as per the standard procedures. Data will be collected on all pertinent agronomic and diseases traits, and actual field performance evaluation every year.

Responsible persons: Nano Alemu, Mekuanent Belay, Alem Eshetu, Birhanu Lelisa, Sisay Zargew and Baker Challo

Duration: one year (2013/14)

Expected output: at least two candidate varieties will be identified for verification by 2014

Budget: 20,000 Birr

Budget source: EIAR (Ethiopian Institute of Agricultural Research)

Acknowledgment

These trials were conducted by the financial support we obtained from Ethiopian Institute of Agricultural Research and Haramaya University. We would like to extend sincere thanks to the Ethiopian Institute of Agricultural Research and Haramaya University for their genuine support.

We would also like to express our sincere appreciation and gratitude to the Office of Vice President for Research Affairs of the Haramaya University for their unreserved support while executing the field experiment at different locations.

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Common Bean Variety Development Activities In Eastern Ethiopia: Completed, Ongoing And New Activities In 2012

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Abstract: *Four sets of regional variety trials, representing four different market classes (Large Red Seeded Bean, Red Mottled Seeded Bean, Speckled Bean and Small Red Seeded Bean), advanced from pre-reginal variety trials in 2010 were conducted at four locations (Haramaya, Hirna, Babile, and Fedis) for two years (2011- 2012) in eastern and western Ethiopia using RCBD design with three replications. In the Large Red Seeded Bean regional variety trial, the location and year main effects as well as their interaction were very highly significant ($P<0.001$) for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location x variety and year x variety effect was very highly significant, except for yield and pods per plant. After final screening for cooking quality related traits in the laboratory, LyAMNGO-85 and ECAB-0267 were recommended for verification and release in 2013/14. Similarly, in Small Red Seeded Bean regional variety trial, combined analysis of variance over locations and years has shown very highly significant differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location and year main effects as well as their interaction were also very highly significant for most of these traits. The location x variety effect was highly significant, except for pods per plant. Similarly, the year x variety effect was highly significant, except for pods per plant, seeds per pod and plant height. The year x variety x year interaction effect was also very highly significant for days to flowering, days to maturity; significant ($P<0.05$) for plant height and 100 seed weight; and non significant ($P>0.05$) for pods per plant, seeds per pod and yield. Based on yield, disease resistance, agronomic performance and cooking quality, NM-12643-1 and SER-118 were recommended for verification and release in 2013/14.In the Red Mottled Bean Regional Variety Trial (RMBRVT), combined analyses over locations and years have shown very highly significant differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The main effects of location and year as well as their interaction were also very highly significant for all measured traits except seeds per pod which was non significant. The location x variety interaction effect was also very highly significant for all measured traits except for seeds per pod. Similarly, the year x variety effect was very highly significant; for yield, days to flowering, days to maturity,100 seed weight and plant height; significant for pods per plant , and non-significant for seeds per pod. The location x year x variety three - way interaction was very highly significant for yield, days to flowering, days to maturity, pods per plant and 100 seed weight($P<0.001$), highly significant for plant height($P<0.01$), and non significant($P>0.05$) for number of seeds per pod. ECAB 0043 and SAB 662 were recommended for verification.In the Speckled Bean Regional Variety Trial (SBRVT), combined analysis of variance over locations and years has shown very highly significant* *differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location and year main effects as well as their interaction were also very highly significant for most of these traits. The location x variety effect was very highly significant, for days to flowering, days to maturity, 100 seed weight and yield, and significant for plant height, and non significant for pods per plant and seeds per pod. Similarly, the year x variety effect was highly significant, except for seeds per pod and plant height. Based on the overall agronomic performance, disease resistance and cooking quality, SAB 626 and SAB 686 were recommended for verification and release in 2013/14.*

Introduction

Common bean is an important part of human diet in Ethiopia. It is among the most important food legumes produced in the country, which has been cultivated as a field crop for a very long time. Common bean stands out among the pulses and is also known as "the poor man's meat" due to its high protein content, which compensates for the deficiency that could have occurred in a population with low income (Teshome and Kirkby, 1990).

Common bean is a good source of energy and provides folic acid, dietary fibre, and complex carbohydrates (Platt, 1962, Cited in Edje *et al.*, 1980). Common bean protein is high in lysine, which is relatively deficient in maize, cassava, and rice, making it a good complement to these staples in the diet. Consumption of common bean is high mostly because it is relatively inexpensive compared to meat. For the poor, common bean plays a strategic role in alleviating malnutrition.

Regular consumption of common bean and other pulses is now promoted by health organizations because it reduces the risk of diseases such as cancer, diabetes, or coronary heart diseases. This is because common bean is low in fat and is cholesterol free. It is also an appetite suppressant because it digests slowly and causes a low sustained increase in blood sugar. Researchers have found that common bean can delay the reappearance of hunger for several hours, enhancing weight-loss programs (Leterme, 2002 in Leterme and Munoz, 2002).

Although common bean is largely grown in Ethiopia, the national average yield is low, ranging from 1.434 tone ha^{-1} (CSA, 2011) which is far below the corresponding yield recorded at research sites (2.5 – 3 tones ha^{-1}) using improved varieties (EPPA, 2004). The low national mean yield observed for common bean could be attributed to various constraints related to low adoption of improved agricultural technologies, drought, and lack of improved varieties, poor cultural practices, disease, and environmental degradation (Legese *et al.*, 2006).

Common bean is also produced in a range of crop systems. About 74 percent of common bean area in Eastern Africa (Wortmann *et al.*,1998) are grown under multiple cropping systems, mainly in association with maize, banana, roots and tubers, sorghum or millet (Allen and Edje, 1990). In Ethiopia except the white canning beans, which account for about 50 percent of the total, are grown as a sole crop while others are grown in association with maize and sorghum.

In Hararghe, common bean is widely grown under intercropping systems with sorghum and maize in diverse agro-ecologies, usually two seasons in a year (*i.e*., *belg* and *meher).*
When rains come late, the risk of growing maize increases and farmers replace maize and sorghum with beans (Legesse *et al*., 2006), implying that the area under beans is likely to be higher when there is rainfall failure in Ethiopia.

The major bean market classes preferred in the region are small reds, large seeded beans, red mottled beans, and white pea (navy) beans, where the latter is mainly produced for market. In addition to its protein source common bean generates foreign currency and becomes one of the major export items among the pulses.

The lowland pulse research program used to have the mandate of developing technologies in common bean, cowpea, pigeon pea and mung bean for eastern Ethiopia. As 95% of the national lowland pulse research focused on common bean, the Lowland Pulse Research Program of Haramaya University is also focused on the same crop even though we are conducting trials on cowpea, Pigeon pea and mung bean in collaboration with Melkasa Agricultural Research Center.

Completed Activities

Four sets of regional variety trials, representing four different market classes (Large Red Seeded Bean, Small Red Seeded Bean, Red Mottled Seeded Bean and Speckled Bean), were conducted at four locations (Haramaya, Hirna, Babile, and Fedis) for two years (2011- 2012) in eastern Ethiopia. All of these were completed in 2012 and the results of each trial are separately presented in the following sections.

Large Red Seeded Bean Regional Variety Trial (RVT)

Materials and methods

Ten large seeded bean genotypes advanced from pre-regional variety trial in 2010 have been tested along with standard check (**MONTCALM /ACOS RED (Red kidney)**) at four locations for two years (2011 to 2012). Randomized Complete Block Design (RCBD) with three replications was used at each location. The plots consisted of four rows of four meter length with inter- and intra-row spacing of 40 cm and 10 cm, respectively. The experimental fields were managed as per the standard field plot techniques, and standard agronomic data and disease severity scores were recorded at each location in each year.

At pod filling and physiological maturity stages, field performance evaluations have been conducted to assess the actual field performances of the genotypes, in addition to yield data. Yield data were adjusted to 10% seed moisture basis in order to offset weight variations due to varying moisture contents. The data were analyzed with Proc GLM procedure of the SAS 9.1 software. Combined analyses of variance over environments were performed after homogeneity of error variances were confirmed using Bartlett's test.

Results and Recommendations

The location and year main effects as well as their interaction were also very highly significant ($P<0.001$) for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location x variety and year x variety effect was very highly significant, except for yield and pods per plant**.**

Table 1: F-values and their significance levels for the various sources of variations in combined ANOVA of large red seed bean regional variety trial (LRSBRVT)

Source of variation	df	F-values						
		Days to flowering	Days to maturity	Pods per plant	Seeds per pod	Plant height(cm)	100 seed weight(g)	Yield(kg/ha)
Location	3	51.01***	905.75***	124***	106.46***	182.83***	153.4***	279.32***
Rep(Location)	8	0.53 NS	0.81 NS	0.51NS	1.71NS	2.15*	0.95NS	0.64NS
Year	1	24.95***	875.14***	45.52***	12.89***	7.3**	61.22***	8.66**
Location*Year	3	79.14***	41.63***	11.9***	40.8***	6.31***	37.53***	7.13***
Year*Rep(Loc)	8	1.85 NS	0.35 NS	0.87NS	1.89NS	0.6NS	0.61NS	1.16NS
Genotype	9	29.32***	48.64***	3**	6.67***	6.91***	154.4***	1.6NS
Location*Genotype	27	3.60***	4.02***	1.26NS	3.13***	3.93***	4.6***	0.79NS
Year*Genotype	9	4.11***	7.49***	0.76NS	2.85**	0.4NS	8.61***	1.16NS

Location*Year*Genotype	27	1.08 NS	3.2***	0.76NS	3.21***	0.83NS	2.62***	0.88NS
Error	144							
CV(%)		3.82	1.91	23.21	13.56	10.48	3.75	24.82

*, **, ***= significant at 5%, 1%, and 0.1% levels, respectively; ns = non-significant (P>0.05)

Yield performances of the genotypes across environments

The mean yield at each location (averaged over years), and the overall mean across years and locations is shown in **Table 2** below**.** All the tested genotypes have shown better performances than **Red Kidney**, the standard check, based on yield data.

Table 2: Mean grain yield (kg/ha) of genotypes in large red seeded bean regional variety trial at four locations over two years (2011 – 2012)

	Mean yield(kg/ha)				Over all mean
Genotype	Haramaya	Hirna	Babile	Fedis	
DVA-8	2097.27	2827.73	1406.73	745.24	1769.24
OBO-A-075	2091.47	2626.05	1113.52	776.34	1651.84
625-BRB-183	2321.65	3005.61	1295.19	673.71	1824.04
AFR-728	2360.14	2664.72	1235.44	908.05	1792.09
LyAMNGO-85	2517.66	2851.02	1391.45	796.04	1889.04
725-INIA-404	2046.2	2966.49	1189.11	842.04	1760.96
ECAB-0242	2605.4	2800.83	1125.53	765.79	1824.39
ECAB-0267	2713.68	2803.43	1043.35	807.83	1842.07
ECAB-0204	2442.42	2789.38	935.8	700.51	1717.03
Red kidney(st. check)	2006.28	2431.41	874.11	647.1	1489.72

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Field performance evaluation

Based on the field evaluation**,** LyAMNGO-85 was the best in overall performance under all environments, followed by ECAB-0267**,** and **625-BRB-183.** These three genotypes were almost free from all the major bean diseases common in Hararghe- CBB, rust, anthracnose, ALS, halo blight, web blight, and root rots; even at Hirna site, which is highly conducive for disease development. In addition, LyAMNGO-85 and ECAB-0267 showed a very good pod clearance. On the other end of the field performance ranking were the genotypes **ECAB-**

0204, ECAB-0242, 625-BRB-183 and 725-INIA-404, which were found to be susceptible to CBB at all locations in all years (data not shown).

The genotype AFR-728 had shown high yield in the moisture stress areas (Fedis and Babile) which might be associated with its early flowering and maturing ability as compared with the other tested genotypes. In addition, it showed high in 100 seed weight. It is also resistant to the major common bean diseases in the region. Therefore, this genotype can be used in crossing programs to improve disease resistance of the released varieties. Therefore, this genotypes may be included in the short rainy season (*Belg*) trial due to its early maturity. The genotype DVA-8 performed well at some locations in some years, especially at the moisture stressed sites (Babile) and resistance to CBB. Similarly, despite their disease susceptibility, **ECAB-0242** has performed well at some locations in some years.

Table 3: **Summary of agronomic characters of** Large Red Seeded Bean **genotypes regional variety trial (averages of 2 years x 4 locations x 3 replications)**

Genotype	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 sw (g)
DVA-8	46.29cd	92.17cd	37.18ab	8.25ab	3.75c	42.89d
OBO-A-075	46.5cd	91.75d	38.12a	7.83ab	3.63c	46.22b
625-BRB-183	45.42de	92.67bcd	36.66ab	8.46a	3.79bc	37.73g
AFR-728	44.25e	89.83e	34.52b	7.29ab	3.79bc	52.7a
LyAMNGO-85	47.08bc	93.38bc	37.97a	7.83ab	3.92abc	44.16c
725-INIA-404	45.92cd	94.1b	38.46a	8.4a	3.63c	41.3ef
ECAB-0242	45.5de	92.92bcd	34b	7.83ab	4.38a	41.89de
ECAB-0267	49.29a	95.83a	38.83a	8.54a	3.96abc	42.46de
ECAB-0204	48.33ab	95.88a	33.88b	8.96a	4.25ab	40.34f
Red kidney (st. check)	42.35f	87.61f	34.09b	6.7b	4.35a	46.9b

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Recommendation

After final screening for cooking quality related traits in the laboratory, **LyAMNGO-85, ECAB-0267** were recommended for verification and release in 2013/14. The variety release application has been submitted to the national variety release committee (NVRC) in May 2013. Therefore, these candidate varieties will be planted on verification plots in July 2013 and will be evaluated by the technical team to be assigned by the NVRC by September/October, 2013.

Small Red Seeded Bean Regional Variety Trial (SRSBRVT)

Materials and methods

Thirteen small seeded bean genotypes advanced from pre-regional variety trial in 2010 have been tested along with standard check (Dursitu) at four locations for two years (2011 to 2012). Randomized Complete Block Design (RCBD) with three replications was used at each location. The plots consisted of four rows of four meter length with inter- and intra-row spacing of 40 cm and 10 cm, respectively. The experimental fields were managed as per the standard field plot techniques, and standard agronomic data and disease severity scores were recorded at each location in each year.

At pod filling and physiological maturity stages, field performance evaluations have been conducted to assess the actual field performances of the genotypes, in addition to yield data. Yield data were adjusted to 10% seed moisture basis in order to offset weight variations due to varying moisture contents. The data were analyzed with Proc GLM procedure of the SAS 9.1 software. Combined analyses of variance over environments were performed after homogeneity of error variances were confirmed using Bartlett's test.

Results and recommendations

Combined analysis of variance over locations and years has shown very highly significant differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location and year main effects as well as their interaction were also very highly significant ($P<0.001$) for most of these traits. The location x variety effect was highly significant, except for pods per plant. Similarly, the year x variety effect was highly significant, except for pods per plant, seeds per pod and plant height. The year x variety x year interaction effect was also very highly significant ($P<0.001$) for days to flowering, days to maturity; significant ($P<0.05$) for plant height and 100 seed weight; and non significant ($P>0.05$) for pods per plant, seeds per pod and yield**.**

Table 4: F-values and their significance levels for the various sources of variations in combined ANOVA of small red seeded regional variety trial (SRSBRVT)

Sources of Variation	F-Values							
	Df	Days to flowering	Days to maturity	Plant height(cm)	Pods per plant	Seeds per pod	100 seed weight(g)	Yield(kg/ha)
Location	3	50.95***	2601***	10.71***	326.89***	47.13***	197.16***	1102.6***
Rep(Location)	8	1.32NS	1NS	9.09***	3.38***	2.38*	2.61**	1.53NS
Year	1	243.49***	334.4***	10.71**	10.36**	0.15NS	165.58***	0.94NS
Year*Location	3	197.88***	203.58***	10.71***	9.45***	4.74**	43.18***	94.63***
Year*rep(Location)	8	0.77NS	1.15NS	9.09***	2.09*	1.31NS	1.49NS	3.13**
Genotype	12	29.95***	37.49***	1.55NS	3.38***	3.68***	86.86***	7.83***
Location*Genotype	36	4.93***	4.61***	1.55*	0.86NS	1.91**	2.49***	2.43***
Year*Genotype	12	3.83***	3.91***	1.55NS	0.51 NS	0.81NS	1.88*	3.22***
Year*Loc*Genotype	36	3.66***	2.64***	1.55*	0.51 NS	0.57NS	1.52*	1.25NS
Error	192							
CV (%)		2.9	1.57	1.15	21.76	11.72	4.25	15.34

*, **, ***= significant at 5%, 1%, and 0.1% levels, respectively; ns = non-significant (P>0.05)

Yield performances of the genotypes across environments

The mean yield at each location (averaged over years), and the overall mean across years and locations is shown in **Table 5** below**.** All the tested genotypes have shown better performances than **Dursitu**, the standard check, based on yield data except SER 95.

Table 5. Mean grain yield (kg/ha) of genotypes in small red seeded bean regional variety trial at four locations over two years (2011 – 2012)

	Mean yield(kg/ha)				**Over all mean**
Genotype	**Haramaya**	**Hirna**	**Babile**	**Fedis**	
RCB—592	3463.23	3954.74	815.07	1015.67	2312.18bcde
NM-12643-1	3487.48	3732.61	1471.15	1398.44	2522.42a
SER 48	3260.90	3499.06	1606.61	770.21	2284.19cde
SER 118	3362.75	3937.11	1358.29	1340.52	2499.67ab
SER 119	3510.75	3546.19	1425.94	1129.54	2403.11abc
SER 125	3131.23	3588.37	1037.24	746.13	2125.74efg
SER 128	3158.82	3343.10	1275.57	962.32	2184.95defg
SER 180	3031.85	3135.00	1180.35	911.87	2064.77g
SER 194	3109.61	3819.21	1050.76	1083.91	2265.87cdef
SER 78	2906.13	3286.52	1319.38	824.55	2084.14fg
SER 176	3035.76	3676.90	1115.83	1542.66	2342.79abcd
SER 95	2464.65	2935.79	1193.79	798.33	1848.14h
Dursitu(St. Check)	2816.12	3405.94	1079.61	832.14	2033.45gh

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Field performance evaluation

Based on the field evaluation**,** NM-12643-1 was the best in overall performance under all environments, followed by SER 118 and **SER 119.** These three genotypes were almost free from all the major bean diseases common in Hararghe-, rust, anthracnose, angular leaf spot (ALS), common bacterial blight (CBB), halo blight, web blight, and root rots; even at Hirna site, which is highly conducive for disease development. Hirna may be considered as a '*natural screening laboratory for bean diseases'* based on close observations made over the last few years. On the other end of the field performance ranking were the genotypes, SER-78, RCB-595, and SER-180**,** which were found to be susceptible to CBB at all locations in all years and moderately susceptible to halo blight(data not shown).

Table 6: The mean values of some agronomic characters across all environments

Genotype	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 sw (g)
RCB--592	51.92a	98.38a	33.75d	13.17ab	5.46a	20.05h
NM-12643-1	50.75b	97.29b	34.1a	13.9a	5.04bc	21.73g
SER 48	47.54de	94.25de	33.89abcd	11.25cde	4.88bcd	25.88ab
SER 118	48.29cd	94.96cd	33.85bcd	11.67cde	5.08b	23.22f
SER 119	48.63c	95.13c	34abc	10.79de	4.88bcd	25.11cd
SER 125	47.33e	94.46cde	33.79cd	10.25e	4.71de	25.64bc
SER 128	47.29e	94.21de	34.058ab	11.88bcd	4.54e	24.88d
SER 180	47.46e	94.08e	33.93abcd	11.79bcd	4.96bcd	24.08e
SER 194	47.13e	93.75e	33.98abc	10.92cde	4.75cde	24.26e
SER 78	46.08f	91.38f	33.94abcd	11.92bcd	5.17ab	22.65f
SER 176	47.88cde	94.58cde	33.95abcd	11.83bcd	4.92bcd	26.44a
SER 95	47.92cde	91.88f	33.97abcd	12.29bc	5bcd	21.38g
Dursitu(St. Check)	47.58de	93.83e	33.86bcd	11.75bcd	5.04bc	23.04f

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Despite its disease susceptibility, the genotype SER -119 and SER-176, have showed reasonably high yield across locations and years. In addition, SER-176 showed high hundred seed weight. Similarly, despite its disease susceptibility, **RCB-592 at Hirna and Haramaya**, Showed high yield, pods per plant and seeds per pod. However, this genotype is late in days to flowering and maturity that makes it susceptible to diseases which fail to escape the disease which occurs late in the growing season.

Recommendation

After final screening for cooking quality related traits in the laboratory, **NM-12643-1** and **SER-118** were recommended for verification and release in 2013/14. The variety release application has been submitted to the national variety release committee (NVRC) in May

2013. Therefore, these candidate varieties will be planted on verification plots in 2013 and will be evaluated by the technical team to be assigned by the NVRC by September/October, 2013.

Red Mottled Bean Regional Variety Trial (RMBRVT)

Materials and methods

Ten red mottled bean genotypes advanced from pre-regional variety trial in 2010 have been evaluated along with standard check (ECAB0056) at each of the four locations for two years (2011- 2012) in RCBD with three replications. Field plot techniques, field performance evaluation, data collection, and data analyses were conducted in the same way as described under **2.1.1** above.

Results and recommendations

Combined analyses over locations and years have shown very highly significant differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The main effects of location and year as well as their interaction were also very highly significant ($P<0.001$) for all measured traits except seeds per pod which was non- significant ($P>0.05$).

Table 7: F-values and their significance levels for the various sources of variations in combined ANOVA o large red seeded bean regional variety trial (LRSBRVT)

Sources of Variation	F-Values							
	df	Days to flowering	Days to maturity	Plant height(cm)	Pods per plant	Seeds per pod	100 seed weight(g)	Yield(kg/ha)
Location	3	657.20***	1935.26***	647.49***	286.78***	15.67***	151.93***	851.74***
Rep(Location)	8	2.83**	1.08NS	1.45NS	0.81NS	0.31NS	1.03NS	1.55NS
Year	1	273.80***	531.07***	182.77***	5.35*	0.91NS	197.49***	6.83**
Year*Location	3	199.89***	611.09***	67.78***	26.70***	6.07***	33.72***	77.17***
Year*rep(Location)	8	0.78NS	1.63NS	3.15**	0.55NS	1.67NS	0.27NS	0.60NS
Genotype	10	73.44***	35.01***	9.79***	10.79***	3.85***	179.56***	4.71***
Location*Genotype	30	13.24***	4.31***	3.18***	4.19***	1.02NS	4.05***	3.36***
Year*Genotype	10	2.64**	4.73***	2.88**	1.89*	1.09NS	17.27***	3.46***
Year*Loc*Genotype	30	4.47 ***	2.69***	2.19**	2.54***	1.05NS	6.97***	2.53***
Error	160							
CV(%)		2.05	1.63	9.51	15.38	15.96	4.47	14.84

*, **, ***= significant at 5%, 1%, and 0.1% levels, respectively; ns = non-significant (P>0.05)

The location x variety interaction effect was also very highly significant for all measured traits except for seeds per pod. Similarly, the year x variety effect was very highly significant (P<0.001); for yield, days to flowering, days to maturity,100 seed weight and plant height significant for pods per plant (P<0.05), and non-significant for seeds per pod. The location x year x variety three - way interaction was very highly significant for yield, days to flowering, days to maturity, pods per plant and 100 seed weight(P<0.001), highly significant for plant height(P<0.01), and non significant(P>0.05) for number of seeds per pod (**Table 7**).

2.3.2.1. Yield performances of genotypes across environments

The genotypes **SAB 662 and ECAB 0043** had better average yield performances than the standard checks as well as the other genotypes in the trial.

Table 8: Mean grain yield (kg/ha) of genotypes in red mottled bean regional variety trial at four locations over two years (2011 – 2012)

	Mean yield(kg/ha)				**Over all mean**
Genotype	**Haramaya**	**Hirna**	**Babile**	**Fedis**	
SAB 648	2437.52	2862.76	944.31	758.19	1750.7bc
SAB 650	2773.87	2954.56	1007.14	901.75	1909.33ab
SAB 658	2722.02	3130.15	969.61	737.33	1889.78abc
SAB 661	2515.91	3181.15	836.95	820.85	1838.71abc
SAB 662	**2844.673**	**3463.18**	**1226.17**	**1131.684**	**2166.43a**
ECAB 0043	**2774.35**	**2903.28**	**1021.44**	**1318.58**	**2041.41a**
ECAB 0047	1961.03	2735.02	1161.63	751.34	1652.26c
ECAB 0019	2334.75	3048.16	873.71	771.79	1760.69bc
ECAB 0097	2654.85	3033.50	1110.69	986.78	1977.71ab
ECAB 0056 (st. Check)	3226.81	2809.73	985.47	963.06	1981.32ab

*Average of 2years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Field performances evaluation

The actual field performances of the genotypes tested in this trial were evaluated at all locations in all years based on plant vigour and uniformity, pod load, growth habit and pod clearance, disease incidence and severity, and maturity duration. Accordingly, the genotypes **SAB 662**, **ECAB 0043** and **ECAB 0097** have consistently shown excellent field performances at all locations in all seasons. Besides, these genotypes are resistant to the major bean diseases prevalent in the region, have up-right growth habit with high pod clearance, and possess the highly preferred red mottled seed types, all of which are the main farmers' variety selection criteria in Hararghe.

The genotypes SAB 648, SAB 650, SAB 658, SAB 661 and **SAB 662** were early in days to flowering and maturity. However, SAB-648, SAB-650, SAB 658 and SAB 661were susceptible to CBB and halo blight. These genotypes can be used in the short rainy season (Belg) where the disease severity is low and may be used in crossing programs to improve their disease resistance in the future.

The genotypes **ECAB 0043, ECAB 0019, and ECAB 0047** were included from the 2011 verification trial for further testing, due to their many desirable characteristics. Among these **ECAB 0043** is recommended for verification while **ECAB 0019 and ECAB 0047** were found to be susceptible to CBB and halo blight.

Table 9: Summary of agronomic characters of Red Mottled Bean genotypes in Red Mottled Bean regional variety trial (averages of 2 years x 4 locations x 3 replications)

Genotype	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 sw (g)
SAB 648	40.63f	87.88f	34.05c	8.96ab	4.42abc	46.84d
SAB 650	42.042d	90.38e	35.19c	7.58bc	4.08bcd	48.84c
SAB 658	42.25d	91.63d	36.7bc	7.58bc	4.042bcd	54.28b
SAB 661	41.17ef	90.42e	35.65c	8bc	3.67d	56.30a
SAB 662	41.7de	90.87de	35.38c	7.26c	4.22abcd	57.34a
ECAB 0043	49.58a	98.042a	37.05abc	8.71bc	4.38abc	45.39e
ECAB 0047	48.88ab	98a	39.70a	10.13a	3.92cd	36.5f
ECAB 0019	47.83c	96.21b	35.61c	8.63bc	4.79a	37.08f

ECAB 0097	48.04c	94.71c	38.84ab	8.21bc	4.7083a	36.09f
ECAB 0056(St. Check)	48.5bc	96.83b	36.55bc	8.38bc	4.5417ab	45.76de

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Generally, clear positive associations were observed between yield data and the actual field performances of the genotypes. As shown in **Table 9**, the genotypes that have shown excellent field performances were also better than the checks in grain yield.

Recommendation

After final discrimination by cooking quality test in the laboratory, **ECAB 0043** and **SAB 662** were recommended for verification, and the variety release application has been submitted to the National Variety Release Committee (NVRC). Thus, these genotypes will be verified on farmers' field in the 2013 planting season, and would be evaluated by the technical team of the national variety release committee in September/October 2013.

Speckled Bean Regional Variety Trial (SBRVT)

Materials and methods

Ten speckled bean genotypes advanced from pre-regional variety trial in 2010 have been tested along with standard check (Cranscope) at four locations for three years (2011 to 2012). Randomized Complete Block Design (RCBD) with three replications was used at each location. The plots consisted of four rows of four meter length with inter- and intra-row spacing of 40 cm and 10 cm, respectively. The experimental fields were managed as per the standard field plot techniques, and standard agronomic data and disease severity scores were recorded at each location in each year.

At pod filling and physiological maturity stages, field performance evaluations have been conducted to assess the actual field performances of the genotypes, in addition to yield data. Yield data were adjusted to 10% seed moisture basis in order to offset weight variations due to varying moisture contents. The data were analyzed with Proc GLM procedure of the SAS 9.1 software. Combined analyses of variance over environments were performed after homogeneity of error variances were confirmed using Bartlett's test.

Results and recommendations

Combined analysis of variance over locations and years has shown very highly significant differences among genotypes for grain yield, days to flowering, days to maturity, pods per plant, seeds per pod, plant height and 100 seed weight. The location and year main effects as well as their interaction were also very highly significant ($P<0.001$) for most of these traits. The location x variety effect was very highly significant, for days to flowering, days to maturity, 100 seed weight and yield, and significant for plant height, and non significant for pods per plant and seeds per pod. Similarly, the year x variety effect was highly significant, except for seeds per pod and plant height.

Table 10: F-values and their significance levels for the various sources of variations in combined ANOVA for speckled bean regional variety trial (SBRVT)

Source of variation	df	F-values						
		Days to flowering	Days to maturity	Pods per plant	Seeds per pod	Plant height(cm)	100 seed weight(g)	Yield(kg/ha)
Location	3	89.19***	906.38***	125.85***	19.18***	146.75***	402.32***	1131.23***
Rep(Location)	8	0.38 NS	0.67NS	0.88NS	1.78NS	1.14	1.87 NS	1.31NS
Year	1	185.23***	597.31***	6.37**	1.90NS	8.22**	3.69 NS	62.08***
Location*Year	3	40.72***	31.19***	5.53***	0.94NS	2.09NS	95.98***	41.33***
Year*Rep(Loc)	8	0.65 NS	0.36NS	0.47NS	1.62NS	0.46NS	2.38*	1.42NS
Genotype	9	11.21***	14.57***	1.77NS	2.98**	1.63NS	38.10***	16.25***
Location*Genotype	27	3.38***	2.45***	0.76NS	1.18NS	1.63*	23.70***	3.86***
Year*Genotype	9	4.81***	6.10***	3.02**	0.88NS	0.70NS	34.03***	5.66***
Location*Year*Genotype	27	2.75***	1.62*	1.48NS	0.88NS	0.54NS	19.66***	3.66***
Error	144							
CV (%)		4.84	2.76	26.71	13.81	10.48	3.76	13.47

*, **, ***= significant at 5%, 1%, and 0.1% levels, respectively; ns = non-significant (P>0.05)

__Yield performances of the genotypes across environments__

The mean yield at each location (averaged over years), and the overall mean across years and locations is shown in **Table 11** below**.** The genotypes **SAB 626, SAB 686 and SAB 663** have shown better performances than **Cranscope**, the standard check, based on mean yield data. All the tested genotypes are early maturing and better seed size as compared to the standard check.

Table 11: Mean grain yield (kg/ha) of genotypes in speckled bean regional variety trial at four locations over two years (2011 – 2012)

	Mean yield(kg/ha)				Over all mean
Genotype	Haramaya	Hirna	Babile	Fedis	Over all mean
SAB 626	2837.10	2738.74	1117.36	903.97	1899.29a
SAB 681	2443.98	2857.56	976.13	774.74	1579.22cd
SAB 686	2443.98	2857.56	976.13	774.74	1763.1b
SAB 693	1940.11	2551.40	982.72	636.07	1527.57d
SAB 694	2127.51	2617.21	847.14	631.72	1555.9cd
SAB 701	1280.73	2284.06	895.41	438.32	1224.63e
SAB 690	2330.87	2582.52	911.12	769.77	1648.57bcd
SAB 632	2346.00	2698.98	916.08	663.53	1656.15bc
SAB 633	2580.46	2643.36	962.97	776.89	1740.92b
Cranscope (st. check)	2283.77	2894.14	911.44	850.71	1718.34b

*Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other.

Field performance evaluation

Based on field evaluation**, SAB 626** was the best in overall performance under all environments, followed by **SAB 686** and **SAB 663.** These three genotypes were almost free from all of the major bean diseases common in Hararghe- CBB, rust, anthracnose, ALS, halo blight, web blight, and root rots; even at Hirna site. On the other end of the field performance ranking were the genotypes **SAB**

701, SAB 693 and SAB 681, which were found to be highly susceptible to CBB at all locations in all years (data not shown).

Table 12: Summary of agronomic characters of Speckled Bean genotypes in Speckled Bean regional variety trial (averages of 2 years x 4 locations x 3 replications)

Genotype	Days to flowering	Days to maturity	Plant height(cm)	Pods per plant	Seeds per pod	100 seed weight(g)
SAB 626	41.88d	86.71ef	36.53abc	7.79ab	4.75a	44.49e
SAB 681	42.92bcd	88.04de	35.82abc	7.46b	4.46abcd	50.28a
SAB 686	42.13d	86.71ef	35.70abc	6.92b	4.7ab	47.0b
SAB 693	42.29cd	88.17d	34.98c	7.33b	4.21d	46.06bcd
SAB 694	41.75d	86.58f	34.49c	7.21b	4.58abc	46.75bc
SAB 701	43.46bc	89.63b	36.66ab	7.38b	4.13d	44.66e
SAB 690	43.63b	89.54bc	37.19a	7.13b	4.29cd	45.7d
SAB 632	42.5bcd	87.96def	37.74a	7.71b	4.25cd	45.39de
SAB 633	42.63bcd	88.83bcd	35.64abc	7.83ab	4.38cd	45.91d
Cranscope(st. check)	46.63a	92.92a	36.38abc	8.88a	4.29cd	41.73f

**Average of 2 years x 3 replications (6 observations per mean), **Average of four locations x 2 years x 3 replications =24 observations per mean; means followed by the same letter are not significantly different from each other*

Recommendation

After final screening for cooking quality related traits in the laboratory, **SAB 626** and **SAB 686** were recommended for verification and release in 2013/14. The variety release application has been submitted to the national variety release committee (NVRC) in May 2013. Therefore, these candidate varieties will be planted on verification plots in 2013 and will be evaluated by the technical team to be assigned by the NVRC by September/October, 2013.

Ongoing Activities

Cost-benefit Analysis of Common bean Seed Business and Gender Mainstreaming in Production and Marketing Value Chain

Initiator: Temesgen Keno

Introduction

Common bean (*Phaseolus vulgaris*) is the world's most important food legume (pulse) crop for direct human consumption. Average per capita consumption is higher in Sub-Saharan Africa with estimated 31.4 kilogram per year, sub saharan Africa (SSA) production is 25% of the global production on a total area of more than 3.5 million hectares (Katungi *et al*, 2010) mainly concentrated in east Africa, the lakes region and the highlands of Southern Africa (Schoonhoven and Voysest, 1991). Ethiopia produces two types of common beans: Canning and cooking types (Dawit and Bekele, 2005). In 2009/2010, total production of common bean in Ethiopia is estimated to be 36,289,030 tones on total of 244,013 hectares (MoA, 2010). At household level, apart from consumption (source of proteins), women in Ethiopia prefer to produce the crop on garden for its fast maturing characteristics and cash income generation (Legesse *et al.*, 2006). At national level, Ethiopia has been exporting significant amounts of common bean for long period of time contributing to the foreign exchange earnings of the country. Common bean exporting constitutes about over 85 % of export earnings from pulses **(**Negash, 2007), standing as the 3rd export commodity in Ethiopia, contributing about 9.5 % of total export value from agriculture

In general, the crop has high nutritional value for consumption, ample commercial potential for income generation and high export value for earning foreign currency at national level, the potentials of which can be used for food security and poverty reduction (Schoonhoven and Voysest, 1991). However, a number of factors do limit large production and marketing of the crop to satisfy the existing demand, scale-up more innovative and productive value-add practices.

Due to the socio-economic and infrastructural constraints, rain-fed based farming in an agronomic setting with marginal environments and low external inputs, abiotic stresses such as drought and soil fertility, production and marketing systems are not efficient. Studies are very limited to look into these issues. On top of this, studies reveal that the main obstacles to women's emancipation to play a significant role in innovative agricultural and entrepreneurial activities are structural and mostly rooted in the reproduction of unequal gender relations in the household and community. This inequality manifests itself in women's widespread inability to access and control productive resources, most notably land and agricultural services (Alderman *et al.*, 2003).

Women find it difficult to graduate from a role in subsistence agriculture to more prominent positions in market-based agriculture like initiation and operation of agricultural enterprises or agribusiness activities (WFP, 2011). In terms of participation in collective groups/initiatives, women often feel more comfortable and safe in women-only groups where there is a tacit shared understanding of women's daily and structural difficulties and grievances. This has made the focus of different gender-centered services in credit delivery, agricultural input delivery like seed and fertilizer to focus on grouping and organization of women (ALINe, 2011). In employment structure of an agrarian economy like African economy, most women are unpaid family workers. They work on the family farm, regardless of the type of crop (cash crops and subsistence crops).

Women either contribute to every stage of the production process or participate in very specific stages of the production process (e.g. weeding and threshing). Women who do engage in the production and trading of cash crops are a minority and correspond mostly to female-headed households.

In general, bean research on socio-economic aspects including production, marketing, value addition, commercialization with equity and equitability has given a very marginal emphasis as compared with breeding for pest and disease resistance, high yields and for adaptation to a wide range of environmental conditions in East and Central Africa in general and Ethiopia in particular

The Ethiopian government has recognized the situation and is currently paying attention to the improvement of agricultural marketing in order to improve the economic well being of the farming population who depend on agriculture as a source of income and employment. Development of agricultural markets contributes towards revitalizing the agricultural sector by increasing agricultural production and productivity.

Objectives of the study: This study is a systematic mainstreaming of gender in innovative common bean seed business through commercialization and value-add orientation in the production as well as marketing activities.

Specific Objectives

1) review the current state of production and marketing system of haricot bean in the study area

2) analyze the production and marketing value-chain of haricot bean in the study area

3) frame/articulate haricot bean seed business (HBSB) and assess its cost-benefit viability

4) study the importance of gender mainstreaming in the haricot bean seed business

5) explore mechanisms of strengthening the participation of women in collective marketing of haricot bean

6) analyze socio-economic constraints and opportunities that affect integration of male and female poor farmers in bean value chains and test different financial options to increase their participation in the chains

METHODOLOGY

Primary data were collected through a survey of representative households from both eastern and western Hararghe. Multistage sampling technique was employed to select the final unit of observation. A structured questionnaire was designed to elicit information on a wide variety of topics including household socioeconomic, agro-ecological and risk factors related to haricot bean production. Appropriate descriptive, linear programming and econometric methods will be applied for analysis

Activities undertaken so far

Data is collected on production, consumption, and marketing. Preliminary investigations from surveys of production and marketing were made. Pre-testing of the profit margins for business feasibility test is underway

Remaining Activities

Cost parameter estimations require farm level inputs, thus, this should be substantiated in the coming production season. Gender issues and gender-centered haricot bean seed business design require consolidating the findings of our study with best practices abroad, which requires a further literature review. Completing the report writing process is on the way. Promotion of the seed business to seed producing women cooperatives (SPWCs) will be done

New Activities Proposed for 2013

On-farm and on-station verification of candidate common bean varieties

Justification/Background

Eight common bean candidate varieties that have shown superior performance across eight environments (2 years x 4 locations) as compared to the standard checks have been identified from four sets of the completed regional variety trials- two candidate varieties from each of the four completed trials (Large Seeded Bean Regional Variety Trial; Small Red Seeded Bean Regional Variety Trial, Red Mottled Bean Regional Variety Trial, and Speckled Bean Regional Variety Trial). The identified candidate varieties were: **LyYAMINGO-85 & ECAB 00267** from large seeded bean; **NM-12643-1 & SAB** 118 from small red seeded bean**; SAB 662** & **ECAB 0043** from the red mottled, and **SAB 626** & **SAB 686** from speckled bean regional variety trial. These have been recommended for release for the major bean growing areas of Hararghe.

According to the National Variety Release policy of Ethiopia, these candidate varieties should be planted on larger verification plots; both on the research stations at which the regional variety trials were conducted and at a minimum of two on-farm sites around each research station for evaluation by the technical committee to be assigned by the National Variety Release Committee.

Objectives

1. To verify the performances observed in regional variety trials on farmers' fields
2. To obtain farmers' assessment and perception about the candidate varieties
3. To fulfill the standard formality for assessment by the national variety release committee so as to get official approval of release and registration

Materials and Methods

The candidate varieties will be planted on four research stations (Haramaya, Hirna, Babile, and Fedis), and at eight on-farm sites along with their respective standard checks in July 2013. Non-replicated plots of 10 m x 10 m will be used at each site. The cultural practices will be applied as per the standard procedures for common bean, and data will be collected on grain yield and other agronomic traits as well as on disease severity. Moreover, farmers' perceptions and preferences will be assessed. The candidate varieties will be evaluated by a technical committee to be sent by the national variety release committee in September or October 2013.

Initiator: Yonas Moges
Persons responsible:Yonas Moges, Birhanu Asfaw, Meklit Ababu, and Suleyman Abdurahman
Duration: one year (2013)
Expected Output: At least two new varieties will be released by April 2014
Budget (total): 100, 000 birr
Budget source: PABRA (Pan African Bean research Alliance) & EIAR

Speckled Bean Observation Nursery

Justification/Background

Speckled beans have large attractive seeds with white background and red or brown stripes (speckles) on the testa. They are highly preferred for local consumption, in addition to their potential. However, no variety of this market class has been released yet for Hararghe, and even at the national level, except one variety that was introduced through technology shopping and registered for production.

In 2013 cropping season, 64 genotypes of this market class will be introduced from Tanzania via PABRA through Melkasa Agricultural Research Center, Lowland Pulse Research Program. These genotypes will be evaluated at Haramaya for their agronomic traits, and disease resistance.
Objective: To develop high yielding and disease resistant speckled bean varieties with acceptable agronomic characters and culinary quality traits

Materials and methods

Sixty four genotypes will be planted along with the standard check (Cranscope) in simple lattice design with two replications at Haramaya in 2013 cropping season. Field plot techniques will be carried out as per the standard procedures. Data will be collected on all pertinent agronomic traits, and actual field performance evaluation and disease severity scoring will be conducted.

Initiator: Yonas Moges

Persons responsible:Yonas Moges, Birhanu Asfaw, Meklit Ababu, and Suleyman Abdurahman

Duration: one year (2013)

Expected Output: At least twenty five genotypes will be identified for regional preliminary variety trial by 2013

Budget (total): 10, 000 Birr

Budget source: PABRA (Pan African Bean research Alliance) & EIAR

Red Mottled Bean Observation Nursery

Justification/Background

Red Mottled beans have large seeds with red background and white spots on the testa. They are highly preferred for local consumption as well as for export to regional markets such as Kenya and Uganda.

Objective: To develop high yielding and disease resistant red mottled bean varieties with acceptable agronomic characters and culinary quality traits.

Materials and methods

Sixty four genotypes will be planted along with the standard checks (Fedis and ECAB 0056) in simple lattice design with two replications at Haramaya in 2013 cropping season. Field plot techniques will be carried out as per the standard procedures. Data will be collected on all pertinent agronomic traits, and actual field performance evaluation and disease severity scoring will be conducted.

Initiator: Yonas Moges

Persons responsible:Yonas Moges, Birhanu Asfaw, Meklit Ababu, and Suleyman Abdurahman

Duration: one year (2013)

Expected Output: At least 25 genotypes will be identified for regional preliminary variety trial by 2013

Budget (total): 10,000 Birr

Budget source: PABRA (Pan African Bean research Alliance) & EIAR

Large Red Seeded Bean Observation Nursery Trial for Drought Tolerance

Justification/Background

Drought is by far the most important constraint limiting livelihood improvements in Ethiopia (Legesse *et al*., 2006). Common bean is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enables households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse *et al*., 2006).

Thirty six large red seeded common bean genotypes introduced from Tanzania via PABRA through Melkasa Agricultural Research Center will be evaluated for their drought tolerance ability at Babile in 2013 cropping season. Babile is characterized by low and erratic rainfall. based on close observations made over the last few years.

Objective: To develop high yielding and drought tolerant large red seeded bean varieties with acceptable agronomic characters and culinary quality traits

Materials and methods

Thirty six genotypes introduced from Tanzania via PABRA through Melkassa Agricultural Research Center will be evaluated at Babile in 2013 cropping season along with the standard check in simple lattice design with two replications.

Field plot techniques will be carried out as per the standard procedures. Data will be collected on all pertinent agronomic traits, and actual field performance evaluation and disease severity scoring will be conducted at each location every year.

Initiator: Yonas Moges

Persons responsible:Yonas Moges, Birhanu Asfaw, Meklit Ababu, and Suleyman Abdurahman

Duration: One year

Expected Output: At least 12 genotypes will be identified for regional preliminary trial

Budget (total): 10, 000 Birr

Budget source: PABRA (Pan African Bean research Alliance) & EIAR

Small Red Seeded Bean Observation Nursery for Disease Resistance

Justification/Background

Common bean production is constrained by a number of bacterial, fungal and viral diseases as well as insect pests. New races of the pathogens are expected to emerge over time, especially under the changing climatic conditions. Most of the genotypes were found to be susceptible for diseases particularly in the hot spot areas like Hirna. The disease severity is higher when there is continuous moisture in the cropping season which favors pathogen development. Identification of resistant genotypes can be used as a potential candidate for crossing programs or directly released. Hirna may be considered as a '*natural screening laboratory for bean diseases'* based on close observations made over the last few years.

Objective: To develop high yielding and disease resistant small red seeded bean varieties with acceptable agronomic characters and culinary quality traits

Materials and methods

Thirty six small red seeded bean genotypes introduced from Tanzania via PABRA through Melkasa Agricultural Research Center will be planted along with the standard check (**Dursitu)** in simple lattice design with three replications at Hirna in 2013 cropping seasons. Field plot techniques will be carried out as per the standard procedures. Data will be collected on all pertinent agronomic traits, and actual field performance evaluation and disease severity scoring will be conducted at each location every year.

Initiator: Yonas Moges

Persons responsible: Yonas Moges, Birhanu Asfaw, Meklit Ababu, and Suleyman Abdurahman

Duration: one year (2013)

Expected Output: At least 12 candidate varieties will be identified for regional preliminary variety trial by 2013

Budget (total): 10, 000 Birr

Budget source: PABRA (Pan African Bean research Alliance) & EIAR

Evaluation of the Nutritional Profile of Released Common Bean Varieties

Introduction

Remarkable ranges of chemical characteristics: mineral, crude protein, crude fiber, dietary fiber and crude fat can be observed based on common bean genetic variety (Prrola *et al*., 2008). As a result, common bean serves as source of protein (16–33%, almost two to three times that of cereals) especially in developing countries where protein energy malnutrition is common (Mikanda *et al*., 2007). Common bean could be also potential source of essential minerals, such as iron, zinc, calcium, and phosphorus. Normally, the iron and zinc contents range from 18.8 – 82.4 mg of Fe/kg and 32.6 to 70.2 mg of Zn/kg (Carvalho *et al*., 2012). Furthermore, it is also an important source of fiber, minerals and vitamins, but has low content of fat and sodium (De La Fuente *et al.*, 2012).

Nutrients found in common bean are not fully accessible to the consumers due to the presence of the anti-nutritional factors. Some of these known natural constituents that affect nutritional quality of legumes are: specific enzyme activity inhibitors, haemagglutinin, saponins, tannins, anti-vitamins and phytic acid (Gashaw *et al*., 2010).

Selection of breeding lines in Ethiopia is based on agronomical performance, environmental adaptability, disease resistance and productivity potential (MOARD, 2010) with no opportunity for quality assessment until the variety is submitted for release (Bulti, 2007). In addition to these, the nutritional quality assessment must be considered along with agronomical performance of a given improved variety mentioned above.

Therefore, this work was, anticipated to characterize the functional properties and nutritional performance of 11common bean varieties released by Haramaya University. Hence, the present study will be conducted with the objective of identification of the nutrient content of released common bean varieties.

Materials and Methods

Experimental Location

The study will be conducted at Haramaya University. Chemical analysis such as Crude protein, Crude oil and antinutrition determination will be carried out at Haramaya University central laboratory. Mineral analysis will be carried out either at central laboratory or soil laboratory. However, crude fiber, ash content and moisture content will be determined at Haramaya University Food Science and Post Harvest Technology laboratory. Similarly, analysis of functional properties will be carried out at Haramaya University Food Science and Post Harvest Technology laboratory.

Experimental Materials

Eleven improved dried common beans varieties which were grown in under the same condition at Haramaya will be studied in the study.

Table 13. **List of common bean varieties grown to be used in the study**

No.	Variety	Seed color
1.	Fedis (ECAB 0060)	Red Mottled
2.	Babile (ECAB 0247)	Red
3.	Hundane (K-132)	Red Mottled
4.	Tinike (RXR- 10)	Red
5.	Hirna	Red
6.	Gofta	Cream
7.	Ayenew	Pinto
8.	Chercher	White(Navy Type)
9.	Haramaya	Cream

10.	Dursitu	Red
11.	Kufanzik	Pinto

Experimental Design

The experiment will be arranged in a factorial completely random design (CRD) with three replications. Among eleven varieties five of them selected to be processed. The nutritional composition, functional properties and physicochemical quality for raw bean are analyzed separately. The design for this study is shown as follows:

Sample preparation

Samples will be cleaned manually by removing any foreign material, damaged and broken bean, as well as shriveled and insect attacked seeds for all varieties considered in the study. The grain will be processed by soaking, dehuling and cooking. The processed samples will be dried in an oven at 50°C for about 24 hr. The dried samples are ground finely to about 42 mesh (Dejene, 2010) and will be kept in air tight container tins at 4 ^{o}C (Shimelis *et al.*, 2006) until used. The bean flours of both the raw and processed samples will be evaluated for nutritional compositions and functional properties.

Chemical analysis and functional property determination

Chemical Analysis such as moisture content, crude protein, crude fat, ash content, crude fiber analysis, total carbohydrate, calcium, iron, zinc, tannin content, and phytic acid content will be determined following appropriate methods. In addition, functional property such as bulk density, solubility and swelling power, water absorption capacity, and oil absorption capacity will be measured using the standard methods.

Statistical analysis

Data will be analyzed by the analysis of variance (ANOVA) procedures using SPSS/15.0 software for windows. Least significant differences (LSD) and Duncan multiple range test will be used for mean comparison tests. Significance will be accepted at probability of 0.05 level .

Initiator: Bulti Tesso

Persons responsible: Yonas Moges, Zelalem Teferi (MSc student), and his advisors

Duration: one year (2013)

Expected Output: The protein profile and other nutritional component of 11 released common bean varieties will be identified

Budget (total): 28, 000 birr

Budget source: PABRA (Pan African Bean research Alliance)

Collaborative National Variety Trials

In addition to the regional variety trials, we also collaborate with the national bean research program (Melkassa) in conducting the national variety trials at Haramaya and Babile. Accordingly, **16 national variety trials** have been conducted at rare and Babile in 2012, and we expect to receive **nine new** collaborative national variety trials in 2013.

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Oil Crops Research Program

General Background

Oil crops research program of Haramaya University is conducting research on groundnut (*Arachis hypogaea* L.), sesame (*Sesamum indicum* L.) and linseed (*Linum usitatissimum* L.). Under each of the crop category, there are different research components which include variety development, crop management, pest management, technology multiplication and transfer, and socioeconomic studies. Under each research components, there are also research activities that are at various stage of the research process. Some of the activities/experiments are completed, and others are either on-going, new, or reinitiated activities. The present report focuses on research activities/experiments that were reported as completed during the 2011/12 cropping season.

Groundnut Research

Completed Groundnut Research Activities

Groundnut (A*rachis hypogaea* L.) Observation Nursery

By

Amare Kebede

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Introduction

Groundnut (A*rachis hypogaea* L.) is one of the most important oilseed crops in the world. It contains edible oil and protein, and is a rich source of dietary fiber, minerals, and vitamins. In addition, it also fetches high price for the producers. Groundnut is food and cash crop in Ethiopia. Groundnut dry pod yield under small scale farming of Ethiopia is low (1.04 t ha^{-1}) and highly variable across years and locations. Among factors contributed to low yield is lack of high yielding varieties. Thus, the objective of this experiment was to develop high yielding varieties with desirable traits.

Materials and methods

Genotypes were introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and planted in 2012 main cropping season under rain fed farming at Babile and Likale, eastern Ethiopia. *BaHa-jidu* and *BaHa-gudo* were used as the standard checks. In addition, *Sartu* and *Oldhale*, local checks, were included in the experiment. The experiment was arranged in augmented block design with three replicates. Inter and intra row spacing employed were 60cm and

10cm, respectively. Dry pod yield data were collected and subjected to statistical analysis**.** Analysis of variance was carried out with GenStat 15th edition statistical package (VSN International, 2012).

Results and discussion

Twenty seven genotypes showed best performance in dry pod yield as compared to *BaHa-jidu* and *BaHa-gudo* standard checks at Babile research site (Table 1).

Table 1. Groundnut genotypes with best performance compared to standard checks at Babile research site

Genotypes	DPY (kgha^{-1})	Genotypes	DPY (kgha^{-1})
ICG – 2249	1052.48	ICGV- 86388	1713.01
ICGV- 87189	1476.68	ICGV- 93134	1161.66
GRRP- 16	1268.48	ICG- 92050	1406.26
ICGV- 86187	1271.26	ICG- 5413	1037.66
ICGV- 89328	1599.16	ICGS- 1	1391.26
ICGV- 88311	1378.96	FLORGENE	1511.26
ICGV- 86325	1099.56	ICGV- 87105	2059.56
ICGV- 87109	1510.46	PI – 337409	1143.56
ICGV- 88430	1003.41	ICGV- 88408	1168.33
BOMBA	1377.46	ICG- 2949	1071.03
ICGS- 7831	1904.76	ICGV- 86229	1302.06
ICG- 9097	1554.96	*Sartu*	1165.65
ICGV- 86462	1307.66	*BaHa-gudo*	1242.64
ICG- 8287	1063.43	*BaHa-Jidu*	1335.84
73 X 23 X Chico	1135.63	*Oldhale*	1041.60
ICGV- 86320	1203.41		
G. mean			831.6827
Root MSE			575.59
CV			69.20
SE (Test and control)			667.229

DPY=dry pod yield; CV= coefficient of variance; MSE = mean square of error; SE= Standard error of means

Similarly, twenty two genotypes, excluding genotypes considered at Babile, showed best performance in dry pod yield than *BaHa-jidu* and *BaHa-gudo* at Likale research site (Table 2). GRRP- 16, ICG- 8287, ICGV- 86320, ICGV- 86229, and ICG- 2949, showed best performance as compared to checks at both Babile and Likale research sites, which may indicate that these genotypes are adaptable in wider environment.

Table 2. Groundnut genotypes with best performance compared to standard checks at Likale research site

Genotypes	DPY (kgha^{-1})	Genotypes	DPY (kgha^{-1})
ICGV- 86231	921.0875	ICGV- 86296	816.9875
ICG- 88329	841.0875	ICGV- 86436	876.2875
VA – 61-4	903.78750	ICGV- 86320*	830.8875
ICGV- ICGV- 92267	804.787	ICGV- 92204	1021.0875
GRRP- 16 *	824.7875	ICGV- 7627	830.88750
ICGV- 86303	805.8875	ICGV- 86229*	1197.3375
ICGS- 93095	964.66250	ICG- 7377	993.1375
ICG- 93382	1172.3875	Chico	1140.8375
Spontex	845.78750	IGFDN- 36	966.43750
ICG- 7944	1002.2375	ICG- 318	817.7375
ICG- 8287 *	921.73750	ICGV- 87187	1023.7375
ICG- 2949 *	1570.2375	Sartu	745.93750
BARBA-RTON	1108.1875	*BaHa-gudo*	1235.3125
ICG- 99	1045.4875	*BaHa-Jidu*	866.41250
ICG- 7464	879.2875	Oldhale	763.58750
Mean	629.28		
Root MSE	293.27		
CV	46.60		
SE (Test and control)	339.96		

‘*’are genotypes showed best performance in dry pod yield both at Babile and Likale research sites. DPY=dry pod yield; CV= coefficient of variance; MSE = mean square of error; SE= Standard error of means

Recommendation

Best performed genotypes in dry pod yield at Babile and Likale research sites need to be promoted to preliminary variety trial for further evaluation to select best performing genotypes in dry pod yield and other desirable traits.

Groundnut Varieties Adaptation Trial in Eastern Ethiopia

By

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Introduction

Although about eighteen groundnut varieties have been released for production in the country, the dry pod yield of groundnut under small holder production system in eastern Ethiopia is yet very low (1.04 t ha^{-1}). Thus, to increase the production of groundnut in eastern Ethiopia, the nationally released varieties were evaluated in Eastern part of Ethiopia for adaptability and yield performance in order to recommend well adapted and high yielding varieties.

Materials and methods

Ten groundnut varieties that are nationally released were planted in 2012 cropping seasonat at Hirna and Fedis under rain feed, and Shinile under irrigation farming. The experiment was arranged in randomized complete block design in 5 rows in inter and intra row spacing of 60cm and 10cm, respectively, with 3 replications. The agronomic practices were applied as per the recommendation for the varieties. Days to maturity and dry pod yield, from three middle rows, data were collected and subjected to statistical analysis. Analysis of variance was carried out with a statistical analysis system (SAS) version 9.0 software (SAS Institute Inc., 2002).

Results and discussion

Analysis of variance was carried out to determine the performance of groundnut varieties at Fedis, Hirna, and Shinile. *BaHa-gudo* showed best performance at Hirna (28.46 quintals dry pod yield per hectare) and Fedis (29.03 quintals dry pod yield per hectare). *BaHa-jidu* is found to be the best performing in terms of dry pod yield (25.19 quintal per hectare) at Shinile (Table 3). Farmers evaluated the groundnut varieties planted at Hirna and ranked *BaHa-jidu* first because of its growth habit (runner type) and pod load.

Table 3. Dry pod yield and days to maturity of groundnut varieties at Hirna, Shinile, and Fedis

	Hirna	Shinile		Fedis	
Varieties	DPY (quintalha^{-1})	DPY (quintalha^{-1})	DTM	DPY (quintalha^{-1})	DTM
Werer 961	26.33^{ab}	18.53^{abc}	121.67^{b}	15.19^{cbd}	114.00^{b}
BaHa-gudo	28.46^{a}	8.83d^{c}	145.00^{a}	29.03^{a}	129.33^{a}
Tole-1	12.88^{d}	8.08d^{c}	145.33^{a}	9.78^{cd}	128.66^{a}
Roba	13.48^{d}	13.25^{bcd}	145.33^{a}	19.24^{b}	129.00^{a}
Sedi	19.37^{cdb}	8.81^{dc}	108.00^{c}	12.57^{cbd}	106.67^{c}

Tole-2	11.89[d]	4.83[d]	146.00[a]	8.12[d]	129.67[a]
Bulki	15.98[cd]	12.09[bcd]	146.00[a]	13.03[cbd]	129.00[a]
Lote	16.52[cd]	21.49[ab]	145.66[a]	16.64[cb]	127.66[a]
BaHa-jidu	24.12[abc]	25.19[a]	146.00[a]	18.34[b]	128.00[a]
Werer 962	23.95[abc]	11.89[bcd]	145.33[a]	20.13[b]	129.33[a]
Mean	19.30	13.30	139.43	16.15	125.13
Error MS	25.83	42.31	42.69	21.24	1.64
CV	26.33	48.91	4.69	28.54	1.02
LSD	8.718	11.16	11.208	7.91	2.20

[a,b,c,d,]Means by the same letter in the column are not statistically different from each other at 0.05 probability level. One quintal is equivalent to one hundred kilo gram. DPY=dry pod yield; DTM=days to maturity; CV= coefficient of variance; LSD = least significance difference; MS = mean square

Sedi is an early maturing among the tested groundnut varieties. It matured with in 108.0 and 106.7 days at Shinile and Fedis, respectively.

Recommendation

BaHa-gudo is best performing groundnut variety in dry pod yield at Hirna and Fedis. As a result *BaHa-gudo* is recommended for production under rain fed at Hirna and Fedis. *BaHa-jidu* is also best performing variety at Shinile so that it is recommended for production under irrigation.Hirna and Shinile were identified as an agro-ecology well suitable for groundnut production. During the experiment, it was noticed that ridge planting is required for clay soils at Hirna. Further study is required to examine the details of ridging to draw appropriate recommendation of this practice for groundnut planting. In addition, the local farming tool *dongora* is required to be used at the time of harvest. Sedi is early maturing groundnut variety at Shinile and Fedis. Thus, this variety may be used under rain fed in areas where the duration of the rain fall is shorter to support the growth and maturation of late maturing varieties.

Sesame Research

Completed Sesame Research Activities

Sesame (*Sesamum indicum* L.) Observation Nursery

By

Amare Kebede
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Introduction

Sesame (*Sesamum indicum* L.) is the second export commodities in Ethiopia. To sustain and increase the national sesame production, continuous and sustainable technology development is necessary. Variety development is among major factors that contributed to sesame seed yield increase. Thus, sesame research is carried out in eastern Ethiopia to develop best performing sesame varieties in seed yield and other desirable traits.

Materials and methods

Eleven sesame accessions were obtained from Werer Agricultural Research Centers and planted under rain fed farming in 2012 cropping season at Babile. In addition, *Abasena* and *Adi* standard checks and the local materials were examined along with eleven accessions. The experiment was arranged in randomized complete block design with three replicates, and inter and intra row spacing of 40 cm and 10 cm, respectively. The recommended cultural practices for the varieties were applied. Seed yield and days to maturity data were collected and subjected to statistical analysis**.** Analysis of variance was carried out with a statistical analysis system (SAS) version 9.0 software (SAS Institute Inc., 2002).

Results and discussion

W-124 (ssm) showed best performance in seed yield (6.53 quintal ha^{-1}) among the tested materials (Table 4). The local check showed least in seed yield (1.8 quintal ha^{-1}) compared to standard checks and accessions.

Table 4. Seed yield and days to maturity of sesame nursery observation trial

Accession	Seed yield (quintal ha^{-1})	DTM	Accession	Seed yield (quintal ha^{-1})	DTM
W-103(wss)	3.95^{abcdef}	115.67^{bcde}	W-119(wsm)	4.371^{bcdef}	114.67^{cde}
W-104(ssm)	4.82^{abcd}	113.00^{e}	W-120(wsm)	5.39^{abc}	114.33^{cde}
W-106(ssm)	5.17^{abc}	117.00^{bcd}	W-122(wss)	4.26^{abcdef}	117.00^{bcd}
W-107(wss)	4.58^{abcde}	115.33^{bcde}	W-124(ssm)	6.53^{a}	115.33^{bcde}

W-109(wss)	4.89[abcd]	114.67[cde]	W-125(ssm)	6.09[ab]	114.00[cde]
W-110(wsm)	3.92[abcdef]	115.33[bcde]	Adi	4.77[abcd]	115.00[cde]
Local check	1.80[gf]	123.00[a]	Abasena	4.57[abcd]	117.33[cb]
Mean	3.63	115.69			
Error MS	2.69	4.46			
CV	45.16	1.83			
LSD	2.69	3.46			

[a,b,c,d,e,f]*Means followed by the same letter in the column are not statistically different from each other at 0.05 probability level. One quintal is equivalent to one hundred kilo gram; DTM=days to maturity; CV= coefficient of variance; LSD = least significance difference; MS = mean square*

W-104(ssm) is an early maturing variety (113 days), whereas as the local check is a late maturing variety (123 days).

Recommendation

Sesame accessions that out yielded the standard checks demand further study to select best varieties in seed yield. Thus, the experiment needs to be promoted to preliminary variety trial for further examination in the next season.

Sesame (*Sesamum indicum* L.) Varieties Adaptation Trial in Eastern Ethiopia

By

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Introduction

Sesame (*Sesamum indicum* L.) is the second export commodities in Ethiopia. Identification and exploitation of new potential areas for sesame is helpful to increase overall production in Ethiopia and thereby diversify household diet and source of income.

Materials and methods

During the last decades, many sesame (*Sesamum indicum* L.) varieties were nationally released for production in different agro-ecologies. Among the released varieties, ten were planted during the 2012 cropping season at Gursum, Likale, Babile and Hirna under rain fed and Shinile under irrigation farming. The experiment was arranged in randomized complete block design in 5 rows in inter and intra row spacing of 40 cm and 10 cm, respectively with 3 replicates. The agronomic practices were applied as per the recommendation. Days to maturity and seed yield data were collected from three middle rows and subjected to statistical analysis. Analysis of variance was carried out with a statistical analysis system (SAS) version 9.0 software (SAS Institute Inc., 2002).

Results and discussion

Abasena showed best performance in seed yield at Babile (7.2 quintal ha^{-1}), Likale (5.6 quintal ha^{-1}) and Hirna (6.9 quintal ha^{-1}). Farmers evaluated the experiment at Hirna and ranked *Abasena* first because of overall growth performance and seed yield. Similarly, *Tate* and *Argene* showed best performance in seed yield at Babile (6.6 quintal ha^{-1}) and Likale (6.1 quintal ha^{-1}), respectively (Table 5).. *Kelafo-74* (36.7 quintal ha^{-1}) was found to be the best in seed yield under irrigation condition at Shinile followed by *T-85* (33.2 quintal ha^{-1}), *Mehado-80* (32.3 quintal ha^{-1}) and *Adi* (31.4 quintal ha^{-1}). The seed yield obtained under irrigation is far higher than that obtained under rain fed which may show further investigation in the future to draw recommendation for wider use. Hirna and Shinile were found to be the suitable agro-ecology for sesame production

Table 5. Sesame seed yield and plant height at Babile, Likale, Hirna, and Shinile

Varieties	Babile		Likale		Hirna	Shinile	
	Seed yield (quintal ha^{-1})	Pant height (cm)	Seed yield (quintal ha^{-1})	Pant height (cm)	Seed yield (quintal ha^{-1})	Seed yield (quintal ha^{-1})	Pant height (cm)
T-85	2.19f^{a}	75.53^{b}	4.03^{bc}	84.53	0.76^{f}	33.21^{ab}	172.33
Serkamo	6.23^{ab}	78.53^{b}	3.97^{bc}	77.67	1.68^{def}	29.98^{ab}	148.00
Tate	6.63^{a}	77.33^{b}	3.60^{c}	82.33	5.34^{b}	30.54^{ab}	165.33
S	4.81^{bcd}	70.53^{b}	3.58^{c}	78.53	0.97^{ef}	28.19^{ab}	166.00
E	5.80^{abc}	74.33^{b}	3.83^{c}	78.87	1.07^{ef}	27.94^{ab}	154.67
Kelafo-74	4.84^{bcd}	71.67^{b}	4.17^{bc}	80.00	1.16^{ef}	36.68^{a}	164.67
Mehado-80	6.40^{ab}	76.33^{b}	5.29^{ab}	79.00	2.75^{cd}	32.32^{ab}	170.67
Argene	4.09^{ed}	79.33^{b}	6.04^{a}	86.73	2.29^{de}	24.45^{b}	159.33
Adi	4.46^{cd}	99.33^{a}	4.72^{abc}	99.80	0.56^{f}	31.41^{ab}	152.33
Abasena	7.21^{a}	100.0^{a}	5.60^{a}	88.33	6.87^{a}	25.09^{b}	156.67
Local	2.75^{ef}	100.33	3.45	91.53	3.64^{c}	14.33^{c}	176.00
Mean	5.04	82.11	4.39	84.30	2.46	28.56	162.36
Error MS	0.97	44.03	0.71	307.78	0.61	33.66	222.60
CV	19.58	8.08	19.13	20.81	31.59	20.31	9.19
LSD	1.68	11.30	1.43	29.88	1.33	9.88	25.41

[a,b,c,d,e,f]Means followed by the same letter in the column are not statistically different from each other at 0.05 probability level. One quintal is equivalent to one hundred kilogram.CV= coefficient of variance; LSD = least significance difference; MS = mean square

Recommendation

In conclusion, *Abasena*, *Tate* and *Argene* are recommended for production at Babile and Likale. Abasena is also recommended for Hirna. Kelafo-74, T-85, Mehado-80 and Adi are best yielding sesame varieties at Shinile under irrigation farming. Hirna and Shinile are suitable for sesame production under rain fed and irrigation condition, respectively.

Linseed Research

Improved Linseed (*Linum usitatissimum* L.) Varieties Adaptation Trial in Eastern Ethiopia

By

Amare Kebede

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Introduction

Identification and exploitation of new potential areas for linseed is helpful to increase overall linseed production in eastern Ethiopia and thereby diversify household diet and source of income.

Materials and methods

During the past decades, many linseed varieties were nationally released for production in different agro-ecologies. Among the released varieties, seven were planted along with local cultivar in 2012 cropping season at Haramaya University (Rare research station) and Boroda under rain fed farming.The experiment was arranged in randomized complete block design with 3 replicates in 5 rows in drill seeding as per the recommended seeding rate (25 kilogram per hectare). The agronomic practices were applied as per the recommendation for the varieties. Seed yield were collected from three middle rows and subjected to statistical analysis. Analysis of variance was carried out with a statistical analysis system (SAS) version 9.0 software (SAS Institute Inc., 2002).

Results and discussion

*Chilalo variety s*howed best performance in seed yield at Haramaya (22.77 quintal ha^{-1}). Similarly, *Kulumsa-1* showed best performance in seed yield at Boroda (19.07 quintal ha^{-1}). Farmers evaluated the experiment at Boroda and ranked *Kulumsa-1* as best among the varieties, which was followed by *Chilalo* because of its seed number per capsule. Haramaya and Boroda were found suitable for linseed production (Table 6).

Table 6. Linseed seed yield at Haramaya and Boroda research sites

Varieties	Seed yield (quintal ha^{-1})	
	Haramaya	Boroda
CI-1652	21.13^{ab}	16.13^{ab}
CI-1525	17.97^{ab}	16.13^{ab}
Belay 96	20.57^{ab}	18.50^{ab}
Kulumsa 1	21.67^{ab}	19.07^{a}
Tole	21.23^{ab}	18.13^{ab}
Berene	22.40^{ab}	18.7^{ab}
Chilalo	22.77^{a}	17.20^{ab}
Local	16.13^{b}	13.37^{b}
Grand mean	20.49	17.22
Error MS	13.53	10.26
CV	17.95	18.60
LSD	6.44	5.60

^{A,b,}Means followed by the same letter in the column are not statistically different from each other at 0.05 probability level. One quintal is equivalent to one hundred kilogram.CV= coefficient of variance; LSD = least significance difference; MS = mean square

Recommendation

In conclusion, *Chilalo* and *Kulumsa-1* are best seed yielding linseed varieties at Haramaya and Boroda, respectively. Haramaya and Boroda are found suitable for linseed production under rain fed farming.

Maize Research Program

The prevalence of fumonisins and aflatoxins producing fungi on maize (*Zea mays L.*) grain and their management in Eastern Ethiopia

By

Amare Ayalew (PhD): Principal Investigator

Melkamu Ayalew (PhD student): Co-investigator (melkamu96@gmail.com)

HrU Funded

Introduction

The area coverage and total production of maize is increasing in Ethiopia, and its importance in Eastern Ethiopia is significant covering 137290.38 ha with a total production of 2733797.33 quintals (CSA, 2010/11). Fungi invade maize grain and cause losses in quantity and quality. Some fungi associated with maize grain also contaminate the grain with mycotoxins posing serious hazard to human health. Aflatoxins and fumonisins are the most important mycotoxins that occur in maize worldwide.

Mycotoxins are secondary metabolites of molds that exert toxic effects called mycotoxicosis on humans and animals. The severity of mycotoxicosis depends on the toxicity of mycotoxin, the extent of exposure, and age and nutritional status of the individual. Mycotoxicosis arises when environmental, social and economic conditions combine with meteorological conditions (humidity and temperature) which favor the growth of molds. Aflatoxin produced by *Aspergillus flavus*, and fumonisin produced by *Fusarium verticillioides* have been associated with liver and esophageal cancer, stunted child growth, malnutrition, and death. In Ethiopia, the investigation on fungi associated with grain, and the extent of the mycotoxins they cause is very limited.

Food safety is one aspect of food security so that building up of information on the mycotoxins and designing appropriate management strategy is becoming an urgent concern. Few investigations done on the mycotoxins status on different crops in Ethiopia revealed that there is a need to undertake research efforts in this aspect. Maize is one of the crops affected by the mycotoxins. Its area coverage is increasing in different agro-ecologies rapidly, and it is the crop on which most of the poor depends for food in different forms. The adaptability of maize to different agro-ecologies gives the chance for the crop to be affected by mycotoxin producing fungi. In Eastern Ethiopia, where, maize is expanding and covering large area in different agro-ecologies, some attempts were done on detecting mycotoxins but without indicating the influence of different environments and storage structures. Therefore, determining the prevalence of *Fusarium verticillioides* and *Aspergillus flavus*, associated with maize, and the status of mycotoxins (fumonisins and aflatoxins) produced by these fungi need to be investigated considering the different agro-ecologies of Eastern Ethiopia where maize is performing. In the storage, grain losses vary from one geographic location to another and from pit to pit, depending on original grain conditions, season, and associated organisms. Farmers in Hararghe are often tempted to reject a significant proportion of their grain due to molding.

Maize varieties adapted in Ethiopia vary in different agronomic traits like maturity, color, size, protein content, etc. The association of these traits with mycotoxin development in maize needs to be investigated. To gear the breeding strategy of maize with regard to mycotoxin resistance, evaluating maize varieties for resistance to mycotoxins contamination is vital.

Objectives:

1. To determine the prevalence of fungi (*Fusarium verticillioides*, and *Aspergillus flavus*) associated with maize (field and storage)
2. To detect and quantify fumonisins and aflatoxins on maize (samples collected from the pre-harvest/pre-storage and storage)
3. To evaluate maize varieties for resistance to mycotoxins in different growing agro-ecologies of eastern Ethiopia.
4. To determine the association of morpho-chemical traits ('markers') of maize with mycotoxins contaminations.

Materials and Methods

Sample grain collection

Representative samples (one kg each) of maize grain were collected from major maize producing districts ("woredas") in Eastern Ethiopia two times, pre-harvest/pre-storage, and four to six months after the grain is stored in farmers' storage structure in systematic random sampling at 5-10 km intervals depending on the availability of maize production. While collecting maize grain from both the field and storage, basic information was recorded.

Analysis of aflatoxins

A representative sub-sample of 75 g maize grain was ground for aflatoxins analysis using the following method:

Enzyme Linked Immunosorbent Assay of AFT (aflatoxins)

Commercially available ELISA kit was used for the analysis of AFT (AFB1 and AFB2) **Extraction of aflatoxins**: 5 g flour was weighed from sample and transferred into 50 ml screw caped falcon tubes. Then 25 ml of 70% methanol was dispensed into each falcon tube containing 5g flour (1:5 w/v ratio) using graduated dispenser. The suspension was shaken with Orbital Shaking Incubator Shaker at 25^{o}C at a speed of 250 rpm for 4 minutes and allowed to settle, and filtered into another new 50ml plastic falcon tube through 24 cm Ø folded Fluted Filter Paper. The filtrate was kept in the cold room for 48 hours till the aflatoxins was analysed using ELISA following the manufacturer's assay procedures for aflatoxins testing.

Evaluation of maize varieties for resistance to aflatoxins

Maize varieties released (normal maize and quality protein maize groups) by the Ethiopian Institute of Agricultural Research and Haramaya University were evaluated at Haramaya University and Hirina testing site in 2012 cropping season. All agronomic practices recommended for maize production were applied.

The response of the varieties to aflatoxins contamination was tested using the procedures for samples collected from farmers' field and storage.

Results

Out of 99 samples collected from farmers' field and storage, 2 samples showed >10 ppb, 8 samples showed 1-10 ppb and 89 samples showed <1 ppb. Over all, the level of aflatoxins from maize samples in eastern Ethiopia was not high. Further sample collection was done for additional analysis.

Amongst maize varieties evaluated for aflatoxin resistance, the varieties, AMH 851 (Jibat), BH 540 and Hora (Synthetic I) had aflatoxin level >10 ppb at Hirna. However, aflatoxins level at Haramaya University was low, the maximum level being 1 ppb.

Activities to be accomplished during the remaining project period

The project will be completed in 2006 EC budget year by accomplishing the following activities:

1. The second year field is being conducted at Haramaya University and Hirna Research Station. This activity will be completed in this budget year.

2. Fumonisins analysis for the samples collected from the farmers' field at harvest and farmers' storage, and for varieties evaluated during the 2004/2005 and 2005/2006 cropping seasons will be done in this budget year.

3. Aflatoxins analysis for the second year (2005/2006 cropping season) variety evaluation for resistance to Aspergillus flavus infection.

4. Determining the prevalence of fungi (*Fusarium verticillioides* and *Aspergillus flavus*) associated with maize (field and storage)

Problems encountered, with solutions taken if any, and solutions proposed in the future

Purchasing ELISA kits for fumonisins and aflatoxins analysis was a serious problem during the 2004 and 2005 budget years. This caused the failure of utilizing 40% of the budget to be invested for the approved project as 50% was supposed to be used in 2004 budget year and purchasing ELISA kits was planned in this budget year.

The possible alternative solution was to approach other individuals and international research centers to support me for fumonisins and aflatoxins analysis. For this, Bioscience for eastern and central Africa (BecA) which is based in Nairobi, Kenya supported me partially for aflatoxins analysis. For the remaining samples to analyze aflatoxins, I am negotiating with the same organizations. For fumonisins analysis of the whole samples, I am negotiating with my co-supervisor at Gottingen University, Germany to send him samples and get analyzed.

School of Natural Resources Management and Environmental Sciences

Propagation of Highland Bamboos *(Y .alpina)* and their Field performance evaluation in East Harerge Zone

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Funded by EIAR Research Grant

Introduction

About 18 million ha of bamboo are distributed in world forest ecosystems in Asia, Africa, and America (UNIDO, 2009). Over 600 million people around the world generate income from bamboo (UNIDO, 2009). There are two bamboo species in Ethiopia, namely the highland bamboo (*Yushania alpina k. Schum)* and lowland bamboo (*Oxytenanthera abyssinica A. rich).* Majority of Africa's bamboo forest (> 60%) is situated in Ethiopia. This implies the country is suitable for bamboo cultivation. However, over the last 10 years, the resource base has been significantly reduced (UNIDO, 2009). Most of the bamboo raw material used in Ethiopia is still extracted from natural stands. This implies, rather, the need for bamboo plantation establishment while considering their agro-ecological conditions.

Objective

To determine optimum propagation techniques of bamboo *(Yushania alpina k. Schum)* and their field performance evaluation in some highlands of East Harerge zone

- Growing bamboo seedlings originated from different provinces of Ethiopia
- Evaluating growth performance of bamboo as raised by various methods of vegetative propagation

- Determine agro-ecological adaptability of these bamboo seedlings in some highlands of East Harerge zone

Methodology

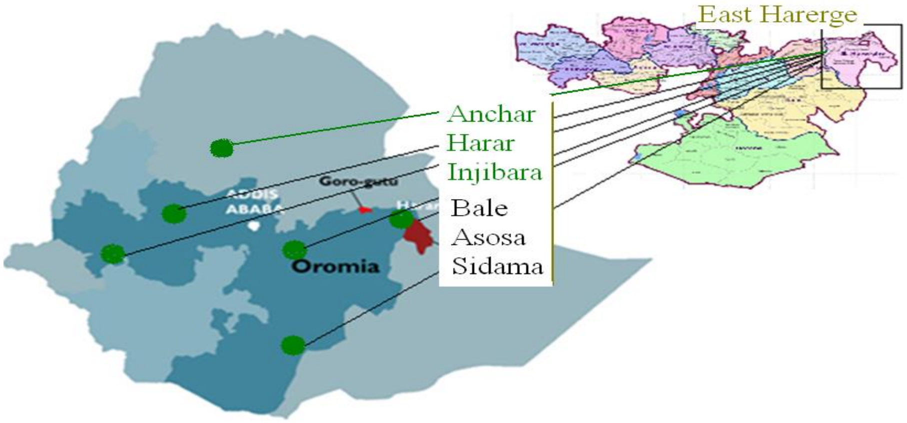

Fig. 1 Sources of the bamboo planting materials

Methods of bamboo propagation

- Cuttings
  - Rhizome
  - Offset
  - Culm
  - Branch
- Macro proliferation (seedling multiplication)
- Field adaptation trial and biometric observation
  - Plots will be arranged in RCBD
  - Seedlings will be planted with 5 x 5m spacing
  - Both organic and the chemical fertilizers will be used on the field trial. The dosage will be determined based on the soil analysis report.
  - Biometric observation such as shoot length, culm diameter, number of culms emerges

Proposed districts of East Harerge zone

S.No	Name of the woredas	Area (km^2)	Altitudinal range (masl)
1	Deder	877.6	1200 - 3140
2	Girawa meyu	596.25	500 - 3230
3	Kurfachelle	301.8	1400 - 3400
4	Kersa	544.9	1400 - 3200

Executed and ongoing activities since September 2012

Executed activities

- Planting materials are collected from three districts (Anchar, west Harerge zone; Injibaram Awi zone and Harar town)

- The collected planting materials are raising at HU nursery sited using various propagation methods

Fig. Rhizome collection at Anchar, West Harerge

Preparing for offset cutting collected from Injibara, Awi zone (Amhara region)

Remained and Ongoing activities

- Interested farmers will be involved and planting sites will be purposively selected based on agro-ecological attributes of the East Harerge highlands
- Soil sample collection and analysis of the planting site
- Field adaptation trial and biometric observation
- Planting site for adaptation trial is not yet selected
- Observation of biometric data at nursery sites
- Planting materials will be collected from Bale (adaba), Asosa (Bambasi) and Sidama (Mocha)

Expected outputs

- The best and successful methods of bamboo propagation in nursery and the most adaptable sources of planting stock will be identified for the East Harerge highlands.
- To establish awareness about development of bamboo and transfer propagation technology among stakeholders
- Entrepreneurship development among local women and youth through promoting integrated growth of the bamboo sector and marketing of bamboo-based handicrafts.
- To promote, develop and disseminate technologies to generate employment opportunities for skilled and unskilled persons, especially unemployed youths.

Results obtained

We are collecting biometric data at nursery sites and promising results are obtained

Characterization of Natural Regeneration and Species Composition of Asebot Forest

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Funded by EIAR Research Grant

1. Introduction

According to FAO (2007) definition, Ethiopian Forest can be classified as Acacia commiphora woodland, Bamboo tickets, Dry evergreen Afromontane forest, Combretum-Terminalia woodland, Moist Afro-montane forest and Low land Semi evergreen Tropical forest. The dry Afromontane forests are either Juniperus- Podocarpus forests or predominantly Podocarpus forests, both with companions of broad-leaved species. The **Dry evergreen Afromontane forest** and **Combretum-Terminalia woodland/**scrublands are the two most representative vegetation communities in Asebot forest.

Forest fires became one of the most important threats to the remaining forests of the country in the last few decades. The forest fire that occurred in 2000 covered almost whole parts of the country which was reported to be the worst of all fires in the last 100 years (MoA, 2000). Asebot forest rather was repeatedly affected with human induced fire damage and massive encroachments. The current study on Asebot forest fire identified intentional manmade causes as the major reason. The majority of the respondents ranked forest camps in general and “Hoja” (local tea preparation) in particular as the main cause of fire introduction to the forest site (Adefires Worku and Worku Zewde @Forum for Environment, 2009).

This project is HU-EIAR sponsored and incorporated under the National Forestry Research Team-Natural Forest case team. This progress report includes description of the project (components and specific activities- both executed and ongoing), interim results and challenges and perceived during the field survey.

Study sites

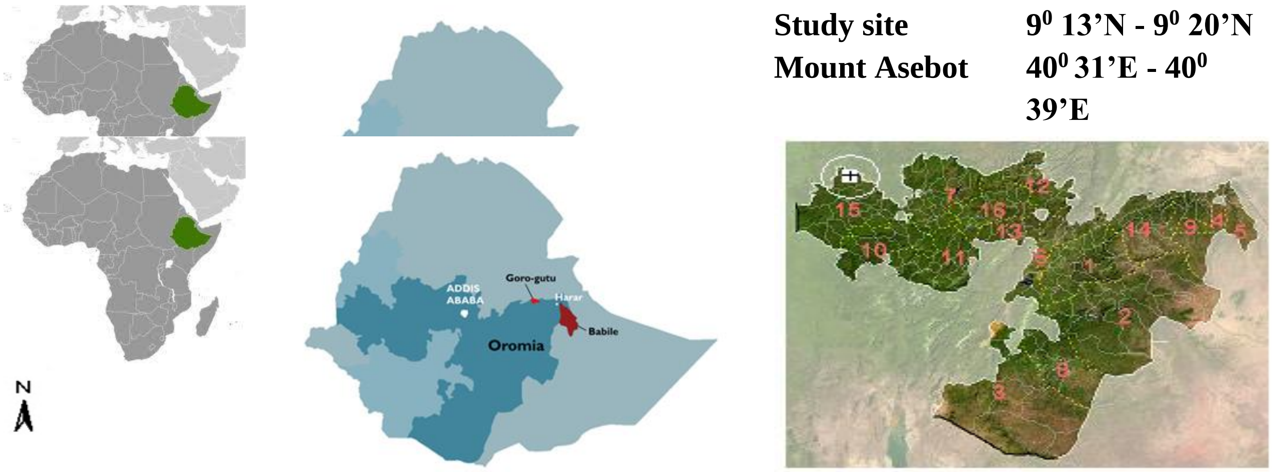

Fig. 1 Location of the study site

1. **Project description**

Component 1: Vegetation structure and Population Dynamics

Activity 1: Characterization of natural regeneration & species composition of Asebot Forest

Objectives

1. to evaluate the natural regeneration status in Asebot Afromontane Forest
2. to examine status of the soil function as seed bank

Methodology

Data was collected through group discussions with key informants representing different stakeholders (local communities, elders, and church communities and administration at Asebot Monastery), personal observation and acquisition of photographs. Systematic species count (trees, shrubs, seedlings/saplings) in each sampling quadrates (10mx10m). The function of soil as seed bank (samples collected from the relics of undisturbed natural forest and disturbed forest with fire and encroachment) is being examined at HU nursery site.

Activity 2: Characterizing floristic composition and structure of Asebot forest

Objective:

To determine species composition and ecosystem functions of Asebot forest.

Methodology

Based on the data of species encountered in each quadrate, the following parameters will be calculated:

- Density (D), Abundance (A), Frequency (F%), Relative density (RD%), Relative frequency (RF%), Relative abundance (RA%) and Importance value index (IVI)

– Develop conceptual model regarding functional relationship among various bio-physical components of the forest

Modified Sample plots used = 10m x 10m for trees and shrub count (previously was designed by 20x20m, but due to the difficulty of the terrain together with comment given during HU annual research review, it is difficult to use systematic sampling plots. Therefore, the modified plots were established randomly and their geographic coordinates are recorded; 2m x 2m for herbs, seedlings/saplings; and 15cm x15cm for soil sample collection to examine status of the soil seed bank.

2. Executed and ongoing activities since September 2012

- Data sheets/recording formats were developed and used for data collection
- MoU was developed and Various stakeholders have been addressed
- Required field materials were collected and organized
- 26 permanent sample plots (10 x10m) are established (9 on the disturbed and the rest on undisturbed forest), (ongoing).
- The soil seed bank status is being examined at HU nursery site (ongoing).
- Conducting a field survey, (ongoing).
- Data analysis, (ongoing).

3. Result obtained

Just for our curiosity, we have tried to look on the regeneration status of some common vegetation species. Despite the pressure of human interference in relics of Asebot forest, regeneration of dominant tree species such as *Podocarpus falcatus and Juniperus procera* were in good status. For, example, count from six sample plots (10m x 10m) from the undisturbed forest, newly regenerated *P. falcatus* were recorded around 6000 stems per ha. To some places it is also common to count abundant seedlings of *J. procera* in the undisturbed forest, for example, 16 stems per m^2. However, such observation is uncommon throughout the forest; rather occur under patches of the mother trees. The data collected are being used to analyze the above mentioned parameters ***(activity 2)***, while the research team is preparing for the second round field survey soon.

Figure 2: Patches of regenerated seedlings and saplings of *Juniperus procera and Podocarpus falcatus*

Challenges perceived

- Security (due to threats of occasional ethnic conflicts)
- Remoteness of the forest site
- Risk of encroachment over the established permanent sample plots

NB: This ongoing project activity was presented at the national forestry research review in February 2013.

Domestication of high priority indigenous plant species in selected pastoral and agro pastoral areas, Ethiopia

Sintayehu Workeneh[1], Tessema Toru[2] and Lisanework Nigatu[2]

Background and rationale

Woody species provide products such as fuel wood, timber, food, gum and resin, medicines, etc. that millions of people in developing countries depend on. Woody plant species also provide important environmental and cultural services, including the provision of shade to crops and people, soil improvement, erosion control and heritage values. However, many woody plant species are threatened and declining (Belcher and Schreckenberg 2007, Rönnbäck et al. 2007, FAO, 2009, Tabuti et al, 2010).

Woody plant species domestication is thought to be one of the remedies for reversing the problem of degradation of Woody plant species. Tree domestication includes a range of many activities – exploration and collection of natural or anthropogenic populations, evaluation and selection of suitable species and provenances, developing propagation techniques, breeding, multiplication and dissemination of germplasm, development of management techniques, utilization and tree-product marketing, and the development and dissemination of relevant technical information. The process of tree domestication involves the identification, production, management and adoption of desired germplasm to meet farmer-driven or market-led needs. The domestication strategies used for individual species vary according to their functional use, biology, target environment, and the domesticator-researcher or farmer (Roshetco and Verbist 2000).

Participatory tree domestication on the other hand refers to the means by which rural communities select, propagate and manage trees according to their own needs, in partnership with scientists, civic authorities and commercial companies. It is usually oriented towards specific local markets and encompasses the use of both indigenous knowledge and genetic selection based on scientific principles. In such cases, scientists generally work at the community/household level with farmers on species of their own choice. Participatory domestication thus empowers the farmers, allowing the outputs and benefits of domestication to remain with the community (Tchoundjeu et al 2006).

In drylands, the sustainability of traditional animal husbandry is becoming difficult. Therefore, new methods or approaches are needed to address the increasing pressure on natural resources, to secure food availability & create alterative income source. One of the emerging new land uses is agropastoralism, which has been spreading into purely pastoral areas (Halt 1989). Farming could be considered both a response to food insecurity as well as an economic diversification (Oba, 1998). Agropastoralism is a form of farming system combining both livestock and crop production. The emergence of agropastoralism could be partly associated with the decline in the range resources as well as decreases in both livestock numbers and productivity. This compounded situation may have forced pastoralists to resort to agropastoralism. Pastoral and agropastoral areas in Ethiopia are estimated to occupy about 61-65% of the total area of the country and are home to 12-13% of the total population. Regionally, pastoral and agropastoral areas in Ethiopia include area in Afar, Somali, South Omo of Southern Nations and Nationalities People Regional State (SNNPRS), the Borena, east and west Harargie Zones of Oromia, Gambela and Benshnagul-Gumuz Regions. In the different pastoral areas, land converted to seasonal crop cultivation cover 178,000 ha in Afar Region (CEDEP 1999), 39,000 ha in the Somali Region (Regional BoA 1999), 1,332,900 ha in the Borena zone of Oromia Region, 58,503 ha in the South Omo of SNNPRS (SNNPRS 2000), 32,452 ha in Gambela Region (Gambela Region 1996), and 38,717 ha in Benshangul Gumz Region (WARDIS 1998). Using these estimates, the total area of rangelands that are in the process of being converted to crop land is approximately 1.9 million ha. Planting of trees in the form of parkland systems can improve the sustainability and productivity of dry land agriculture because trees are capable of increasing the efficiency of water and nutrient use in the system. Perennial trees also reduce pressure on remnant woodlands. Since the functioning of dryland agriculture depends greatly on the presence of trees, the domestication and management of indigenous fruit and fodder trees in the form of traditional agroforestry parkland system seems a better option of sustainable land use.

Crop cultivation is recently introduced means of living in pastoral communities. Since the opportunistic crop production support households in terms of employment, income generation and food supply several pastoralist in southeastern Ethiopia has started tilling the land (Kejela *et. al*, 2005). The major cause of increase in the cropland is increased poverty due to death of animals in the prolonged drought season. However, the erratic rainfall and recurrent drought in the pastoral areas make crop production a risky undertaking. Compared to livestock production, crop production is more vulnerable to climatic uncertainties. For example in Borana area, the probability of good crop harvest is two to three times in a period of eight years whereas livestock may suffer from drought once in eight years. However, as livestock production is also becoming a difficult livelihood system, agropastoral is a necessity, and can effectively address food insecurity if supported also by appropriate land use planning. Establishment of appropriate landuse would reduce the contradiction between crop and livestock production and minimize the danger of ecological hazard since pastoral areas already environmentally fragile. A comprehensive study on such multi-purpose woody plant species will leads to selection of priority species, domestication strategies, germplasm collection, plant genetic improvement, agroforestry enhancement, innovation on harvesting and post-harvest technology, economic analysis and market research.

In this proposal we hypothesize that parkland and other agroforestry techniques that involve fruit, fodder, medicinal and other potential perennial plant species having commercial interest (like *Aloes*) has to be integrated as an opportunity and options to back-up sustainable agriculture and as a means to mitigation climate change within these vulnerable and fragile drylands. The availability of wild fruits, medicinal and fodder species on farmlands and around homestead will help in providing nutritious food and income. The agropastoralists engaged in crop production need to be supported to improve their farming techniques and use suitable species and varieties of crops. Establishment and management of fruit and fodder Woody plant species both for income and household consumption are very crucial as an adaptation strategy and product diversification.

Objectives of the project

General

To domesticate high priority indigenous fruit, fodder, medicinal and salt tolerant woody plant species thereby enhance tree planting and to address the food, feed and health problems in the selected pastoral and agropastoral areas.

Specific

1. To identify and prioritize woody plant species for domestication, determine planting scheme preferences, investigate the experiences of the local people in their uses, tree establishment and management and determine the role of woody plant species and their products in household economy.
2. To investigate the phenology of the target fruit and fodder Woody plant species and determine their seed production capacity
3. To determine the germination and storage behaviors of seeds of the target species
4. To determine the nutrient content of the food and feed parts of the selected Woody plant species
5. To design appropriate nursery techniques, determine the nursery life, and produce high quality seedlings from selected individuals
6. To select best performing individuals simultaneously both on station and on farm for the areas
7. To develop better ways of pre and post harvest handling techniques of fruits,
8. To equip the local people with tree nursery and silvicultural skills and disseminate the information generated through the project for furthering tree domestication and planting.

Components/discipline

Title: wild edible, medicinal and salt tolerant multipurpose plant species identification, prioritization, indigenous knowledge and socioeconomic investigation

Objective: To identify and prioritize wild edible, medicinal and salt tolerant multipurpose plant species for domestication, determine planting scheme preferences, investigate the experiences of the local people in their uses, tree establishment and management and determine the role of woody plant species and their products in household economy.

Selection of study area

Methodology:

Reconnaissance survey was conducted in Sept., 2011 in the pastoral and agropastoral areas of East and west Haragge zones of Oromia region, Afar region and Shinile zone of Somali Region. Stockholders were identified. Six kebeles were selected from pastoral and agropastoral areas of east and west Hararge Zone.

Result

The team has conducted a reconnaissance survey in the pastoral and agropastoral areas of East and west Haragge zones of Oromia region, Afar region and Shinile zone of Somali Region.
After a serious of discussion among the team members and the various stack holders in these areas it was decided to conduct the actual research in the following specific sites.

1. The domestication of wild edible fruits and fodder tree species the team decided two Wereda in east and west Hararge zones. i. e.
    - **i.** Mieso
    - **ii.** Babile
2. The domestication of medicinal plants
    - **i.** Mieso
    - **ii.** Babile
3. Screening of salt tolerant plant species
    - **i.** Mieso
    - ii. Babile
    - iii. Erre Gota

A cross-sectional multi-stage sampling, with Woreda as highest and kebele as lowest sampling stages were used to select study kebeles. Thus, Huse Mander, Kurfassa and Dh Missoma kebeles from Mieso woreda and Erer Ebada, Tulu Ero and Sheki Hussen were randomly selected. In these selected Weredas the potential stockholders were consulted. Among which Pastoral, Land Use and Environmental Protection offices in Mieso Wereda were consulted and consensus was reached to work together on this project. Similarly, in Babile Wereda the Agriculture and Rural Development Office was consulted and agreement was reached for working together on this project.

Identify and prioritize woody plant species for domestication.

Data collection

Questionnaires survey

Enumerators were selected in collaboration with woreda officials**.** From each PAs, 3 enumerators were assigned. Two from the PAs and one from woreda office were selected. A total of 9 enumerators were used for data collection from each wored and one supervisor from the officials. Totally 2 supervisor and 18 enumerators were participated in questionnaires survey.
During house hold selection, 25% of the populations were taken randomly from each Pas.

PAs	Total household	Sample
DH. Missoma	684	171
Use Mandhera	662	165
Kurfassa	514	128
Total (Meiso)		464
Sheki Abdi	471	118
Erer Ebda	655	164
Tulu Horoo	614	153
Totaal (Babile)		435

Household were selected randomly with equal proportion of male and female household. Quaternaries were tested practically. Supervision by team member were made in each 2 days in each PAs. Data were analyzed by using SPSS. Focus group discussion was done in time seclude.

Results

The present study on identify and prioritize woody plant species for domestication showed that

No.	Local name	Scientific name	Used	Woreda
1	Rooqa	*Tamarindus indica*	Fruit	Meiso/Babile
2	Jajabba	*Berchemia discolor*	Fruit	Meiso/Babile
3	Huda	*Xemenia caffra*	Fruit/fodder	Meiso/Babile
4	Mandera	*Cordia monoica*	Fruit	Mieso
5	Quriqurra	*Ziziphus Abysinica*	Fruit/fodder/medicinal	Meiso/Babile
6	Wangeyo		Fodder	Mieso
7	Obosha		Fodder	Mieso
8	Tedecha		Medicinal	Mieso
9	Ulaga	*Ehretia cymosa*	Medicinal	Mieso/Babile
10	Hamaessa	*Acacia brevispica*	Fodder	Babile
11	Jerma		Fodder	Babile

12	Dbeso		Fodder	Babile
	Biressa		Medicinal	Babile
14	Geda		Medicinal	Babile

Nursery establishment

Nurseries were established in Meiso and Bbile Wereda. Each Nursery has an area of 150 m^2. Seed beds were prepared and nursery sites were fenced.

Evaluation and optimization of promising agroforestry technologies and practices: Green manure for increased Soil fertility and productivity of agricultural crops

Lisanework Nigatu (PhD, Assoc. Prof) & Muktar Mohammed (PhD, Asst. Prof)

Introduction:

Several agroforestry technologies such as taungya system, windbreaks, green manure, fodder bank, woodlots, alley cropping, home-garden practices etc have been developed by several national and international agroforestry research institutions since the 1970s. Despite the availability of these technologies, very limited agroforestry activities are observed on farmers' fields in Ethiopia. Such agroforestry technologies can contribute to the economic and environmental performances of Ethiopian farming systems. Generally, in Ethiopia the potential of agroforestry in addressing the problems of integrated rural development, energy, animal feed, soil fertility climate change issues through agroforestry development are not encouraging. The low adoption of the technologies could be due to, among others, the lack of demonstration of the technologies and knowledge for implementing them.

The effectiveness of green manure application on crop productivity has been demonstrated in an on-farm research at Hirna area, Tullo district. Despite that the adoption of this technology in the area is not seen on farmers' fields due to the lack of information and knowledge exchange between the researchers and the beneficiary farmers. Currently, we scale- up the technology on three farmers' fields in Hirna area and monitor and document the influence of incorporation of this bio-fertilizer in to the soil on the soil fertility improvement as well as in crop yield. Increase.

Objectives

- *Investigate the effect of Senna siamea and Lantana camara green manure and inorganic fertilizer on maize crop yield and soil fertility of the farmland*

Accomplished Activities

- The study was conducted in Tullo district, in kira kufis Peasant Association near the town of Hirna, 420 km east of Addis Ababa, Ethiopia.
- A field trial was established **on three farmer's plots** to compare maize yields and soil nutrients availability resulting from applications of green manures of *Senna siamea* (Senna) and *Lantana camara* (Lantana) and recommended fertilizer. Both green manures consisted of leaves collected from near by the experimental farm plot. A randomized complete block design with three replications was used.
- Green manures from Senna and Lantana were applied to cropping area at rates of 2.5 and 5 tonnes per hectare. Commercial fertilizer was applied at the recommended rate. Control

plots received neither green manure nor commercial fertilizer. Maize was sown at the spacing of 0.25m by 0. 75m.

- Hand weeding is done twice in each growing season. Crop residues were removed at harvest to reduce confounding effects from additional organic inputs of different qualities. Maize crop agronomic data were collected and evaluated. Soil was sampled to 15 cm depth before application of the green manure and after planting at four locations in each plot.
- These samples were bulked and were analysed for the physico-chemical properties following standard procedures.Soil was sampled to 15 cm depth before application of the green manure and after planting at four locations in each plot.
- Biomass, stand count, hieght and stalk diameter, No. of ears per plant, No. Heads, wt of cob, ear length, ear width, rows per ear, kernl per row, grain yield----per plot. Data on soil physico-chemical properties include:Soil Texture, soil colour, pH, EC,%OC, %OM, %TN, Av.P(ppm),Cations(Na,K,Ca, Mg) and CEC.

Results highlighted:

- These agronomic data and soil physic-chemical properties are being analyzed (Table 1 and 2) and interpreted to ensure that the soil fertility and crop productivity has positively increased with the incorporation of green manure as bio-fertilizer compared to the control and fertilizer added plots. It can be cautiously suggested that the current result is in agreement with the ones previously reported from on station trials.
- Moreover, the outcome of the green manure with Latana and Senna leaves experiment will be compared with the adjacent hedge row inter cropping which has been established for long term study to generate agroforestry technology of integrating tree farming with crop .

Table 1. Effect *Senna* and *lantana* green manure and commercial fertilizer on maize grain yield (Kg/ha) in Kira Kufise PA, Hirna, Tullo district

Treatments	Yield (Kg/ha)	Biomass (Kg/ha)
Comtrol	3674	4712
Senna (2.5 t/h)	4327	5640
Senna(5.0 t/ha)	5663	6204
Lantana(2.5 t/ha)	3957	5430
Lantana (5.0 t/ha)	5495	6148
Rec. Fertilizer	5509	6247

Table 2. Effect of senna and lantana green manures and commercial fertilizer on soil organic matter, total nitrogen and available phosphorus on small holder farmer plot ($25m^2$) of Kira Kufise PA, Hirna, Tullo district

Treatments	% OM	% Total N	Av. P (ppm)
Comtrol	1.95	0.15	30.20
Senna (2.5 t/h)	2.45	0.23	37.25
Senna(5.0 t/ha)	2.99	0.54	48.92
Lantana(2.5 t/ha)	2.72	0.20	43.98
Lantana (5.0 t/ha)	2.89	0.25	51.33
Rec. Fertilizer	2.43	0.56	27.69

Studies on the use of plantations with indigenous and exotic species on degraded land in the Eastern highland Ethiopia

By

Lisanework Nigatu (PhD, Assoc. Prof) & Muktar Mohammed (PhD, Asst. Prof)

Introduction

The degradation of the eastern highland undifferentiated dry afromontane forests of Ethiopia has been unprecedented in speed and scale over the past several decades. Deforestation, overgrazing, water and soil erosion, loss of biodiversity and soil fertility, and declining or poor crop yields are alarming indicators of environmental venerability due to rapid and ever increasing population pressure. Under the conditions of shortage of arable land, more marginal and forest lands are being reclaimed for agricultural use, and this accelerates the degradation of the fragile highland ecosystems in eastern Ethiopia. Such everlasting deforestation and land degradation need to be curbed through effective implementations restoration and /or rehabilitation the forest lands of the eastern highlands.

Ethiopia is a country with great diversity of vegetation types which are mainly influenced by variations in topography and climate. The remnant dry undifferentiated afromontane forests in eastern highlands of Ethiopia are composed of diversities of indigenous tree/shrub species and herbaceous vegetation cover. Currently the ever increasing human population and livestock pressures coupled with changes in global climate are threatening this forest ecosystem at an alarming rate. In order to understand and document the dynamics of this degraded forest lands restoration and/or rehabilitation of the forest land needs to be given paramount considerations. Besides, interdisciplinary and integrated approaches towards long term ecological research undertakings and monitoring are imperative. These undoubtedly will have immense contribution to ensure sustainable productivity of the forested lands and also at generating valuable scientific information for monitoring global climate change on a long term basis. Accordingly, Degraded forest lands in two sub catmints of Hirna, Tullo districted were proposed to to rehabilitate the land with mixed plantations of species and monitor the dynamics of the vegetation cover and soil fertility over time.

Study Objective

- Evaluate the performance and productivity of the plantation species in pure and mixed stands.
- Investigate the diversity, biomass and nutrient contents of the understorey species.
- Investigate the Carbon stock of the vegetation cover

Accomplished Activities

- Tree planting in mixture was done based on prior knowledge of their ecological combining abilities.
- The criteria for species selection were growth rate and economic value, potential impacts on soil fertility, and seedling availability.

The tree species selected for the study:

- Cordia africana
- Erythrina brucie
- Eucalyptus globulus
- Gravillea robusta

- The plantation was established using randomized block design with four replicates and six treatments:
- 4 single -species plots of each species
- A mixed - species plot (with the 4 species)
- A natural regrowth plot
- The conventional 2 m spacing between trees was used for planted tree species
- The experimental site was fenced to halt human and livestock interferences while encouraging regeneration from soil seedbank

Results highlighted

- 60 % of the seedlings are now established and perform very well while 40 % have died as obtained from the survival count made two months after planting.

- Replacement planting has been tried for two consecutive years, but due to fund constraint only established seedlings were considered thereafter.

- As the substrate on which the species were planted is highly degraded the growth rate was very slow than anticipated. Consequently it may take several years to determine the carbon stock.

- However, the dynamics of the vegetation cover is encouraging and we need to maintain these enclosed areas despite fund constraints.

- Upto 1500 gm dry matter biomass and more than 25 species of the under-storey vegetation have been recorded in the Mixed-species plantation plots compared to pure stands . The adjacent natural vegetation plot is also improving in aboveground biomass and species composition.

School of Animal and Range SciencesEvaluation of Fodder Trees and Shrubs Suitable for Eastern Hararghe, Ethiopia

Dargo kebede and Haftay Hailu

Abstract: Even if stall-feeding is a common practice in Eastern Hararghe, and attempts have been made to introduce and disseminate forage grass species, still farmers are facing shortages of animal feed due to land scarcity to produce them. Filed experiment was conducted with the aim of selecting edaphically and climatically adaptive fodder tree/shrub species for Eastern Hararghe Zone. The study was conducted at Babile and Kersa districts. Vegetation survey was made using transect walk. Sixty farmers from each district were randomly sampled and interviewed to assess their need for the introduction of fodder species using structured and open ended questionnaires. Seeds of *Sesbania sesban*, *Cajanus cajan, Moringa oliefera* and planting material (cuttings) of *Morus alba* were planted at Haramaya University's forestry nursery. Then they were planted to experimental plots at both sites (Babile and Kersa districts). Seedlings were planted in 6 m long rows with spacing of 2 m x 1 m using randomized complete block design RCBD in three replications at both sites. Most of the interviewed farmers in Kersa district indicated that they do not have fodder trees and shrubs on their farm. Incase of Babile, farmers stated that they have some species of fodder trees and shrubs such as *Zeziphus mauritiana* on their farmland whose leaves and fruits serve as fodder. But, they need the ones which are green through out the year having reasonable feed biomass. Survival count of fodder trees/shrubs planted at Kersa and Babile research sites was made at two times i.e. three months (SN3) and twelve months (SN12) after planting. The over all result of the survival count revealed that *Morus alba* performed best (89.58% survival) at Kersa followed by *Cajanus cajan* (87.5% survival)**,** *Sesbania sesban* (81.25% survival**)** and *Moringa olifera* (56.25% survival). At Babile, on the other hand, *Cajanus cajan* survived much better than species with survival rate of 31.25% while other species showed poor performance with performance of 25, 18.75 and 12.5% for *Sesbania sesban*, *Morus alba* and *Moringa olifera,* respectively. Leaf retention of the fodder trees and shrubs during the dry season was estimated. Data revealed that *Morus alba* retained much of its leaves (90%) followed by *Cajanus cajan* (85%), *Sesbania sesban* (50%) and *Moringa olifera* (10%) at Kersa research site. On the other hand, at Babile experimental site, it is only *Cajanus cajan* which retained about 40% of its leaves. Other species showed poor performance at this site. We conclude that *Morus alba* and *Cajanus cajan* showed promising result on their survival rate and leaf retention potential during the dry season at Kersa. Where as, *Cajanus cajan* showed good performance at

Babile. Therefore, due attention should be given to these species as source feed of for the experimental sites.

Key words*: *Evaluation, fodder trees and shrubs, leaf retention, seedling survival

Introduction

Background and rationale

In Ethiopia, about 85% of the total population directly depend on agriculture and live in rural areas (Krause *et al*. 2007). The livestock sub-sector plays an important role in the Ethiopian economy. Livestock contributes to the livelihoods of 60-70% of the population, and beside this, the sector serves as source of food, income and employment, manure , and also the subsector serves as productive assets that allow households to be self reliant (Zinash and Tegegne, 2000; Ayele *et al.* 2002). Despite of having good number of livestock, per unit productivity in Ethiopia is quite low (Shenkute *et al*. 2012). The current low productivity status of livestock in Ethiopia is caused by lack of forage. As grazing land becomes scare due to expansion of agricultural land attributed to population growth and related factors, it aggravates the poor nutrition of livestock. Fodder trees and shrubs have always played a role in feeding livestock (Azim *et al.* 2011). In Ethiopia, trees and shrubs have long been considered as source of feed for livestock in different parts of the country. Fodder trees and shrubs are an effective insurance against seasonal feed shortages or risk of drought, and hence vulnerability of farmers' livelihood to climate changes. They provide green feed when grasses and other herbaceous materials are dry and they provide the only source of energy and protein during drought when all other feed is absent (Lefroy *et al*.1992). Trees and shrubs are increasingly recognized as important components of animal feeding, particularly as suppliers of protein especially in harsh environmental conditions when grazing is not sufficient to meet the maintenance requirements of animals, at least for part of the year (Speedy and Pugliese, 1992).

Eastern Hararghe zone of Oromia National Regional State of Ethiopia is known for its cash crop production such as khat (Catha edulis), which is exported to Ethiopia's neighboring countries to the east and north-east (Djibouti, Yemen, Oman and Saudi Arabia) and others such as coffee, Irish potatoes and onions produced in the highland areas and to some extend groundnuts grown in the southern lowlands of East Hararghe Zone (Yves Guinand, 2000). Because khat is a highly valued cash crop and has a certain drought tolerance, Hararghe farmers increased and intensified khat production and started to grow it even in the lowlands.

In addition to these, the area is characterized by high population pressure and its consequence of limited and rapidly diminishing land for food and forage production. This has resulted in scarcity of animal feed. Even if attempts have been made to introduce and disseminate forage grass species, still farmers are facing shortage of animal feed. Some alternative feed resources that fit the existing farming system and adapted to the economic realities of the farmers are needed. However, researches on the availability of fodder trees and shrubs integrated into agricultural system have not been conducted yet.

Even if stall-feeding is a common practice in East Hararghe and attempts have been made to introduce and disseminate forage grass species, still farmers are facing shortages of animal feed due to land scarcity to produce them. Thus, this study was carried out to assess the availability of fodder trees and shrubs integrated into farming system; and to identify available feed resources and feeding system, and to evaluate some selected fodder trees and shrubs.

Objective

General objective

To enable farmers have access to fodder by planting trees and / or shrubs at the border of their crop field, at marginalized land or around homestead so that they can have additional income either by fattening oxen or small ruminants (goat and sheep) or rearing dairy cows. And in the mean time for carbon sequestration purpose indirectly by serving as buffer to the remaining patches of forest resources.

Specific Objectives

To select edaphically and climatically adaptive fodder tree/shrub species for Hararghe Zone that can be integrated with crops or planted at the border of crop fields or degraded land.

Material and methods

Study areas: The study was conducted at Babile and Kersa districts. The intention to conduct the experiment at both these districts was to test the adaptability of selected fodder trees and shrubs at

Babile district which is mainly found in lowland agroecological zone of Eastern Hararghe while Kersa represents mid altitude and highlands of the zone.

Located east of Harar, Babile district is mainly situated in the lowland (kola) agroecological zone. The altitude of this woreda ranges from 950 to 2000 meters above sea level. The altitude of experimental site is 1500 meters above sea level. The area receives an annual average rainfall of 569 mm with erratic distribution. The rainy seasons are from May to October with mean maximum and minimum temperature of 27.2 and 14.8˚C, respectively. The soil of the experimental site is sandy loam in texture. The experiment was conducted at farmers training center. Since rain started lately; it delayed planting the seedlings with serious implications for seedling establishment.

Kersa is one of the districts in Eastern Hararghe. The district ranges from 1400 to 3200 meters above sea level. According to the information obtained from the woreda administration, out of the 38 Kebeles, 2 are lowland, 22 are temperate, 7 are a mix of lowland and temperate and the remaining 7 are highland, containing 2.8 %, 60.2, %, 17 % and 20 % of the district population, respectively. The experiment was conducted at an elevation of about 2100 mater above sea level at marginalized land near a farmer’s homestead.

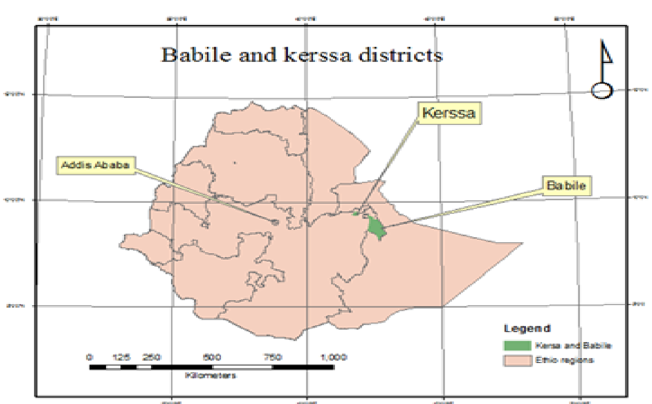

Fig 1 : Map of Kerssa and Babile

Assessment of fodder trees and shrubs

Sampling procedure and data collection method

The intention to conduct the survey at both these districts was to test the availability of fodder trees and shrubs integrated in to the farming systems at two districts which have different agroecological characteristics i.e. Babile falls in the lowland agroecology while Kersa represents mid and highland agroecology. A total of 268 respondents with one hundred thirty four household heads each from Kerssa and Babile districts respectively were randomly selected and interviewed independently.

Data were collected from sample respondents, personal observations of physical features, and informal discussions with Development Agents (DAs). Both structured and semi- structured questionnaire was prepared for individual households. Before conducting the survey, the questionnaire was pre-tested by interviewing some households from the study area. The necessary adjustment to the questionnaires was then made before fully duplicating and distributing to the enumerators. Regular monitoring was made by the researchers while enumerators were interviewing the respondents and daily evaluation of the filled questionnaires was undertaken throughout the data collection processes. The major contents of the questionnaire focused on the issues: the availability of fodder trees and shrubs integrated into agricultural system, factors affecting integration of fodder trees, feed resources and feeding systems.

Tree inventory was carried out to record all woody species found in the traditional agroforestry practices in their frequency. The sample households that were selected for household survey were employed as a sample plot for inventory. Farmers were asked about name of the trees in local language (Oromifa) and the use of the plant species. Identification of species was done in the field. Nomenclature of the plant species followed the Flora of Ethiopia (Hedberg and Edwards 1995).

Fig.2 Cattle feeding crop residue during the dry season

Seedling establishment and survival count

Seeds of *Sesbania sesban*, *Cajanus cajan*, *Moringa oliefera* and planting material (cuttings) of *Morus alba* were planted at Haramaya University's forestry nursery. Then, they were planted to experimental plots on 26 and 27 July, 2012 at both sites (Babile and Kersa districts respectively). Seedlings were planted in 6 m long rows with spacing of 2 m x 1 m using randomized complete block design (RCBD) in three replications at both sites. Sixteen seedlings per plot were planted for each species in three replications with total seedling of 48 at each experimental site. Seedling survival percentage was calculated by dividing the number of survived seedlings to the total number of seedlings planted at each plot (replication).

Seedling survival count was made at 3 and 12 months after transplanting of seedlings at the experimental sites. Seedling survival at 3 months (SN3) after planting has been counted amid November, 2012, and survival count at the 12^{th} month after planting of seedling was made in July, 2013.

Green-leaf retention: The percentage of green leaf was estimated by comparing with a plant with 100% green leaves.

Sampling of fodder tree and shrub leaves for determination of chemical composition

Sampling of leaves was made during the wet season (at about the middle of the long rainy season) when the leaves were fully green. During the sampling period, browse leaves and twigs of less than 5 mm stem diameter were picked. Then, samples were sun dried until the field work was completed. Finally, samples were dried to constant mass in an oven at 55ºC for 48 hours before subsequent nutrient analyses. The samples were analyzed for dry matter (DM) and ash (Anon., 1990). Samples of fodder tree and shrub leaves were also analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) hemi-cellulose and lignin (Van Soest & Robertson, 1990). Nitrogen was determined using the micro-Kjeldahl method (AOAC, 2000) and crude protein (CP) was calculated as N x 6.25 as stated in Garcia *et al.,* (2003). Digestible dry matter (DDM) values were calculated using the equation DDM% = 88.9 – (ADF% x 0.779) (Garcia *et al*., 2003).

Statistical analysis

To analyze the quantitative and qualitative data statistical package for social sciences (SPSS 16 version) was used. Descriptive statistical methods such as frequency, percentage, mean, and standard deviation were used. For categorical variables, a chi-square test was used to test the difference between the agroecologies at the significance level (0.05). The trees species composition between the different agroecology was computed using the Sørensen's Similarity Index: $IS_S = 2c/ a + b + 2c$; where: IS_S is Sørensen's Similarity Index; a representing the number of species unique to sample a; b representing the number of species unique to sample b; and c representing the number of species in common. The coefficient is multiplied by 100 to give a percentage.

The data from the seedling survival, leaf retention trial and nutrient analysis of the fodder tree and shrub leaves were subjected to analyses of variance (ANOVA) for a completely randomized block design using the GLM procedure of the SAS system for Windows (SAS 9.2 version).

Results and discussion

Availability of fodder trees and shrubs integrated into agricultural systems in Eastern Hararghe, Ethiopia

Socio-economic characteristics of the respondents: Interviewed respondent comprised 75.4% male and 24.6% female with age ranging from 20 to 72 years and an average age of 36.05± 11.8 years. The average family size of the respondents was 6.01±2.45; and the average land holding size was 1.34± 1.08 ha (table 1). The production system in the studied areas is a mixed crop livestock production system where farmers grow crops and keep livestock. The dominant crops that are grown vary with agroecology. In Kerssa district cereal crops such as sorghum, maize, wheat, barley and beans are cultivated. Sorghum and maize are given priority mainly targeting animal feed for their high biomass as animal feed. *Khat*, sweat potato and vegetables are also grown. Khat is the main cash crop followed by vegetables and sweat potato. In Babile District oil crop such as groundnut followed cereal crops such as sorghum and maize are given priority. Oil crop is the main cash crop followed by mango fruit. The type of livestock keep by farmers both in the highland and lowland agroecology are cattle, goat, donkeys and hen. Camels are kept only in the lowland ecology (Babile).

Table 1: The socio-economic profile of sampled household (n=268) in Kersa and Babile districts, eastern Ethiopia

Variable definition	Categories	Value	Percent
Sex	Male	202	75.4
Sex	Female	66	24.6
	0-0.5	74	27.6
	0.5-1	74	27.6
Agricultural land holding size(ha)	1-1.5	80	29.9
Agricultural land holding size(ha)	1.5-2	36	12.7
Agricultural land holding size(ha)	>2	4	2.2
Agricultural land holding size(ha) Age mean $\pm$ Std. Deviation		36.6 $\pm$ 11.8	
family size mean $\pm$ Std. Deviation		6.1 $\pm$ 2.5	

Availability of fodder trees and shrubs integrated into farmlands

The result of the respondent's response for integration fodder trees and shrubs into their farmlands were not varied with agroecology (X^{2} = 1.63; df = 1; p =0.21) (Table 2). The result of household survey revealed that, about 67.2% of the respondents have not integrated any fodder trees and shrubs into their farmlands whereas only 32.8% of the respondents integrated fodder trees and shrubs into their farmlands.

Fodder or browse production from trees is one of the benefits of agroforestry. Fodder trees and shrubs become then important as a source of energy and protein to keep the animals' body healthy, improve growth rates and even increase milk and wool production (Azim *et al*. 2011). Hence, it is clear that farmer's involvement in establishment of fodder trees and shrubs in the development of new agroforestry technologies is important, right from the beginning. However, in the study area most of the farmers (i.e. about 67.2% of the respondents) have not integrated any fodder trees and shrubs into their farmlands. Roothaert, (2000) noted that farmer's decisions to allow trees to grow on the farm are influenced by such as beauty, tradition, believes or personal preferences. In the study area factors such as inadequate extension services, lack of planting material and land scarcity respectively (fig 1) are the reasons that were identified by the respondents for not integrating fodder trees and shrubs into their farmlands. Although farmers seem to have a clear idea of the feeding value of fodder trees, and interested to grow them on-farm, ignoring these farmers' factors may result in reduction of farmer's adoption of agroforestry practice for fodder production.

Table 2: Farmers' response on fodder trees and shrubs in different agroecologies in eastern Hararghe, Ethiopia

Variable definition	Categories	Kerssa district (%)	Babile district (%)	Total (%)	X^2- Test
Fodder trees and shrubs integrated into farmland	0 = no 1= yes	61.5 38.5	72.5 27.5	67.2 32.8	0.06
tradition of tree inclusion on farmlands	0 = no 1= yes	16.9 63.1	23.2 76.8	20.1 79.9	0. 21
Feeding system	Stall feeding Stall feeding + grazing Grazing	50.8 36.2 13.1	5.1 29.0 65.9	27.2 3.5 40.7	0.000***

***superscript indicates significant difference between studied parameters of respondents

However, few numbers of respondents (32.8%) integrated different trees species as dry season fodder source. While, about 79.1% of the respondents have maintained different types of tree species on their farmland. In general, a total of twenty tree and shrub species were identified in the study area out of which seven species were primarily promoted for construction material, nine for fodder and four for fruit (table 2). As stated by Franzel and Scherr (2002) agro-forestry is a dynamic ecologically based natural resource management system that through the integration of tree/woody perennials into farm and rangelands diversifies and sustains production for increased social, economic and environmental benefits. Thus, fodder agroforestry systems can be designed to deliver additional benefits such as soil and water conservation, timber and fuel wood. Yet, most of the farmers in the study area owned few trees species for the use of construction material. Mainly, *Eucalyptus robusta* is the most dominant and preferred tree species that was maintained by farmers followed by *Cordia africana* in both districts. Farmers in the study area choice *Eucalyptus robusta* as most preferred for construction material because of its fast growing habit and farmers have got a secured market for the species.

Farmers can plant trees/shrub species on the edge of their farm or integrate with food/cash crops. Homestead, farm boundary, live fence, grazing land and farm land were the niches where trees were planted and maintained in the study areas. Among the aforementioned niches, homestead was the most preferred niche by the majority of the respondents followed by farm boundary and farmland (Fig2).

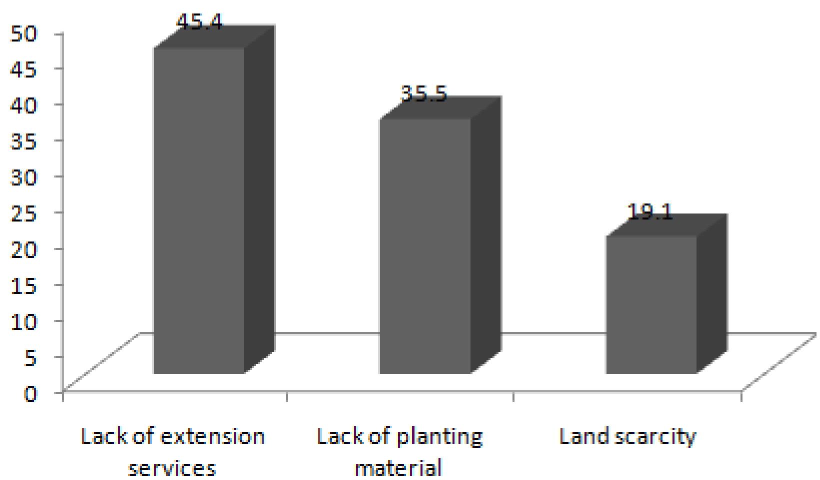

Fig 3. Farmers' Response for the factors not to integrated fodder trees and shrubs into agricultural system in Easten Hararghe, Ethiopia

Tree species composition: Sørensen's Similarity Index was used to assess species composition variation between the different agroecologies (Table 3). The tree species composition showed clear pattern of distributions in relation to the agroecologies. Sørensen's Similarity Index between the districts indicated that only 46% of the tree and shrub species were found common in both districts, whereas about 54% tree species were dissimilar between the districts.

Table 3: Frequency of tree species identified in Kerssa and Babile districts, eastern Ethiopia

Species name	Kerssa	Babile	Species name	Kerssa	Babile
Construction material			*Carissa edulis*	*	*
Cordia africana	*	*	*Gardena ternifolia*	-	X
Casuerina cunninghamiana	*	*	*Grewia bicolour*	-	X
Croton macrostachyus	X	-	*Ricinus communis*	X	-
Eshretia cymosa	-	X	*Sesbania sesben*	X	-
Eucalyptus robusta	*	*	*Terminalia brownie*	-	X
Juniperus procera	X	-	*Ziziphus spina-christi*	-	X
Olea europaea	X	-	*Fruit*		
Fodder			*Annona senegalensis*	X	-
Acacia sieberiana	X	-	*Casimiroa edulis*	X	-
Acacia brevispica	-	X	*Mangifera indica*	*	*
Carissa edulis	*	*	*Psidium guajava*	*	*

*= common species in Kerssa and Babile districts; X = species only found at one district

Not all types of fodder trees and shrubs perform well in each area. Different types of trees and shrubs are suited to different altitudes, climates (depending on temperature and amount of rainfall) and soil types (André van, 2004). In the study area among the identified species as fodder trees only *Carissa edulis* was found in common in both districts. Species used as dry season fodder like *Acacia sieberiana*, *Ricinus communis and Sesbania sesben* were identified only in Kerssa district. While, *Acacia brevispica, Gardena ternifolia, Grewia bicolour, Terminalia brownie and Ziziphus spina-christi* were found only in Babile district. Most of the identified fodder trees in the present study area were indigenous species, which are most suited to the local climatic and edaphic condition of the area. However, exotic species like *Sesbania sesben* also identified in the highland agroecology conditions. *Sesbania sesben is* an important multipurpose fodder shrub exotic to Ethiopia and is originally from east Africa (Mekoya, 2008).

Some of the fodder species identified in the study area (table 2) are similar to those described by many authors in Ethiopia (Shenkute *et al*. 2012; Beyene, 2009; Teferi, 2006; Abule, 2003). Shenkute *et al*. (2012) documented *Acacia tortilis, Ficus gnaphalocarpa, Balanites aegyptica, Dichrostachys cinerea* and *Grewia bicolour* as most widely utilized browse species in Mid Rift

Valley of Ethiopia. Beyene (2009) in his study in south western Ethiopia indicated *Rhus natalensis, Grewia ferruginea, Bauhinia farea, Deinbollia kilimandscharica* and *Acacia seyal* as the common browse in the Gembella National Regional State, Ethiopia. *Acacia species* and *Grewia mollis* were also reported as the most commonly utilized species in the Rift Valley of Ethiopia (Abule, 2003). Teferi (2006) also documented *Ziziphus spina-christi, Acacia asak, Acacia lahai, Balanites aegyptiaca* and *Terminalia brownie* as some of the most distributed browses species in northern Ethiopia.

Feed resource and feeding systems

Grass and crop residues are the main sources of feed in both districts. However, the feeding system are significantly different with agroecology in the study area ($X^{2} =$ 98.8; df = 2; p = 000). In Kerssa district the main feeding system is stall-feeding. The major feed resources are sorghum and maize stover, straw, maize and sorghum leaves, thinned maize and sorghum seedlings and sterile plants, sweet potato leaves, haricot bean leaves and weeds grown in crop fields. Cattle, sheep and goats were observed tied with rope near crop fields or *Khat* fields. However, in Babile district livestock feeding is based on free grazing on communal grazing lands, road sides and crop residue (maize and sorghum stover, groundnut leaf and stem). The most common form of management in the area is mixture of grazing (communal land, crop land) and stall-feeding. Particularly in the khat based agroforestry system of Kerssa district, zero grazing system with stall-feeding technique is the most common practice. This agrees with the idea that grazing land in eastern Hararghe is very little and usually fewer animals are found (Gebregziabher and Gebrehiwot, 2011). More intensive utilization of tree forages and shrubs is dependent on the type of feeding systems practiced. But, an important problem diagnosed in the study area specifically at Kerssa is lack of fodder during the dry season (Figure 3)

Feed shortage is a critical problem in the study areas, mainly during the dry season (March to June) when farmers finish stored feed (Gebregziabher and Gebrehiwot, 2011). According to Preston (1995) the existing feed in resources in the study area, grass and crop residues are poor in quality and provide insufficient protein, energy, vitamins and minerals. Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Hindrichsen *et al.* 2004). In view of the potentially high nutritive value of tree foliage, it was reasoned that deep rooted, woody plants could help to overcome these problem if fed as a supplement to the basal diet (Kabirizi, *et al*. 2006). A number of authors (Alemu *et al*. 1991; Oosting, 1993; Tsige, 2000) also proposed means to achieve better utilization of fibrous feeds include the cultivation and use of leguminous forage crops (herbaceous legumes and fodder trees and shrubs).

Unlike most farmers in the study area, farmers in different region who have similar production systems showed a potential for integrating fodder trees in their farming systems. For example, the farmers in Central Kenyan highlands have experienced the habit of planting fodder trees as a fodder bank around the compound or near the zero grazing units (Thijssen *et al.* 1993). Fagg and Stewart (1994) also noted that browse species have considerable potential for mixed crop livestock production system to overcome low nutritive value of crop residues and mature native pasture that limit livestock productivity in sub-Saharan Africa. Study conducted in Kenya Van der Veen (1993) indicated that browse species can be successfully used in feeding milking animals. Generally, the importance of fodder trees and shrubs become prominent in animal feeding towards the end of the dry season when crop residues are all used up and the quality and quantity of grass is at its worst.

Adaptation and Nutritional Evaluation of Some Selected Fodder Trees and Shrubs Suitable to Eastern Hararghe

Seedling establishment

Based on the data obtained from the seedling survival count, seedlings planted at Kersa experimental site performed better than their counter part at Babile (Table 4). There was no significant difference among most species in their survival rate except *Moringa oliefera* which recorded the lowest ($P \leq 0.05$) survival rate. Among the evaluated species, *Morus alba* performed best (89.58% survival) at Kersa followed by *Cajanus cajan (*87.5% survival**),** *Sesbania sesban (*81.25% survival**)** and *Moringa oliefera* (56.25% survival). At Babile, on the other hand, *Cajanus cajan* survived much better than other species with survival rate of 31.25% while other species showed poor performance with survival rate of 25, 18.75 and 12.5% for *Sesbania sesban*, *Morus alba* and *Moringa oliefera*, respectively.

Table 4: Seedling survival at three and twelve months after planting at Kersa and Babile experimental sites

Treatments	Seedling survival at Kersa at SN3 (%)	Seedling survival at Kersa at SN12 (%)	Seedling survival at Babile at SN3 (%)	Seedling survival at Babile at SN12 (%)
Sesbania sesban	89.583a	81.250a	83.33a	25.000a
Moringa oliefera	68.750b	56.250b	45.83b	12.500b
Cajanus cajan	93.750a	87.500a	70.83ab	31.250ab
Morus alba	93.750a	89.583a	62.50ab	18.750ab
CV (%)	11.042	6.069637	28.966	45.175
LSD ($P \leq 0.05$)	17.976	8.988	35.79	18.606

NB: Values followed by the same letter are not significantly different at $P \leq 0.05$

Morus alba, which has not been considered as fodder tree in Ethiopia, showed good performance at the experimental site. This could be attributed to the agroecological suitability of the area for species. The species grows in areas with a subtropical or mild temperate climate (Orwa *et al*., 2009). The least survival rate recorded by *Moringa oliefera* may be due to the cool climatic condition of the area. Dechasa and Sonder (2006) indicated that the family *Moringaceae* is a native tree in arid and semi-arid regions in the southern Rift Valley of Ethiopia. Therefore, *Moringa oliefera* is more adaptable to lowland agroecology of the country. Orwa *et al*. (2009) also indicated that the species grows best in the altitude ranging 0 to1000 meter above seas level and can grow in areas where the mean annual temperature ranging 12.6 to 40 C^{o}, and mean annual rainfall of at least 500 mm.

Leaf retention potential of fodder trees and shrubs

Data on leaf retention of the fodder trees and shrubs during the dry season revealed that *Morus alba* retained much of its leaves (91.67 %) followed by *Cajanus cajan* (83.33 %), *Sesbania sesban* (45 %) and *Moringa oliefera* (11.67%) at Kersa experimental site. On the other hand, at Babile experimental site it is only *Cajanus cajan* which retained about 40% of its leaves. Other species showed poor performance at this site (Table 5).

Table 5: Leaf retention potential of fodder trees and shrubs during the dry season

Treatments	Leaf retention potential (%) of seedlings at Kersa
1. *Sesbania sesban*	45.00b
2. *Moringa oliefera*	11.67c
3. *Cajanus cajan*	83.33a
4. *Morus alba*	91.67a
CV (%)	29.276
LSD (P≤0.05)	31.925

NB: Values followed by the same letter are not significantly different at P≤0.05

The greatest leaf retention potential of *Morus alba* during the dry season indicates its water stress tolerance capacity. Huang *et al*. (2012) also found that even in the drought stressed systems, growth variables of *Morus alba* increased with time, and no plants died, indicating adaptability to severe drought conditions. The authors concluded that mulberry (*Morus alba)* plant has the ability to adapt to summer drought and soil drought in the hydro-fluctuation belt. Therefore, it can be used as potential source of feed to livestock during dry season when feed becomes scare for the study area. Similarly, Cajanus *cajan* also retained much of it leaves. According to Odeny (2007), the ability of the species to withstand severe drought better than many legumes is attributed to its deep roots and osmotic adjustment (OA) in the leaves. On the other hand, *Moringa oliefera* retained few of its leaves which in turn could be attributed to the less adaptation potential of the species to highland areas.

Nutritional composition of fodder trees and shrubs

Chemical constituent of leaves of fodder trees and shrubs are presented here under (Table 6). There were differences in nutrient content between the studied fodder trees and shrub species. There was significant (P≤0.05) difference among treatments in their dry matter content (DM %). It varied from 88.355 % (*Moringa oliefera)* to 90.984 % (*Cajanus cajan).* There was also significant (P≤0.05) difference among treatments in their ash content. The highest ash content (12.6%) a was recorded in *Morus alba* while the lowest (7.513%) was in *Cajanus cajan.* Significant (P≤0.05) difference was also recorded among treatments for neutral detergent fiber (NDF) and acid detergent fiber (ADF) content of leaves. The highest NDF value (65.360%) was recorded in *Cajanus cajan* and the lowest NDF content (47.010%) was recorded in *Moringa oliefera.* The ADF value also ranged from 21.705% (*Moringa oliefera)* to 37.166% *(Morus alba).* Acid detergent lignin (ADL) value of the studied tree and shrub species also ranged from 9.425% *(Moringa oliefera) to* 14.495% (*Morus alba).* Ether extract (EE %) value of the studied species ranged from 3.042% *(Sesbania sesban)* to 5.783 % (*Cajanus cajan).* The species also showed significant difference (P≤0.05) in their crude fiber (CF %) content where the lowest CF (7.513%) was recorded in *Cajanus cajan and* the highest CF value *(*12.600 %) was recorded in *Morus alba.* Relative feed value (RFV) of the candidate species showed significant difference (P≤0.05) that *Moringa oliefera* recorded the highest value (142.463) followed by *Sesbania sesban* (127.938) and *Morus alba* (117.482) whereas the lowest value (89.851) was recorded in *Cajanus cajan*. Significant difference (P≤0.05) was also observed in hemicelluloses (Hem) and cellulose (Cel) content of the evaluated fodder tree and shrub species. Hence, the highest Hem (32.23) was recorded in *Cajanus cajan* and the lowest (10.359) was recorded in *Morus alba* . On the other hand, the highest Cel value (22.670) was recorded in *Morus alba* and the lowest Cel (11.598) was recorded in *Sesbania sesban.*

Table 6: Some chemical compositions of fodder trees and shrubs planted at Kersa experimental site, eastern Ethiopia

Treatments	DM%	DDM%	Ash%	NDF%	ADF%
1. Sesbania sesban	89.893b	71.244a	9.281b	51.925b	22.665c
2. Moringa oliefera	88.355c	71.992a	9.865b	47.010c	21.705c
3. Cajanus cajan	90.984a	63.092b	7.513c	65.360a	33.129b
4. Morus alba	89.306bc	59.948c	12.600a	47.525c	37.166a
CV (%)	0.5767	2.317	7.546	3.915	6.906
LSD (P≤0.05)	0.973	2.904	1.394	3.904	3.727

NB: Values followed by the same letter are not significantly different at P≤0.05

Though the evaluated species found to have good protein content as most of the browse species had greater CP content than 19, they had high NDF content. Even if there is significant difference among the species for their crude protein content, most of the studied fodder trees and shrubs except *Morus alba* fall in the prime quality standard (above 19%) (Garcia *et al*. 2002, Rivera and Parish, 2010). The CP recorded by *Morus alba* in this study falls in the very good standard range (14 to

16%). The result from the present study agrees with Azim *et al*. (2011) who reported a CP content of 15.46 from the same species. But, the CP value (18.6 %) obtained by Shayo (1997) falls in the excellent standard range (17 to 19%). On the other hand, Deshmukh (1993) and Vu *et al*. (2011) found a CP value of 22.13 and 22.3%, respectively. The lower CP value in the present study might be the poor soil fertility of the experimental site. This indicates that the species has sufficient CP if grown in a relatively good soil condition. The highest CP value of *Moringa oliefera* (i.e. the 25.123% recorded from the present study) indicates its potential as source of protein for animal feed though not the usual practice to use the species as animal feed in the study area. Nouman *et al*. (2013) also indicated that fodder leaves of *Moringa oliefera* have a CP value of 21.87 which is in the prime quality standard range according to Garcia *et al*. (2002), and Rivera and Parish (2010).

The NDF value of the evaluated species ranged from very poor (>65%) to very good (47 to 53%) quality standard according to Garcia *et al*. (2002), and Rivera and Parish (2010). The highest NDF value recorded by *Cajanus cajan* shows its low fodder value. The NDF value found in the present study agrees with the NDF value recorded by Cheva-Isarakul (1992) who found a NDF value of 61%.

Similarly, the ADF content of most of the species except *Morus alba* which recorded a value that falls in the very good range(36 to 40%) falls in the excellent to prime quality standard range (i.e. 31 to 35% and <31%, respectively) . The digestibility of dry matter of all species fall in the very good (58 to 61%) to prime quality standard range (>65%) (Garcia *et al*. 2002, Rivera and Parish, 2010). On the other hand, the dry matter intake of the species fall in the very good range (2.3 to 2.5%) except *Cajanus cajan* which recorded a dry matter intake that falls in the fair range (1.8 to 1.9%).

Conclusion and recommendation

This study indicated that although farmers have clear idea of the feeding value of fodder trees, and interested to grow on their farm, ignoring farmers' factors such as inadequate extension service, lack of planting material and land scarcity would result in reduction of farmers’ interest to integrate fodder trees and shrubs into their agricultural system. Farmers also indicated that if adequate demonstration program is organized and aware them on the potential contribution of trees and shrubs as source of feed for livestock, their management technique and feeding systems, there is still a room to integrate fodder trees and shrubs in to their farming system. The other important point farmers rose as bottleneck is lack of planting material. This justifies the need to provide farmers sufficient planting materials (seed, seedlings or cuttings) and intensify the planting and utilization of fodder trees and shrubs in the available niche at the farmland. By doing so it is possible to increase the current level of the contribution of trees and shrubs as source of feed for livestock in the study areas. However, the species described as fodder by few farmers need further investigation in terms of chemical and tannin analysis, palatability and digestibility in order to enhance their utilization in the future.

Once the species which most easily established, and ones which survived the drought season retaining much of their leaf selected, the next step should be to evaluate their biomass production potential. Therefore, we concluded that *Morus alba* and *Cajanus cajan* showed promising result on their survival rate and leaf retention potential during the dry season. However, nutritionally, *Cajanus cajan* has the greatest NDF value which makes it less preferred by livestock. *Moringa oliefera* also showed poor seedling survival and leaf retention potential though it recorded the best nutritional values. Therefore, due attention should be given to *Morus alba* as a potential fodder tree for mid and highlands of eastern Ethiopia.

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The Ecology of African Elephant:its Implications for HE conflict mitigation, Conservation and sustainable management of the species and their wider habitat in Babile Elephant Sanctuary (BES), Ethiopia

Sintayehu Workeneh

Introduction

African elephants (*Loxodonta africana* Blumenbach) are ecosystem engineers in that they create and maintain ecosystems through physically changing the habitat (Jones et al., 1997). The elephant is believed to be a crucial keystone species for African savannah and forest ecosystems (Western 1989). They play a major role in maintaining the linkages in a food web, and the extermination of these species is expected to cause dramatic changes or extinctions in ecosystems. Moreover, Elephants play an important role as umbrella species, maintaining biodiversity of the ecosystems they inhabit. The elephant is also a flagship species, being closely associated with the social and cultural aspects of people, and this factor can be harnessed to promote its conservation. However, because of the lack of historical evidence on changes in African vegetation and wildlife, there is little direct evidence to show whether the loss of elephants from particular areas has actually led to the loss of other species.

L. africana (Blumenbach, 1797), is one of a number of wildlife species being conserved in Ethiopia's protected areas. Until the turn of the 19th century, the African elephant was widely distributed in the country (Largen and Yalden, 1987). At present, elephants in Ethiopia are among the 37 mammal species that are threatened by extinction (Yirmed et al., 2006). Since the 1980s, Ethiopia has lost about 90% of its elephant population, and hence the species is nationally regarded as critically endangered (Yirmed, 2006). Since then, however, the poaching of elephants for ivory and problems associated with human population growth and expansion has reduced the species range and number drastically. As a result, it is restricted to remote protected areas and a few fragmented populations also exist in the eastern part of the country at Babile Elephant Sanctuary (BES) (Largen and Yalden, 1987). BES, located in the semi-arid part of eastern Ethiopia, is part of the Somali-Masai Centre of endemism. BES, located in the semi-arid part of eastern Ethiopia, is part of the Somali-Masai Centre of Endemism (Yirmed Demeke et al. 2006). This sanctuary is one of the protected areas in the country established to protect the only viable elephant population in the Horn of Africa. These elephants have been separated from other populations in Ethiopia for more than eight decades. Despite the establishment of the Sanctuary in 1970, their range of distribution has shrunk considerably. As a result of mass influx of a large number of farmers and their livestock from the east and north, the home range of elephants of Babile has shrunk by about 65.5 percent since 1976 (Yirmed Demeke et al. 2006). Moreover, a recent year 10,000 hectares of the north western part of the land given to a private company engaged in the cultivation of castor used for production of biofuel (Yirmed Demeke et al. 2006) is being described as a calamity to the already declining elephant population and other wildlife. Of the total 10,000 hectares of land granted to the company, 87.4% was proved to fall within the boundary of the Sanctuary, and of this 79.2% were within the present elephant ranges movement corridors and regular feeding grounds for elephants (Yirmed Demeke et al. 2006). Local communities around the area are highly dependent on vegetations for fencing, medicine, construction and fuel wood (Anteneh and Feaven, 2008). However studies dealing with conflicts between the conservation of Elephant and human activities are scarcely known in many region of Ethiopia including Babile Elephant Sanctuary where large numbers of Elephants are found (Yirmed Demeke et al. 2006). So, the present investigation was aimed to provide information on human impact and interference on conservation of elephant (Loxodonta africana) and their wider habitat in the area. This study quantify the history, type and nature of the conflict between conservation of elephant and human activity in the study area

Results

Attitude of the local people towards conservation area: Out of the 220 respondents, 86.4% opposed the existing Elephant conservation systems, while 9.5% supported. However, there was significant difference on attitude towards the conservation of Elephant in the area among village residents ($x^2 = 4.3$, DF=6, P>0.05). There was a significant difference in the attitude towards wildlife conservation between different age classes ($x^2 = 181.24$, DF=6, P< 0.05). Younger generation, age class (16-30) showed more significantly positive attitude than older age groups (age >31 years). Sex was important in determining the attitude towards conservation area (x2 = 29.2, DF=2, P< 0.05). Male respondents had more positive attitude (81%) than females (19%). conservation systems, while 9.5% supported.

Benefits from protected area: Out of the respondents, 83.2% believe they did not receive any benefit from the existence of sanctuary in their area. The expected benefits were opportunities for job, social services such as clinic, school and resources (firewood, free grazing and grass for own use and sale). Few of the respondents (16.8%) noted that they have received benefits from the protected area. There was difference in the vision of benefit ($x^2 = 0.876$, DF=3, P> 0.05) between respondents among the study sites.

Views of respondents on Elephant: Among the respondents, 40.91% stated that Elephant is not important and the continued existence of Elephant had a negative impact on their livelihood, while 30.45% had no idea on the matter. However, 28.64% of this considered elephant as important. Reason given for the importance of elephant includes elephant attracting tourists, enjoyment of seeing, and importance for future generations. The views of elephant did not differ significantly (x2= 1.3, DF=6, P>0.05) among respondents from the four study sites.

Trends in Elephant population: The surveys in the villages around BES revealed the views of villagers on trends of elephant populations in the Sanctuary. Most of the respondents (56.8%) have remarked that elephant populations have declined in their areas. However, 27.3% of the respondents remarked that the elephant populations have increased. Only 15.9% of the respondents were unsure whether the population of elephant is increasing or decreasing. The view of respondents among the different villages was statistically significant (x2= 27.8, DF=6, P<0.05).

Resource conflict between human and elephant: The basic premise in the present study, the conflict between conservation of elephant and human activities has escalated because of a change in land use especially, the expansion and intensification of arable farming land in and around the Sanctuary and the high increase in livestock number and settlement in the Sanctuary.

Human population

The Babille ES has been continually under threat from growing human populations, particularly in the northern and northwestern parts of the Sanctuary and its adjacent areas, where agriculture is the predominant activity of the residents. Population pressure in and around the area has resulted in high environmental degradation and loss of habitat for the elephant. Based on the crude estimates of the Population and Housing Census of 1994, the population density of Babille District had increased from 18 persons per km2 in 1990 to 26 persons per km2 in 1995, an increase of 47.8% (EHPEDO, 2004)

Habitat destruction and disturbance

Results of direct field observations in the study area showed that the habitat and vegetation of the BES has changed dramatically. The major components of habitat destruction and disturbance in the study area were settlement in and around the Sanctuary, overstocking livestock, frequent fire and bush encroachment and tree cutting. Tree cutting was mainly associated with new settlements, expansion of agriculture and use of tree as raw materials for households, and for fuel, sale and construction of huts and used the grass primarily for grazing, thatching house and sale which resulted in deterioration of Elephant habitats. This also minimizes the feeding and mating and resting site of the Elephant. Field observations and group discussions in the study area showed that the purpose of expanding cropland and to avoid wild carnivores that attack human and livestock. Disturbance through the habitat and constant passage of local people on horseback and on foot by uttering and shouting along the length and width of the Sanctuary have become a common activity.

Clearing of the Sanctuary area for investment

The company started its operations inside the Sanctuary in March 2007 with the consent of the Ethiopian Investment Agency (EIA) and the Oromia Investment Commission for plantation of castor seeds for biofuel production. With the help of about 15 tractors, Flora Ecopower cut down the *Acacia commiphora* and bush vegetation in the northern and northwestern sections of the Sanctuary. No Environmental Impact Assessment was prepared by or required from the company before commencing these activities. The consequences of allowing the investment project to operate in this core elephant conservation area were outlined. According to Yirmed (2008) of the total 10,000 hectares of land granted to the company, 87.4% was proved to fall within the boundary of the Babille ES, and of this 79.2% were within the present elephant ranges

Elephant poaching

According to the questionnaire survey, 65% of the respondents claimed that elephant poaching had been practiced in the area while the rest said it was not practiced in the area. Out of those claiming the presence of elephant poaching, 37% said it was practiced until the establishment of EPRDF, while most (63%) claimed it is practiced even now in the area. Regarding the period at which elephant poaching was intense, most of the respondents (86%) said it was very intense during the Transitional Government, 7% of them said it was during the Dergue Regime, while the remaining said they did not know about it. The main causes reported to contribute for intense elephant poaching during the Transitional Government were illegal firearm trade, and political and social instability in the country. Subsequent restoration of political and social order in the country, local disarmament of illegal firearms and the initiatives taken by the local governmental body to protect the area might reduced the poaching pressure on elephants.

Elephant induced damage

The result of group discussion with the local peoples revealed that elephants were consistently raiding crops, vegetables and fruits and attacking crop-stores around their home range. They were also causing social problems including preventing people from walking at night. According to the group discussion and direct observation in the study area showed that crop-raiding by elephants is often a severe problem in the area, and individual farmers lose an entire year's crop overnight, and risk their lives in defense of their crops. Among the households, 58.2% experienced crop damage. The majority of respondents (45%) reported elephant caused very little damage to their crop and none of the respondents faced very much damage. Respondents differed ($x2= 45.43$, DF=2, $P<0.05$) in their views on whether or not elephant caused problems in relation to distance from their respective areas. People who live inside the Sanctuary area generally face many problems than those living within 4 km vicinity of the Sanctuary. Regarding the seasonal distribution of the crop damage problem, 71.1% said that it occurs during the wet season. When asked about other problems caused by elephants, out of the 73 households surveyed, 46.6% claimed that elephants have not caused any other problem, 33.3% claimed that elephants brought Tsetse flies and as a result livestock are attacked by trypanosome, while 30.2% expressed that elephants caused sleeplessness and extra labor cost on family members.

Protective measures adopted

All the respondents used different traditional methods to mitigate crop damage due to elephants. These include staying in the field watching, throwing objects, producing noise by biting drum or shouting loudly, keeping fire burning, use of brightly coloured objects and a wide and deep trench as a barrier and using banging on tins or drums to chase away approaching elephants. The technique has been used for millennia and is successful.

Monitoring Elephant population size, structure and distribution

Data on the population size, status and the spatial and temporal distribution of elephant was collected for effective management and conservation of this endangered species. To achieve this objective, we continued gathering population size, status and distribution data in the Erere, fedid, and fike area of Babile elephant sanctuary. Two methods were used namely attempted total counts and line transects method.

Objective 2: Determinants of spatial and temporal distribution of elephant

We proposed to investigate the factors which determine the distribution of elephant. In particular, we proposed to investigate the ecological, anthropogenic, and physical factors that determine how elephant use space. These factors included vegetation type, vegetation cover, slope, distribution of water, human settlements, number and diversity of other animals, human presence etc. We had also proposed to use GPS-GSM (Global positioning System - Global System for Mobile communication) collars in order to obtain real-time data on elephant locations and movements. However, we could not obtain financial resources to implement this component. We therefore only report the influence of human settlements on the distribution of elephant. We mapped all the human settlements areas using GPS receivers.

Basic information

- ✓ Demography(sex, age, household size etc)
- ✓ Farming system
- ✓ Number and type of animals they own
- ✓ Total human population in the study area
- ✓ House type and safety
  - Were collected

Elephant data

- Attacking approach of elephants(Any Behavioral change)
  - ✓ In groups, pair, single
  - ✓ Time of attack both animals and humans (Morning, Evening, Mid-day or mid night etc)
  - ✓ History of similar attack in the last 5 years (yes, No, if yes where…)
  - ✓ Seasonality of attack(Months with high incidence)
  - ✓ Number of elephants died in retaliation by people
- Possible reasons for the attack (To be ranked)
  - ✓ Habitat disturbance by men
  - ✓ Feed shortage/scarcity
  - ✓ Overpopulation/high density
  - ✓ Retaliation or revenge of human beings
  - ✓ Attack by other clans that do not belong to them
  - ✓ Rabies suspicion
    - Were collected

Discussion

Protected areas are a cornerstone of conservation policy (Wynne, 1998). However, such areas are continually under threat from growing human population in the tropical developing countries. This is particularly the case in the Babile area, where growing population has developed as a threat protected areas directly by encroachment of wildlife area. Community perspectives towards the conservation area stem from a variety of contributing factors including loss of access to resources and benefits generated from conservation area, awareness concerning the importance of wildlife and crop depredation by wild animals (Kiss, 1990). Human-wildlife conflict in BES is longstanding issue (Yirmed et al 2006). The increased number of human population resulted in a severe competition with the wildlife resources of the conservation area. The Sanctuary is fully affected by human impact throughout the year. Such intense pressure will curtail the normal activities of Elephant. The absence of a proper fence also makes people and livestock easily to move through the Sanctuary in all direction without any limit. The failure to take action to revert illegal firearm possession in the past fifteen years makes the country lose its wildlife resources due to poaching (Shibru Tedla, 1995; Yirmed Demeke, 1997). Since 1995, however, local disarmament of illegal firearms from the local people and the interest local officials have developed and the action they have taken to bring the area under protection could have played major role in minimizing elephants and other wildlife killing in the area. Thouless (1994) mentioned that the extent of crop raiding varies depending on habitat type, elephant use pattern and distance from the boundary. The relatively high incidence of crop raiding in BES was also related to the above three factors. Crop raiding takes place during wet season with its peak in June and July that may be due to the optimal stage of growth of cultivated. Many studies have shown that the cost of conservation is the result in negative attitudes while benefits create a positive outlook (Fiallo and Jacobson, 1995). Most communities strongly need free access to grazing for their livestock in the Sanctuary. They also claim that they have the right to utilize the natural resources of their area. To bring sustainable wildlife management and rural community development at Babile, it requires reconciling the interest of stakeholders. These will be achieved only when their interest become balanced. To balance it, requires solving the conflict between the interest of the community and the conservationists. Some of the measures to reduce the problems are introducing family planning, reducing the livestock number, emphases on quality, introduction of animal forage extension, and awareness program towards wildlife, solving the problems of potable water, grazing land shortage, low production and productivity and introducing other community services.

Conclusion

There is a continuing decline in the extent and quality of elephant habitats in BES. Having poor conservation status, BES is faced with many threats attributed to an increase in human activities including intensive agricultural activities, incursions of large number of livestock, deforestation for fuel wood and construction, uncontrolled bush fires for charcoal production, investment for biofuel production and poaching. The activity of human is increasingly affecting elephant conservation as many elephants get killed by illegally by local people in attempts to reduce the conflict.

Uncontrolled human activities will ultimately result in considerable loss of biodiversity, hamper movements of large herbivores such as elephants and consequently intensify human wildlife conflicts. The habitat of Elephant destruction is caused by alteration of natural habitats for different human uses such as ultivation, livestock grazing, investment and space for human settlement. Changing the attitude of local communities through education and sharing of benefits associated with the wildlife can serve as a means for sustainable conservation measure.

Evaluation of the Potential of Camel Milk and Extracts from Major Plants Browsed by Camel for the Treatment of Diabetes

By

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Sponsered by HrU Government Research Grant

Introduction

The camel (*Camelus dromedaries*) is an important livestock species uniquely adapted to hot arid environments (Yohannes et al, 2007) and it is the most numerous in the arid areas of Africa, particularly in the arid low lands of eastern Africa namely, Somalia, Sudan, Ethiopia, Kenya and Djibouti (Schwartz and Dioli, 1992) covering close to two thirds of the world’s camel population (Yohannes et al, 2007). Ethiopia's camel population is estimated to be one million head (FAO, 2001). This number ranks the country third in Africa after Somalia and the Sudan and fourth in the world. Camel’s milk constitutes an important part of the diet in pastoral societies in arid and semiarid regions (Sallam Bakheit et al, 2008).

The annual camel milk production in Ethiopia is estimated to be 75, 000 tones (Felleke, 2003) but surplus of camel milk is produced in the country during the rainy season. Although not studied in depth as compared to milk of other domestic animals, so far a lot of information has been reported about camel milk from different countries. However, despite the important contribution of camel milk to pastoralists living in the lowlands of the Ethiopia, little emphasis is put into find out the potential of camel milk in healing some of the ailment in the pastoral society.

Camel milk has traditionally been used to treat diabetes because camel milk does seem to contain high levels of insulin or an insulin-like protein which appears to be able to pass through the stomach without being destroyed and it is an effective supplementation in the management of type I diabetes as there is a significant reduction in the dose of insulin along the betterment of life for the diabetic patients (Agrawal et al, 2002).

The primary treatment for Type I diabetes mellitus is insulin replacement, however, at present the entire physiological insulin replacement can’t be achieved in clinical practice and the metabolic disturbance of the patient can’t be normalized. However, still insulin therapy is the best treatment, yet the medical procedures and the cost of treatments attached with it makes patients to look for an alternative way of therapy (Agrawal et al, 2002).

Studies have suggested that drinking almost a pint of camel milk daily improves blood glucose levels and reduces the need for insulin. Experiments done around the world have shown that camel milk was successfully tested on laboratory animals and clinical studies on diabetic patients resulted in a drastic fall in their blood sugar levels (Rastellini et al, 1997).

The pastoralist community seems to be immune to diabetes to some extent because camel milk is part of the staple diet. Several reports indicated that daily drinking of camel milk may supplement as much as 60 percent of the insulin in diabetic patients. This is due to the fact that camel milk is not neutralized by the acidic juices in the stomach, unlike other forms of orally administered insulin sources obtained through foods. The stomach's acidity would normally destroy insulin and this is probably the case why developing oral administration of insulin is such a challenge (Ikebukuro et al, 2002).

Diabetes is a chronic disease that is relatively common throughout the world. In the year 2004, according to the World Health Organization reports, more than 150 million people suffered from diabetes (WHO, 2004). In this regard, the challenge to the mankind has been enormous and the quest to overcome this challenge has increased in many fronts.

Ethiopia has a population of 85 million. This figure would rise to 160 million by 2050. The number of people affected by diabetes is not accurately known. However, it would be the largest in the African continent. The use of natural products and easily available drugs especially milk from camel is the best choice since it is the food source and also a possible crude drug that could be used to treat many major diseases such as TB, Diabetes etc.

Therefore this study was aimed to investigate systematically with well developed scientific methodology, the potential of camel milk and extracts of major plants browsed by camel for the treatment of diabetes. By doing so it also aimed to add more value on camel milk so as to be used one opportunity to improve the livelihood of the pastoralist community. In the first phase of this project the data on plant species browsed by camel was completed, extracts was prepared and nutrient analysis was done in the animal nutrition laboratory of Haramaya University. For the second phase, experiment on the diabetic rat, the major chemical known as Streptozocin/STZ couldn't be able to get in the Ethiopia so that we are trying to access it from India.

Research Question

Several reports have indicated that camel milk is being used by the pastoralist community for the treatment of diabetes.

- Where is this therapeutic potential coming from?
- Is it the inherent property of the camel milk or is it coming from the plants browsed by the camel?

Hypotheses

Camel Milk Vs Experimental Animals

Ho: There is a direct relationship between the camel milk and the experimental animals (rats) which are positive for diabetes. Therefore, the experimental rats which are positive for diabetics and feed on camel milk for three months will show improvement of insulin level in the blood.

Ha: There is no relationship between the camel milk and the diabetic rats under the experiment. Therefore, at the end of the study the diabetic rats which feed on camel milk for three months do not show any change on the insulin level in the blood.

Plant Extracts Vs Experimental Animals

Ho: There is a direct relationship between the plant extracts browsed by camel and the experimental animals (rats), which are positive for diabetes. Therefore, the experimental rats which are positive for diabetics and feed on plant extracts browsed by camel for three months will show improvement of insulin level in the blood.

Ha: There is no relationship between the plant extracts browsed by camel and the diabetic rats under the experiment. Therefore, at the end of the study the diabetic rats which feed on plant extracts browsed by camel for three months do not show any change on the insulin level in the blood.

Objectives

Specific Objectives

The objective of the study will be:

1. To enhance the value of camel milk through analysis of the safety, quality and efficacy of camel milk for the treatment of diabetes

2. To assess the contribution and relevance of vegetation browsed by camel as source of drug value in camel milk for the treatment of diabetes.

3. Promotion and popularization of camel milk for the wider consumption

4. To include MSc thesis project as part of the project.

5. To generate baseline data helpful for further research approach.

Methodology

Streptozotocin or Streptozocin or Izostazin or Zanosar (STZ) is a synthetic antineoplastic agent that is classified as an anti-tumor antibiotic and chemically is related to other nitrosureas used in cancer chemotherapy. Streptozotocin sterile powders are provided and prepared as a chemotherapy agent. Each vial of sterilized Streptozotocin powder contains 1 gram of Streptozotocin active ingredient with the chemical name, 2-Deoxy-2-[[(methylnitrosoamino)-carbonyl] amino]-D- glucopyranose and 200 mg. citric acid. Streptozotocin was supplied by Pharmacia Company. Streptozotocin is available for intravenous use as a dry-frozen, pale yellow, sterilized product. Pure Streptozotocin has alkaline pH. When it is dissolved inside the vial in distilled water as instructed, the pH in the solution inside the vial will be 3.5-4.5 because of the presence of citric acid. This material is prepared in 1 gram vials and kept in cold store (Refrigerator temperature of 2-8 °C) away from light (Weiss, 1982).

Sampling plants browsed by camels

The major plants frequently browsed by camels were carefully and properly collected from the study areas namely Erer valley (Babile Wereda of Oromia region) and Shinile areas of Somali region. The botanical origin and taxonomical identification was made at the University's Herbarium. The collected plant materials were dried, grounded and and the nutrient analysis was done in animal nutrition laboratory of Haramaya University. The rest of the powder was stored for further analysis of plant extracts on the diabetic rats.

Induction of diabetes and management of experimental rats

Hundred adult rats from both sexes weighting 250-300 grams (75-90 days old) will be purchased from the Health and Nutrition Institute in Addis Ababa. The rats will be segregated according to sex and given one week of adaptation to their new home. Body weights will be measured at the start of the experiment. Then, they will be divided into three groups: Group one Control and Group two will be induced for diabetics using streptozotocin. Group three will be injected with the extracts of plants browsed by the camels. This group will be again divided into subgroups according to the number of plant species browsed by the camel. The animals will be injected intravenously with streptozotocin at the dose of 60 mg/kg body weight. Streptozotocin induces diabetes within 3 days by destroying the beta cells (Karunanayake et al, 1975).
Diabetic animals and non-diabetic control group will be kept in metabolic cages individually and separately and under feeding and metabolism control. Body weight, blood Glucose, and urine volume will be measured from each rat before the beginning of the experiment. Food consumption (grams), water consumption (ml), and urine volume (ml) will be measured daily. However, C-peptide, insulin and blood glucose will be measured every 30 days of the experimental period so that the chemical diabetes will be verified in rats injected with Streptozotocin (Bhuyan et al, 1974). Glucose, urea, and creatine will be monitored in the urine as deemed necessary.

Measurement of glucose, insulin and C-peptide in rats' serum

Normal and diabetic rats will be anesthetized with ether (two min. contact with ether does not affect blood glucose, insulin or C-peptide concentrations). One ml. of blood will be taken from rats in order to measure glucose, insulin and C-peptide (Levi et al, 1977). Blood will be taken from the heart. The samples will be collected in sterilized tubes and kept at 4 °C and, after separating the clot, the serum will be separated by centrifuging. Blood glucose will be measured by the glucose-oxidase method, insulin and C-peptide by radio-immunoassay method. This phase of the work will be carried out once every 30 days for 90 days in diabetic and control counterparts (Thulesen et al, 1997).

Pancreatic biopsy of normal and diabetic rats

For the study and comparison of pancreas Langerhans islet beta cells in diabetic rats inducted by Streptozotocine, and normal rats, pancreatic biopsy of normal and diabetic rats will be done and samples will be fixed in 10% formalin, stained by Hematoxylin&Eosin and will be photographed by microscope camera for the comparison of these tissues and the tissues of Pancreatic Langerhans and the beta cells of diabetic rats will have been degenerated irreversibly (Holemans et al, 1997).

Treatment of diabetic rats by camel milk

The model diabetic rats will be provided with 0.1lit/kg.day of camel every day until the end of the experiment. The camel milk will be provided in an individual drinking trough every morning for ninety days of the experiment. The camel milk will be purchased from the local community from Shinille and Erer valley areas per arrangement. The milk will be stored in milk coolers during transport and refrigerated upon arrival from the source and will be kept in separate storage. The camel milk obtained from different locations will be provided to individual rats in cages through watering trough. Moring, midday, and evening milk provisions will be made as scheduled in the beginning of the experiment.

Treatment of diabetic rats with plant extracts browsed by the camel

Fresh samples of major plants and all plant parts which are browsed by camel were collected dried under shade to protect the loss of any compound due to sun radiation. The dried samples were ground and the crude extracts were prepared in the chemistry laboratory of the HU. Then, the crude extracts of each plant was kept under low temperature to be used as a feed for the various groups of diabetic rats.

Data Analyses

The plant data were organized on the excel data sheet, analysed and presented in graphs and tables.

In the second phase the data will be collected from control, diabetic sham, diabetic rats treated with camel milk, diabetic rats treated with vegetation extracts, and the combinations (diabetic rats treated both with camel milk and vegetation extracts). Data collected will be processed using the statistical analysis system (SAS Institute and Cary, Inc, NC). Means for triplicate observations will be compared using LSD tests to identify the significant differences among the groups.

Major activities performed

Reconnaissance survey – Study sites were fixed

- From east Hararge zones Babile Wereda was selected and from this Wereda two kebeles were identified based on the number of camel population i. e. Aw-Sherif and Erer Ebada Kebeles

- From the Somali region Shinile zone is selected.

Informant selection was done

- A total of 75 households from each Kebele or village was taken randomly and key informants selected. The selection of key informant was using systematic random sampling and other informants by random sampling method.

Questionnaire was developed and pre-tested

Preliminary Results

The major/top plant species browsed by camels

The plant species which are browsed by camel are documented

- From AW-Sherif Kebele of Babile Wereda a total of **29** plant species were documents which are browsed by the camel
- From Erer Ebada in which the natural vegetation is in a good stand and high population of camel is found a total of **59** plant species were documented as browsed by the camel.
- From Shinile a total of **21** plant species which are browsed by the camel were documented

In all study sites top browsed plant species by camel was identified with the local community (Table 1).

Table 1. List of top browsed plant species by camel from Babile and Shinile

Top browsed plant species by camel in Babile study sites				
Code No.	**Local name**	**Scientific name**	**Family**	**Habit**
B01	Haroresa (Or)	*Grewia bicolor* Juss.	Tiliaceae	Shrub
B02	Hudu Qable (Or)	Not identified		
B03	Jirme (Or)	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Shrub
B04	Dergu (Or)	*Pavonia burchellii (DC.) Dyer*	Malvaceae	Shrub
B05	Dhirii (Or)	*Acalypha fruticosa* Forssk.	Euphorbiaceae	Shrub
B06	Sophensa (Or)	*Acacia senegal* (L.) Willd.	Fabaceae	Shrub
B07	Likimee (Or)	*Rhus natalensis* Krauss	Anacardiaceae	Shrub
B08	Serkema (Or)	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	Tree
B09	Alibal (Or)	*Ochna inermis* (Forssk.) Schweinf. ex Penz.	Ochnaceae	Shrub
B10	Hamareessa (Or)	*Acacia brevispica* Harms	Fabaceae	Shrub
Top browsed plant species by camel in Shinile study site				
Code No.	**Local name**	**Scientific name**	**Family**	**Habit**
Sh01	Qudaha (S)	*Acacia tortilis* (Forssk.) Hayne	Fabaceae	Tree
Sh02	Adad (S)	*Acacia senegal* (L.) Willd.	Fabaceae	Shrub
Sh03	Adey (S)	*Salvadora persica* L.	Salvadoraceae	Shrub
Sh04	Gelol (S)	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	tree
Sh05	Geres (S)	*Dobera glabra* (Forssk.) Juss. ex Poir.	Salvadoraceae	Tree
Sh06	Asha'ado (S)	*Grewia schweinfurthii* Burret	Tiliaceae	Shrub
Sh07	Lebi (S)	*Delonix elata* (L.) Gamble	Fabaceae	Tree
Sh08	Qalan (S)	*Cadaba rotundifolia* Forssk.	Caparidaceae	Tree
Sh09	Qadew (S)	*Cadaba glandulosa* Forssk.	Caparidaceae	Shrub
Sh10	Qud (S)	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	Tree
Sh11	Sala'asays (S)	*Triumfetta heterocarpa* Sprague & Hutch.	Tiliaceae	Shrub
Sh12	Hangey (S)	*Sarcostemma viminale* subsp. *stipitaceum*	Ascelepiadaceae	Climber

Or = Afan Oromo; S= Somali language

Population structure of woody species browsed by camel in the Babile site

The population structures for some of the woody species browsed by camel were analyzed for the Babile site. The population structure of woody plant species which are highly browsed by camel exhibited both healthy (like, *Grewia bicolour, Acalypha fruticosa*, *Acacia brevispica*) and hampered regeneration (like, *Acacia nilotica*, *Dichrostachys cinerea*) (Figure 1). Most of these highly browsed plant species are locally threatened.

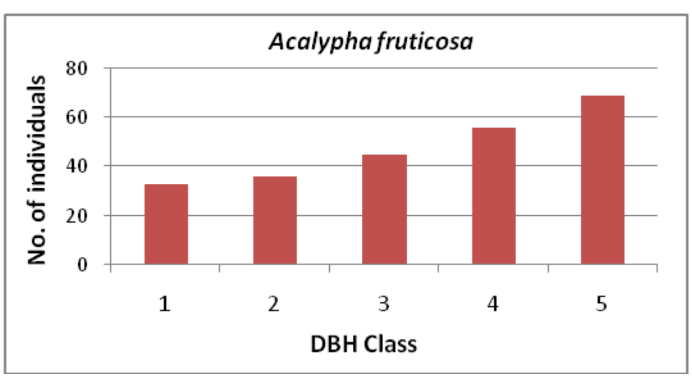
In general, the population structure of the ten highly browsed woody species by camel in the Babile site reveals four main patterns of population distribution.

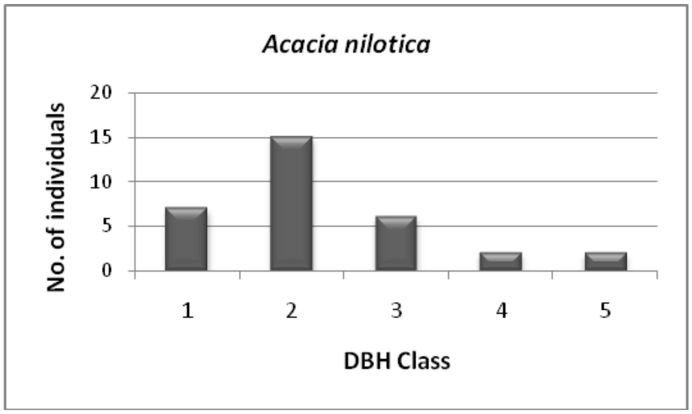
I) An inverted J-shaped, which shows a pattern where species frequency distribution has the highest frequency in the lower diameter classes and a gradual decrease towards the higher DBH classes e.g., *Grewia bicolour, Pavonia burchellii,* Acacia *brevispica.*

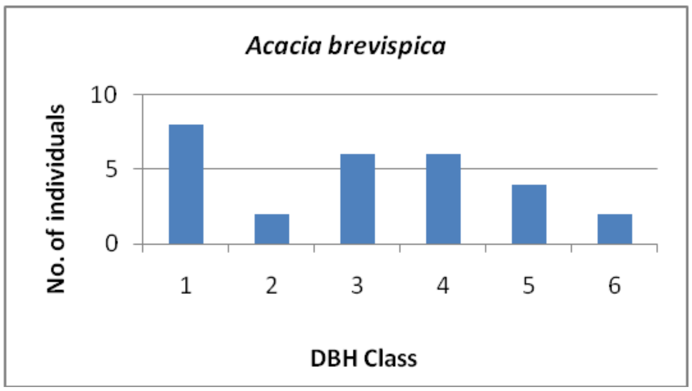
II) Broken inverted J-shaped. e.g., *Rhus natalensis.*

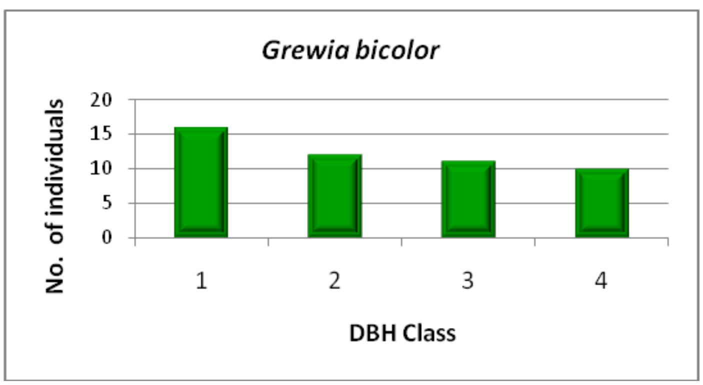
III) U-shaped, this shows a type of frequency distribution in which there is a high number of lowest and highest diameter classes but a very low number in the intermediate classes e.g., *Dichrostachys cinerea.*

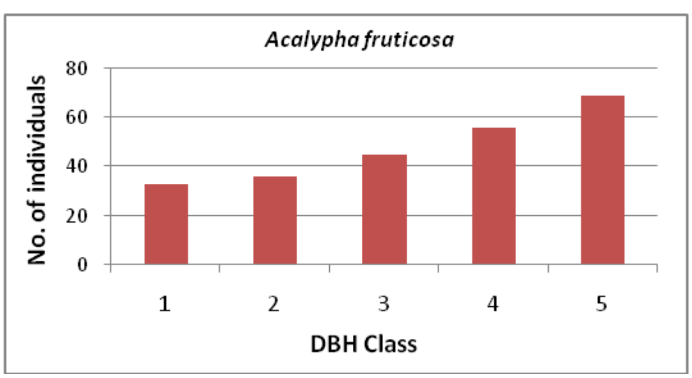
IV) Bell-shaped, which is a type of frequency distribution in which number of individuals in the middle diameter classes is high and lower in lower and higher diameter classes e. g., *Ochna inermis.*

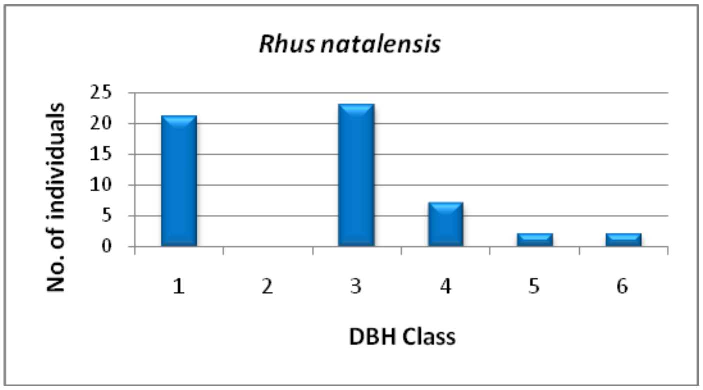



Acacia nilotica
No. of individuals
20
15
10
5
0
1
2
3
4
5
DBH Class


Acacia brevispica
No. of individuals
10
5
0
1
2
3
4
5
6
DBH Class


Grewia bicolor
No. of individuals
20
15
10
5
0
1
2
3
4
DBH Class


Acalypha fruticosa
No. of individuals
80
60
40
20
0
1
2
3
4
5
DBH Class



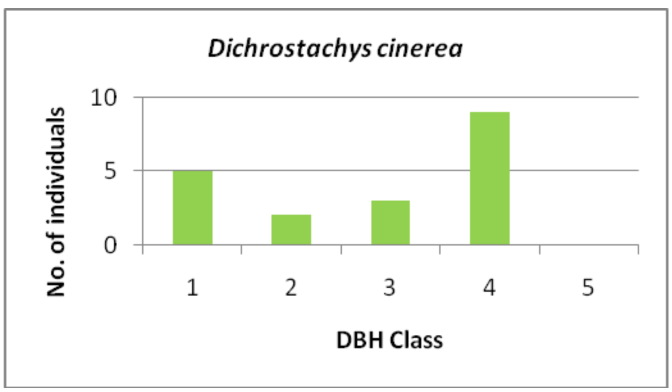


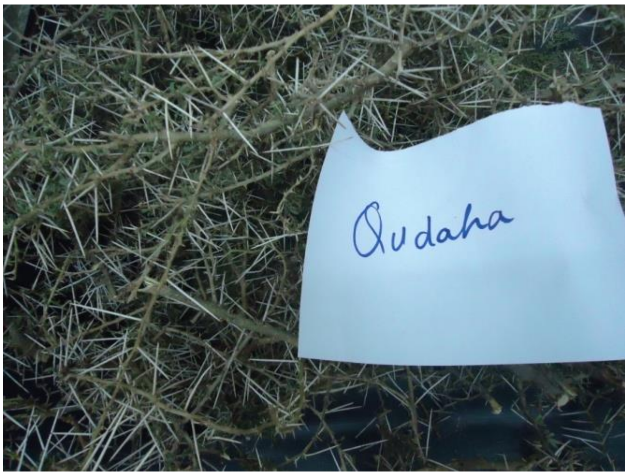
Figure 1. Diameter class frequency distribution of multi-purpose woody species (DBH class: 1 = 1-4.99 cm; 2 = 5-9.99 cm, 3 = 10-14.99 cm, 4 = 15-19.99 cm, 5 = 20-24.99 cm, 6 = 25-29.99 cm, 7 = 30-34.99 cm, 8 = 35-39.99 cm, 9 = 40-44.99 cm, 10 = 45-49.99 cm…).

The hampered regeneration may indicate selective removal/exploitation of the trees by the local people, poor regeneration due to over browsing and recruitment in the lower class and may be absence of regeneration at one particular time in the past. In general, the population structure analysis showed more irregularities in which the regeneration of most important woody species which are browsed by camel are hampered, suggesting an urgent need for a conservation plan to promote sustainability of these woody vegetation resources in the Babile area so as to develop the camel population in this potential camel breeding sites.

Discussion with the key informants to identify the plants species browsed by camel according to the degree of preference

Field observation and confirmation to collect the plants mentioned by the community

Identifying the plant species best preferred by the camel along with the community with in the natural stand



Phase II. Nutrient analysis of top browsed plant species by camel

A total of 22 plant species from Babile and Shinile were collected. The fresh samples on the parts browsed by the camel were collected, dried under shade, ground and analyzed in HU for nutrient content.

Triplicate of each sample were analyzed so a total of 66 sample were analyzed (of course two plant species are common for both Babile and Shinile but the analysis were done separately) for moisture, crud fiber, protein, fat, and ash contents.

Table 2. Nutrient content of top browsed plant species by camel in Babile (B01-B10) and Shinile (Sh01-Sh12)

Sample code	**Species name**	**Family**	**Vernacular name & Language**	**DM %**	**ASH**	**OM %**	**EE %**	**CF %**	**CP %**	**TN %**
B01	*Grewia bicolor* Juss.	Tiliaceae	Harore sa (AO)	92.03	10.08	89.92	3.27	24.57	15.36	2.46
B02			Hudu qable (AO)	91.90	12.23	87.77	2.44	21.55	18.18	2.91
B03	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Jirme (AO)	92.21	6.51	93.49	1.92	19.26	15.17	2.43
B04			Dergu (AO)	91.53	7.70	75.97	3.92	12.18	23.43	3.75
B05	*Acalypha fruticosa* Forssk.	Euphorbiaceae	Dhirri (AO)	91.48	14.81	85.19	3.22	20.83	20.13	3.22
B06	*Acacia senegal* (L.) Willd.	Fabaceae	Sophen sa (AO)	90.02	11.41	88.59	3.13	23.76	17.01	2.72
B07	*Rhus natalensis* Krauss	Anacardiaceae	Likime (AO)	92.89	18.23	81.77	3.17	21.34	25.18	4.03
B08	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	Serkama (AO)	91.97	5.31	94.69	4.22	12.25	12.44	1.99
B09	*Ochna inermis*	Ochnaceae	Alibal (AO)	92.87	6.35	93.65	3.42	15.58	13.22	2.11
B10	*Acacia brevispica* Harms	Fabaceae	Hamar esa (AO)	92.44	7.50	92.49	3.07	16.92	21.88	3.5
Sh01	*Acacia tortilis*	Fabaceae	Qudah a (S)	91.88	14.15	85.85	4.04	21.32	11.47	1.84

SH02	*Acacia senegal*	Fabaceae	Adad (S)	91.59	9.38	90.62	3.02	19.32	13.22	2.12
Sh03	*Salvadora persica*	Salvadoraceae	Adey (S)	90.52	32.97	67.03	2.52	12.76	10.59	1.69
Sh04	*Acacia nilotica*	Fabaceae	Gelol (S)	91.17	10.75	89.25	3.81	17.88	10.98	1.76
Sh05	*Dobera glabra*	Salvadoraceae	Geres (S)	90.25	23.19	76.81	0.72	20.72	10.5	1.68
Sh06	*Grewia schweinfurthii* Burret	Tiliaceae	Ashaado (S)	92.61	17.37	82.63	3.89	18.16	16.92	2.71
Sh07	*Delonix elata* (L.) Gamble	Fabaceae	Lebi (S)	90.55	17.14	82.86	6.33	11.09	12.06	1.93
Sh08	*Cadaba rotundifolia*	Caparidaceae	Qalan (S)	92.235	15.52	84.48	1.77	8.06	15.55	2.49
Sh09	*Cadaba glandulosa* Forsk.	Caparidaceae	Qadew (S)	92.65	23.50	76.49	2.19	19.44	9.63	1.54
Sh10	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	Qud (S)	92.61	18.28	81.72	2.29	18.44	15.07	2.41
Sh11	*Triumfetta heterocarpa*	Tiliaceae	Sala'asays (S)	92.10	9.84	90.15	7.66	20.98	11.67	1.87
Sh12	*Sarcostemma viminale* subsp. *stipitaceum*	Asclepiadaceae	Hangey (S)	93.49	10.46	89.54	7.69	11.43	4.77	0.76

AO = Afan oromo; S = Somali;

Activities to be accomplished

Treatment of diabetic rats with plant extracts browsed by the camel and camel milk after the subscribed chemical (Streptozocin/STZ) from India reached to the research team.

Problem encountered and solution

Streptozocin/STZ (CAS number 18883-66-4) is still not available in the Ethiopian chemical sellers company. Therefore, we are facilitating the purchasing of STZ from India through the expatriate staff of HU.

School of Agricultural Economics and Agribuisness

Impact of disappearance of Lake Haramaya on the livelihood of the surrounding community: the case of haramaya district in oromia national regional state, Ethiopia

By
Jema Haji and Seifemicheal Abebe

General background

The socio-economic values of wetland ecosystems are extremely significant and critically important for all local communities that are dependent on wetland products and resources. Wetlands contribute to the national and local economies by producing resources, enabling recreational activities and providing other benefits (EPA, 2006). Since the year 1900, one-half of the world's wetlands have disappeared (WWAP, 2011). It is also estimated that by the year 2025 approximately 1,800 million people will experience "absolute" water scarcity with less than 500m^3 of available water per year per capita, and two thirds of the world's population could be under "stress" conditions, with only between 500-1000 m^3 of available water per year per capita (FAO, 2011). This is alarming, as water is a vital life source, common to all living creatures, and crucial to the survival of any ecological system (Strang, 2005). The familiarity with existing literature on conflicts, particularly in Africa, suggests that an overwhelming percentage of conflicts are resource-based conflicts (Masari, 2008). The unfolding scenario in the Lake Chad basin is a nodal example in this regard. The rich water resources of this lake have been a source of economic livelihood, sustaining over 20 million people inhabiting the catchments areas. However, in the last few decades, the size of the lake and its resources has continued to diminish. The impact of this depletion is being felt by the Lake Chad basin population who depend on the lake for their livelihood.

Wetlands and their value remain little understood and their loss is increasingly becoming an environmental disaster. While rates of wetland loss are documented for the developed world, the limited study of these ecosystems in countries like Ethiopia is disappointing (Barbier *et al.*, 1996). Ethiopian lakes are of great importance to Ethiopia's economy and essential to the survival of the local people. However, they are threatened by increasing consumption and environmental degradation. The study district was a mother of four lakes. These lakes were excellent surface water resources utilized for irrigation, drinking, and other domestic consumption for rural and urban communities in the district including Haramaya University and home for different beautiful birds and fishes (Abdulatif, 2004).

The water treatment of the study site i.e., Lake Haramaya was designed to serve a maximum population of 70,000. However, currently the user population is more than 150,000. It is constantly threatened by anthropogenic interventions rather than the natural phenomenon. As the calculated water balance for this Lake basin shows, annual abstraction of the groundwater is by far greater than annual recharge rate, indicating that groundwater is depleting at an alarming rate (Wagari, 2005). Lake Haramaya has been used as a major irrigation water source and as a local fishery for Haramaya town and the surrounding farming community for over 40 years (Abdulatif, 2004).

Lake Haramaya is shrinking and completely dried up since 2005 (Haramaya Univesity, 2005). However, especially, after complete disappearance of Lake Haramaya, cultivation of the water dried areas continued in a wider rate. Experts believe that such activities may result in serious negative effect on the ecosystem, environmental balance, the economy of the community (reduction in vegetable production[2]), loss of common grazing land and source of conflict among the individuals around the Lake in particular and the district in general (Abdulatif, 2004).

Abdulatif (2004) indicated that, the loss of the Haramaya lake water resulted in loss of wildlife and nesting habitat, different types of fishes habituating in the Lake, drinking and irrigation water, fishing activities, climatic imbalance (such as increased frost during cold time and increase in temperature during hot season), increased cost of production and decreased productivity and creates occurrences of conflicts among farmers due to land ownership and therefore, these adverse impacts of the environment are obviously catastrophic and have an evil consequence on the country's economy in general and the rural livelihoods in particular.

There were various studies on Lake Haramaya focusing on identifying the causes of the deterioration, ultimate death of the lake and its adverse effects. However, there were no empirical studies which analyzed the impact of the disappearance of this lake on the livelihood of farmers using rigorous econometric methods. There is no single study regarding the impact of the Lake that provides possible areas of policy intervention in the district. So this study is aimed at filling this research gap.

Objectives of the Study

The general objective of this study is to measure the impact of disappearance of Lake Haramaya on the livelihood of the surrounding community.The specific objectives are:

i) to identify factors affecting the treatment and total income of the households;

ii) to measure the impacts of disappearance of Lake Haramaya on the households' total income generated from livestock and crop production in the study area.

[2] Haramaya was the only vegetable exporting District to Djibouti and Somalia, while this is almost history after the full or partial disappearance of this Lake (Abdulatif, 2004).

Significance of the Study

This study measures the impact of dried Lake Haramaya on households' livelihood status. The information generated from this study is crucially important and helpful to identify gaps and opportunities that could be used by researchers and policy makers as baseline or as a benchmark for further research to design appropriate interventions for the impact created on societies' livelihood. The research results may also provide benefit to different stakeholders, higher learning institutions, smallholder farmers. In addition, it gives warning and alert for other existing lakes to be properly protected and managed by the concerned bodies from unsustainable human utilization of water. Moreover, it can serve as a good input for sustainable utilization and management of the country's resource base in general and its fresh water resource in particular.

RESEARCH METHODOLOGY

The Data Set and Variables

Haramaya is one of the districts in East Hararghe Zone, Ethiopia. The district is stretching between 1400 and 2340 meters above sea level. Of its total area, 90% is mid-highland while the remaining 10% is lowland agro-climate zones and the mean annual rainfall and temperature are 790 mm and 16.34^0c, respectively (BoFED, 2008).

Haramaya is an agriculturally potential area among the districts in East Hararghe zone. Lakes, Rivers, and springs are irrigation water resources in the district. The district was a mother of four Lakes named Tinike, Haramaya, Addele and Harajitu Lakes. Among the four lakes, Harajitu Lake disappeared before many years, Haramaya and Adelle lakes are now disappearing or became seasonal, while Lake Tinkie is the only living and currently utilized lake in the district.

Livelihood characteristics

The livelihood status (income diversification) of the community in the study areas is mainly based on mixed farming systems with crops and livestock production. Other sources of livelihood in the districts are petty trade and other off/non-farm activities (financial capital), daily labor (human capital), food aid in the form of public work and direct support. The district cash crop economy is widespread, but the higher proportion of the household income came from *chat* production which is about 36.5% (HDARDO, 2011).

Crop production is the primary source of income generation in the study area. The production system in the study area can be described in two ways, i.e. rain-fed and irrigated systems. The rain-fed production system is most dominant and is practiced by the majority of the farmers. Horticultural crops are often produced using irrigation. In vegetable production, farmers practice multiple cropping. The dominant crops grown in the study district are sorghum, maize, haricot beans, vegetables and *chat*. Vegetables and *chat* are the two major cash crops grown in the area. However, the farmers are facing market problem when all farmers produce and harvest at similar seasons. Farmers can produce vegetables three times per year using irrigation (Bezabih and Hadera, 2007).

Methods of Data Collection and Analysis

The study used primary data collected from the six targeted *Kebeles*, which surrounds the Haramaya and Tinike lakes.To account for the problem of heterogeneity in the study area, stratified three-stage random sampling technique was employed and a total of 200 households were randomly and proportionately sampled.

The impact analysis used both descriptive statistics and econometric model. Among econometric methods propensity score matching was employed to quantify important empirical results. Statistical Soft-ware STATA was used for this purpose.

Propensity score matching (PSM) method

Rosenbaum and Rubin (1983) were the first to develop the PSM statistical tool. The technique has attracted attention of social program evaluators since the last twenty five years (Jalan and Ravallion, 2003; Dehejia and Wahba, 2002).

PSM matches each participant household with a non-participant household that has almost the same likelihood of participating into the program. This study also applies a propensity score matching technique to address its main objectives, which is a widely applied impact evaluation instrument in the absence of baseline survey data for impact evaluation.

According to Caliendo and Kopeinig (2008), there are steps in implementing PSM. These are estimation of the propensity scores, choosing a matching algorism, checking on common support condition, testing the matching quality and test sensitivity analysis, and illustrated as:

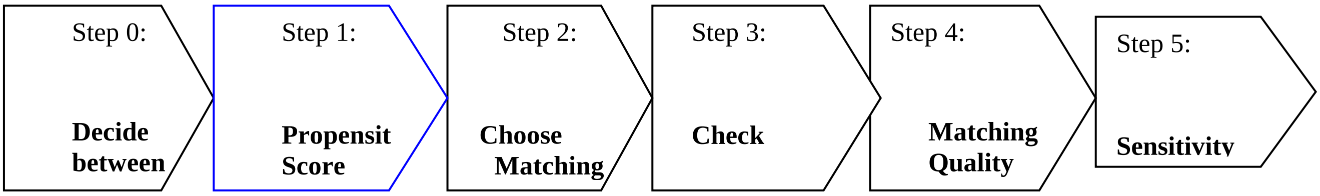


Figure 1: PSM implementation steps

The first step in PSM method is to estimate the propensity scores. When estimating the propensity score in the binary treatment case, logit and probit models usually yield similar results. Hence, the choice is not too critical, even though the logit distribution has more density mass in the bounds (Caliendo and Kopeing, 2008). Therefore, Logit model was applied to predict propensity scores for the PSM method in this study.

2.1.4. Specification of the logit model

Here a question may arise, why Logit model was run for the sampled households, on observable variables. The major concern is that, the logit distribution has more density mass in the bounds and it is the best model to predict the probability of a household to be influenced by the vanished Lake i.e. to predict propensity scores, based on which, the treatment and control groups were matched using the kernel (0.1) estimator. In estimating the logit model, for impact analysis the dependent variable is being near Haramaya Lake that takes a value of 1 and for being near Lake Tinikie that takes the value of 0. Arpino and Mealli (2009) also noted that the logit model which has more density mass in the bounds could be used to estimate the propensity score p(X).

Following Gujarati (2004), the logistic distribution function for the determining factors in livelihood status of the households is specified as follows:

$$P_i = E(Y = 1/X_i) = \frac{1}{1+e^{(\beta_0+\beta_1 \chi_1)}}$$

(1)

$$P_i = \frac{1}{1+e^{-Z_i}}$$

For ease of exposition, we write (1) as (2) The probability that a given household is affected by the disappearance of the lake (participant) is expressed by (2) while, the probability for not being affected (non-participant) is:

$$1 - P_i = \frac{1}{1+e^{Z_i}}$$

(3)Therefore, the odds ratio can be written as: $\frac{p_{(i)}}{1-p_{(i)}} = \frac{1+e^{Z(i)}}{1+e^{-Z(i)}} = e^{z_i}$

(4)

Now ($P_i/1-P_i$) is simply the odds ratio in favor of participating (being affected by the dried lake); the ratio of the probability that a household would be influenced by the Lake to the probability of that they are not influenced. Finally, Taking the natural logarithms of the odds ratio of equation (4) would result in what is known as the logit model as indicated below.

$$L_i=\ln\left(\frac{P_{(i)}}{1-P_{(i)}}\right)=In\left[e^{Zi}\right]=Z_i$$

(5) Where: Z_i= is a function of n explanatory variables (X_i) which is also expressed as

$$Z_i=\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_nX_n \quad (6)$$

Where: β_0, is an intercept, β_1, β_2 . . . ., β_n are slopes of the equation in the model. L_i is log of the odds ratio, which is not only linear in X but also linear in the parameters. X_i is vector of explanatory variables. If the disturbance term U_i is taken into account the logit model becomes:

$$Z_i=\beta_0+\beta_1\chi_1+\beta_2X_2+...+\beta_nX_n+U_i \quad (7)$$

Choice of matching algorithm

The next stage was to choose the matching algorithm which best estimates the p-score. The choice of matching method involves a trade-off between matching quality and its variance. Various matching estimators have been suggested in the literature. The most commonly used matching methods include the nearest neighbor matching, radius (caliper) matching, and kernel matching estimators. Therefore, the estimated average treatment effect on treated (ATT) was done by implementing kernel matching estimator with band width (0.1) and the already mentioned PSM model in this study.

2.2. Definition of Variables, Measurements and Hypothesis

The choice of covariates to be included in the first step (propensity score estimation) is an issue. Heckman *et al.* (1997) argue that omitting important variables can increase the bias in the resulting estimation. Here, pre-intervention characteristics, which bring variation in outcomes of interest among participants and non-participants, were used.

Dependent variable of the model

The dependent variable for this model is participation and has dichotomous nature (dummy); it assumes a value of 1 if the household is the previous vanished lake (Haramaya) users and a value of 0 for the living lake (Tinikie) beneficiaries. This was done by relating the previous and current services of these two lakes with the society's livelihood status in the study area.

The outcome variable: It is a variable which show the livelihood impacts/status of the farmers, and it is measured by the value of annual income from (livestock and crop production) per household.

Explanatory variable of the model

Based on the findings of past studies on determinant of community livelihoods, the major endogamous variables were hypothesized to determine farmers' livelihood status include Age of household head (years), Education level by household head (years), family size (AE), Total livestock holding (TLUs), off-farm and non-farm income (EB), frequency of extension visit (per month/year), farm machinery ownership (binary), use of manure (binary), membership in cooperatives (binary), total cultivated land owned (hectares), number of crops grown/cultivated (hectares), average distance from basic services (KMs) and farming experience of the household head (years) .

RESULTS AND DISCUSSION

Descriptive results

The study results indicate that the before matching difference between the two groups with regard to the agricultural outcome variables (the total mean income from livestock and crop production) per household in the study area were 342472.00 Birr per household per year. Accordingly, the mean income of treated household is 273415.30 Birr and non-treated mean income is 411528.80 Birr.The difference in mean incomes of the treated and non-treated groups is around 138113.60 Birr which is significant at 1 % probability level.

Econometric Model Results

Estimation of propensity scores

A logistic regression model was used to estimate the propensity scores of respondents which help to put into practice the matching algorithm between the treated and control groups in the study area. In estimating the propensity scores, data from both groups were pooled such that the dependent variable takes a value of 1 if the household was participant and 0 otherwise.

In this section, the selected explanatory variables were used to estimate the logit regression model to analyze the determinants of household income and livelihood status. Therefore, the model is a binary logit where the test for linear correlation of covariates is irrelevant and no statistical software is needed to determine the best subset of explanatory variables that are good predictors of the dependent variable.

The pseudo-R^2 indicates how well the regressors explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo-R^2 should be fairly low (Caliendo and Kopeinig, 2008).

Estimating treatment effect on treated (ATT)

After the distributions of treated and non-treated units were located in the same domain, the pre-intervention differences were controlled.The estimated average treatment effect was done by implementing kernel matching estimator with band width (0.1) and the already mentioned PSM model. Therefore, in order to attain the objective of this study the following aggregate level impact indicator of the treatment effect was performed using the PSM model.

Impact estimate on livelihood outcome variable (aggregated on farm income)

Table 1: Estimation of ATT for average total impact on livelihood outcome variable (total annual income) estimated in Birr

Outcome-variable	Treated	Controls	Difference	t-value
Average total annual income	282795.39	409275.43	-126480.00	-2.76***

Source: Own survey data result, 2012 ***, indicates significance at 1% probability level

After controlling for differences in socio-economic characteristics of the participant and non-participant households, it has been found that the average treatment effect on treated (ATT) and/or the average total impact difference on the outcome variable of the treated group is nearly 126480.04 Birr (31%) decreased by average annual total income. In other words, the impact of vanished Lake Haramaya has minimized the mean annual total income of the treated households nearly by 31% where the mean total impact differences on this outcome variable of the two groups is statistically significant at 1 % probability level (Table 1).

Impact estimate on specific/individual level outcome variables

Table 2: ATT for mean impact estimate on individual level outcome variables, estimated in Birr

Outcome-variables	Treatments	Controls	Differences	t-value
ɜrage annual income from vegetables l root crops (R-fed +Irrigated)	215355.40	294890.70	-79535.35	-1.92*
ɜrage annual Income from *chat* ps (Rain-fed +Irrigated)	23747.40	66496.99	-42749.62	-6.24***
ɜrage annual income from overall gated crops I_c^3	87682.6	267443.70	-179761.15	-4.29***
ɜrage annual income of Inter-crop ps (Rain-fed +Irrigated)	24768.48	55385.04	-30616.57	-3.17***
ɜrage annual income from over cultivated crops/ cropping systems	244064.44	351739.31	-107674.87	-2.79***
ɜrage annual income from overall livesto production	30020.74	33249.74	-3229,00	-1.18

Source: Own survey data result, 2012

***, & *indicates significance at 1% and 10% probability levels, respectively

Impact estimate on total income from crop and livestock production

I_c^3 indicates contribution of irrigated crops to overall household crop income relative to other cropping patterns in the study district

After controlling for differences in demographic and socioeconomic characteristics of the participant and non-participant households, it has been found that, on average the impact has decreased average annual income from crop production by 107674.87 Birr (31%) and their annual livestock income generation by 3229. 00 Birr (8%) and didn't have significant differ ences (Table 2). The estimated difference on average annual income from agricultural production in participant households is mainly attributed to absence of irrigation water supply due to disappeared Lake Haramaya.

Impact on total income from vegetables, chat, irrigated and inter-crop production

The average annual income of participant and non-participant farmers from vegetables and root crops production was 215355.40 and 294890.72 Birr respectively, with the mean difference of 79535.35 Birr; while the mean comparison between the two groups is statistically significant at 5 % probability level. This implies that control groups have 27% more income than the treatment groups by vegetable crop production using both rain-fed and irrigation cultivated systems (Table 2).

The mean annual income value of *chat* crop production using both rain-fed and irrigation cultivated systems for participant households was 23747.40 Birr, while that of non-participant was 66496.99 Birr per households, with 42749.62Birr (64.30%) mean difference (income gap) in the non-participant households.The statistical analysis shows that there was statistically significant difference in mean value of *chat* crop production per households of participant and non participant households at 1 % probability level.

Various vegetable varieties were produced through irrigation in the study area.The Lake Tinkie surrounding sampled farmers earned 267443.68 Birr by using the currently living lake irrigation services, whereas the treated group earned Birr 87682.53 from different sources irrigated crop production. Table 2 also shows that on average, non-participant household get more income (67%) than the treatment group from irrigated cultivated commodities of intervention. This revealed that irrigated farming has paramount contribution to household crop income in the study area. This result has also a negative impact on participant households and even though it is statistically significant at 1% probability level.

Intercropping is practiced to economize their available land. According to the survey data, from intercropping practices using both rain-fed and irrigation pattern it has been found that, on average, being the current living lake beneficiary households has increased by 30616.57 Birr. The mean difference between participant and non-participant households is statistically significant at less than 1% probability level (Table 2). As discussed before this implies that farmers living nearby Lake Tinkie had more intercropping practices and income capacity than the treatment groups.

Sensitivity of the evaluation results

In this section the issue whether the final evaluation results are sensitive with respect to the choice of the balancing scores is addressed. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Likewise sensitivity analysis was undertaken to detect whether the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or the estimated ATT is robust to specific failure of the CIA.

Table 3 gives the result of the Rosenbaum bounds sensitivity analysis obtained using the rbounds command in Stata 11. As noted by Hujer *et al*. (2004), sensitivity analysis for insignificant effects (ATT) estimates is not meaningful and is therefore not considered here. For the statistically significant effects, we increased the value of e^{γ} until the inference about the treatment effect changed. The $p -$ critical values represent the upper bound of the p value from the Wilcoxon signed rank test for estimated dried lake effect (ATT) for each level of unobserved selection bias (e^{γ}). Given that the estimated treatment effect is positive, the lower bounds under the assumption that the true treatment effect has been underestimated were less interesting (Becker and Caliendo, 2007) and therefore not reported in this study.

However, the results indicated in Table 3 shows that the inference of the effect of dried lake participation is not changing though the participant and non-participant households have been allowed to differ in their odds of being treated up to $e^{\gamma} = 3$ (200%) in terms of unobserved covariates. That means ATT of each outcome variables were estimated at various levels of critical values of gamma, the p-critical values are significant (i.e., there is no hidden bias due to unobserved confounder) which further indicated that we have considered important covariates that affected both participation and outcome variable y setting the maximum value for 200% ($e^{\gamma} =3$ with increment of 0.25). We couldn't get the critical value e^{γ} where the estimated ATT is questioned even if we have set largely up to 3, which larger value compared to the value is set in different literatures which is usually 2 (100%). Thus, we can conclude that our impact estimates (ATT) are insensitive to unobserved selection bias and are a pure effect of vanished lake interventions by participant households.

In order to control for unobservable biases, Table 3 below shows the result of sensitivity of the vanished Lake Haramaya intervention and its livelihood impacts measured in terms of different specific outcome variables.

Table 3: Result of sensitivity analysis using Rosenbaum bounding approach

		p-critical values(the upper bound of Wilcoxon significance level (Sig+) at different critical value of Gamma(e^{γ})								
No.	Outcomes	$e^{y}= e^{y}{}_{=1}$	$e^{y}{}_{=}1.25$	$e^{y}{}_{=}1.5$	$e^{y}{}_{=}1.75$	$e^{y}{}_{=}2$	$e^{y}{}_{=}2.25$	$e^{y}{}_{=}2.5$	$e^{y}{}_{=}2.75$	$e^{y}{}_{=}3$
1	Vegtcrop-Income	P<0.000	P< 4.2e-07	4.2e-09	3.8e-11	3.4e-13	2.9e-15	0.00	0.00	0.00
2	*Chat*cro*p*-Income	P<0.000	P<0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Irgatedcrop-Income	P< 2.4e-13	P< 1.1e-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Intercrop-Income	P< 2.3e-15	P<0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	TAnual Crop-Income	P< 3.3e-08	P< 8.6e-11	2.2e-13	5.6e-16	0.00	0.00	0.00	0.00	0.00
6	TAnual Income	P< 4.3e-08	P< 1.2e-10	3.2e-13	8.9e-16	0.000	0.000	0.000	0.000	0.000

Source: Own estimation, 2012; e^{y} (Gamma)=log odds of differential due to unobserved factors where Wilcoxon significance level for each significant outcome variable is calculated.

- ✓ Table 3 above show the estimated ATT effects and the specific sensitivity analysis of significance outcome variables used in the mode*l.*

Interpretation of Econometric Model Results

The pseudo-R^2 value of 0.29 shows that, the estimated model performs well for the intended matching exercise. A low pseudo-R^2 value means participant households do not have much distinct characteristics over-all and as such finding a good match between participant and non-participant households becomes easier. The statistical significance of the different variables varies widely; some are statistically significant at less than 1%, 5% and 10% level of significance while others are not significant even at 10% level of significance. In general, the model performs well. Therefore, it is possible to interpret the model results meaningfully.

Table 4: Estimated Logistic regression results for determinants of participation and livelihood status

Model variables	Coefficients	Std. Err.
Age	0.03	0.06
Education	0.21***	0.07
Family size	-0.22**	0.11
Cult. Land holding	-1.23	0.82
Livestock Owned in TLU	-0.11	0.09
Off/Non farm income	0.00006	0.00005
Frequency of extension visit	-0.15***	0.03
Avg. distance from basic services	0.04	0.09
Number of crops grown	-0.15	0.11
Farm experience	-0.05	0.06
Farm machinery ownership	-0.76**	0.36
Use of manure	0.86**	0.40
Membership in cooperatives	0.65*	0.36

Constant	2.95*	1.66
Number of obs = 200		
LR chi2(13) = 81.31		
Prob > chi2 = 0.00		
Log likelihood = -97.98		
Pseudo R^2 = 0.29		

Source: Own estimation result, 2012

***, **, & * indicates significance at 1%, 5% and 10% probability levels, respectively

Looking into the estimated model coefficients presented in Table 4 above illustrates that among the 13 variables considered in the model, six variables were found to have a significant impact on determining the participant groups and hence livelihood status of households at 1, 5 and 10% probability levels. These variables include household family size, education level, use of manure, membership in cooperatives, frequency of extension visit and farm machinery ownership. However the sign of the last two variables was not as expected. Seven of the 13 explanatory variables were found to have no significant influence household income and hence livelihood status of households. Here it follows description and interpretation of the effect of significant explanatory variables on participation and livelihood status of households in the study area.

Household family size in AE (Faml_Size): The result shows that the variable is found to have negative impact on livelihood status and found to be significant at 5 percent probability level.

In other words, the level of household income status (welfare) decrease as household size increases and the chance to be in misery life under poverty line increase with increasing household size. The coefficient (-0.22) indicates the marginal effect of the variable on household income. This implies that decreasing household size by one unit, ceteris paribus, will increase mean household income by 22% and hence improves the livelihood status of households. This output clearly shows the importance of decreasing fertility at household level. The more probable solution is improving access of the poor to education and information on family planning and expansion of birth control methods.

Education level of the HH-head (Educ-Level): This variable is significant at 1% probability level and has a positive relationship with household's welfare and negative association with poverty status. The coefficient 0.21 shows that, holding other factors constant; incremental of education level by one year by household head will increase the mean income status of households by 21%. The plausible explanation is that if there is better educated individual/ household head within the household, the knowledge will be diffused within the household members than uneducated or less educated households and the household became active in accepting new technologies. Therefore, presence of better educated person in general has an opportunity to manage own resources, credit received, as well as can allocate and use them properly.

Use of manure (Manure-Use): This variable is a dichotomous variable which takes a value of 1 if a given household use manure and 0 otherwise. As evidenced from different research and extension outcome, the use of organic and local manure or fertilizer has a direct positive contribution for agricultural productivity and production. This variable is significant at 5% probability level and has a positive relationship with household's welfare and negative association with poverty status. The coefficient 0.86 shows that, holding other factors constant; incremental of use of manure by one unit by household head will increase the mean income status of households by 86%.This is expected to improve the livelihood condition of participants indirectly through its positive impact on household income. Therefore, here it is hypothesized that soil fertility expressed by use of manure is positively related with household income and negatively with poverty status.

Membership in cooperatives: This variable is a dichotomous variable which takes a value of 1 If a household is member to cooperative and 0 otherwise. This variable is significant at 10% probability level and has a positive relationship with households' livelihood and negative association with poverty status. The coefficient 0.65 shows that, holding other factors constant; incremental of membership to cooperatives by one unit will increase the mean/percentage change in dependent variable/ income/livelihood status of households by 65%. Membership to cooperatives also will increases households access to services that might be granted by being a member. Cooperatives pursue meaningful livelihoods, and contribute to rich cultural landscape, while effectively competing in a global economy.

Frequency of extension visit (Extn_Cont): The regression model result shows negative relationship of this variable with household income per AE and significant at 1% probability level. This indicates as frequency of extension visit increases households' income level decreases and the likelihood that the household being poor increases/livelihood status decreases. The coefficient (-0.15) implies, keeping other factors constant, household income decrease by 15% when frequency of contact with development agent increases by one unit. This is in contrary to the hypothesis initially set by the researcher.

Farm machinery ownership (Mach_Own): Whether the farmer has farm machinery (tractor, water pump) or not was expected to have a positive effect on households' income generation. Mishra and El-Osta (2002) indicated a positive relation between machinery ownership and diversification of livelihood strategy. This implies that this variable has a positive effect on the livelihood status and the welfare of the household. The regression model result shows negative relationship of this variable with household income per AE and significant at 5% probability level. This indicates as farm machinery ownership increases households' income level decreases and the likelihood that the household being poor increases/livelihood status decreases. The coefficient (-0.76) implies, keeping other factors constant, household income decrease by 76% when farm machinery ownership increases by one unit. This is also in different to the hypothesis initially set by the researcher.

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ADAPTATION STRATEGIES OF THE COMMUNITIES SURROUNDING HARAMAYA LAKE TOWARDS ITS DISAPPEARANCE, EAST HARARGHE ZONE, ETHIOPIA

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Introduction

Water is essential for human life, development and environment, but it is a finite and vulnerable resource which has quantitative limitations and qualitative vulnerability. Rapid industrial development, urbanization and increase in agricultural production have led to fresh water shortages in many parts of the world. Water resources of the basins over the world are decreasing while the demand for water continues to increase because of increasing population and as a result of economic development. In view of the increasing demand of water for various purposes and its limited availability, a greater emphasis is being laid for a planned and optimal utilization of available water resources (Abebe, 2010).

Degradation of water resources such as, rivers, lakes, ground water and wetlands in their extent and their quality is a key threat to socio-economic development and existence of mankind. This situation has accelerated because of human interference, for instance, the Aral sea was once a thriving irrigation schemes were put in place, which made the sea to lose 60% of its water within

20 years. Over 27,000 km^2 of former sea bottom is dry and toxic waste (Dukhovnyl, 1990). For people around the Aral Sea disease like typhoid fever, viral hepatitis, TB, threat cancer and anemia are rife (Medecins San Frontieres, 1998). The 20,000 years old Lake Chad has shrunken to 5% of its size within 40 years over tapping for huge irrigation schemes and domestic use; in 1963, the lake covered about 25,000km^2 but today it is 1/20 of that size (Mayell, 2001).

The summation of both man-made and climate-related disasters has killed Haramaya Lake and Adele. The predicted likely death of Lake Tana, Lake Ziway, Lake Abiyata and river Awash water resources and the bio-diversity they hosted for many years are too costly and painful to tolerate. There is great fear and challenge of meeting the demands of escalating population water needs for food production, irrigation, domestic, municipal, and industrial and energy uses. Feed and water availability for livestock has greatly reduced, and livestock number has declined. This has already claimed lives of millions of financial and capital assets and threatens the livelihoods of majority (NAPAE, 2007).

There is a widespread perception that water is becoming scarce as a result of trends that are, to some extent, unavoidable, especially population growth and the resulting increased demand for water for food production and domestic, industrial and municipal uses. This leads many to jump to the conclusion that a ‘water crisis’ is inevitable. Yet, the more predictable challenges or potential crises can be largely avoided by adjusting the way in which water is managed and governed (Moriarty *et al*., 2004). The scope for water management to contribute effectively to basic human needs and livelihoods is now well documented (CAWMA, 2007; UN, 2012).

The livelihoods of people living in or along the borders of lakes and rivers depend partially on ecosystem services. Loss of the water harms them directly and indirectly as ecosystems play a critical role in their daily life and in maintaining the quality of the environment by absorbing and processing waste products. Strategies to increase food production often entail the withdrawal of water from lakes and rivers for irrigation (Petra *et al*., 2008).

Different studies were done on Haramaya Lake by different researchers during the past few decades. Among these studies, Solomon (2002) predicted that the Haramaya Lake would dry up after fifteen years due to siltation even if the Lake never lived that long as it vanished in 2004/5. Shimelis (2003) showed that increased water abstraction for irrigation have resulted in the decreasing of the Lake water to the extent that it can no longer be used to supply water for domestic consumption to all its users. Tariku (2004) reported that, siltation, internal drainage and water withdrawal from the lake for domestic use and irrigation purpose are among the reason for the drying of Haramaya Lake which causes the community to miss what they have been utilizing from the lake. According to Wagari (2005), the principal losses for the Lake are: evaporation, abstraction of water from the Lake and siltation, out of which evaporation takes the highest rank.

Seifemichael (2013) reported that the dried Haramaya Lake affected the livelihood of farm households whose life was based on its existence for different purposes.

However, since no work has been done on the adaptation strategies that the surrounding communities follow towards the impact of water problem due to dried Lake, Haramaya and factors affecting their choices, this study aims at filling this research gap

Objectives of the Study

The general objective of this study is to assess the adaptation strategies used by Haramaya Lake surrounding communities towards the impacts posed due to the dried Lake.

The specific objectives of the study were:

- To assess the adaptation strategies used by the communities of Haramaya Lake surrounding against the impact of the dried Lake and
- To identify factors affecting the choices of adaptation strategies of the surrounding communities against the impact posed due to the dried Lake in the study area.

Significance of the Study

Since this study was designed to assess adaptation strategies followed by farm households and identifying factors affecting their choices of adaptation strategies, this study would have significance for the study area as it enables policy makers on which adaptation strategies to focus by tackling factors affecting them.

Furthermore, the findings of this study would provide general information and knowledge related to adaptations strategies, indicate the factors that need urgent intervention and identify aspects that need further research works. It can be an opportunity to the zone in general and to the district in particular to have an organized document that can serve as a guideline in the future development. Researchers, NGOs and extension workers can utilize the results of this study in modifying research and extension activities particularly for adaptation strategies.

Above all, the result of this study would help the surrounding communities to take the best adaptation strategies towards the impact posed due to the dried Lake and at the end, the result would serve as a good input for sustainable utilization and management of the surrounding natural resources.

Research Methodology

Description of the study area

Haramaya District is one of the 17 districts of East Hararghe zone of Oromia national regional state in Ethiopia. It is located at a distance of 510 km away from Addis Ababa along the main road towards Harar town. The district lies between 9^0 09` and $9^0$ 32` N latitude and $41^0$50` and $42^0$05` E longitude to the west of Harar town. It is bordered by Dire Dawa Administrative Council in the north, Kombolcha district in the north east, Harari Peoples' National Regional State in the east, Fedis district in the south east, Kurfachele district in the south west and Kersa district in the west. Haramaya District has a total area of 521.63 km^2, accounting for about 2.31% of the total area of the zone. Its capital city, Haramaya is located at 16kms west of Harar town (HDAO, 2011).The district is stretching between 1400 and 2340 meters above sea level. Of its total area, 90% is mid-highland while the remaining 10% is lowland agro-climate zones and the mean annual rainfall and temperature are 790 mm and 16.34^0c, respectively (BoFED, 2008).

Socio-economic characteristics and resources

The livelihood of the communities in the area is mainly based on mixed farming with crops and livestock production and off-farm activities, especially for urban dwellers. The dominant crops grown in the study district are sorghum, maize, wheat, haricot beans, vegetables and chat. Chat and vegetables are the two major cash crops grown in the area. Agriculture sector is highly dependent on rainfall. Coupled with low modern input use and land fragmentation, the farm productions are mostly for subsistence or household consumption and not aimed at marketing except for Chat and vegetables. In addition to various impediment such as high population pressure, natural disaster, like frost and environmental imbalance resulting to drought and poor infrastructure development have hampered the development of the sector in the district (HDARDO, 2006).

Data and Sampling Design

Data sources and types

Qualitative and quantitative primary data were collected using semi- structured questionnaire, and focus group discussion. Secondary data from both published and unpublished sources were also collected from relevant institutions and individuals.

Sampling techniques and sample size

In this study, a three stage sampling technique was employed. The first stage was purposive selection of the Kebeles that used the Lake before its disappearance and those kebeles affected by the disappearance of Haramaya Lake in the Woreda, followed by selection of households who were using the Lake and finally selection of sample households. The kebele identification was made through review of secondary data on their purpose of water utilization from Haramaya Lake. Accordingly, four kebeles were purposively selected. Before selecting household heads to be included in the sample, those households used the Lake for irrigation and other purposes were identified in collaboration with kebele leaders, key informants and development agents of the respective four kebeles. In the third stage, 120 farm household heads were selected from the total households using simple random sampling technique taking into account probability proportional to size.

Table 18. Sample of households by *Kebeles*

Kebele Adiministration	Total users (N)	S HHs (n)	% KAs to total
Ifa Oromia	460	30	25
Ifa Bate	80	5	4
Haramaya town	534	35	29
Tuji Gabisa	783	50	42
Total	1857	120	100

Source: Woreda Agricultural Office

Methods of data collection

Pre-testing of the questionnaire was conducted in May of 2004 E.C by interviewing ten farmers. An informal group discussion was held with the district Agricultural Officers, DAs, concerned Woreda Agricultural Office experts, *kebele* extension personnel from the selected *kebeles* in order to obtain general information on the study area prior to formal data collection. Adjustments were made to the survey questionnaire following the pre-testing and informal group discussions. Information generated through semi-structured questionnaire was supplemented by focus group discussions held with different groups of the community surrounding the dried Haramaya Lake. To avoid respondents' bias and by way of introduction of the research, a one page statement of the objective of the study proceeded the survey questions. *Kebele* extension personnel with diploma-level training in agriculture and students from Haramaya University who were conversant with the local language took intensive one-day training on data collection techniques prior to the survey. Finally, the survey was conducted under close supervision of the researcher.

Methods of data analysis

For this study, both descriptive statistics and econometric methods were used. The data were initially analyzed using descriptive statistics like mean, standard deviation and percentages to summarize information on the socio-demographic and institutional characteristics of the respondents. Tests like chi-square for categorical variables and one way ANOVA analysis (F-test) for continuous variables were also used to test if there are significant differences between farmers following different adaptation strategies in terms of these explanatory variables .

For this study, multinomial logit model was used to determine factors affecting adaptation strategies of the farm households against the impacts of water shortage due the dried Lake. The advantage of the MNL is that it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories. Moreover, Koch (2007) emphasizes the usefulness of this model by describing the ease of interpreting estimates from this model. To describe the MNL model, let *y* denote a random variable taking on the values {1, 2...*J*} for *J*, a positive integer, and let X denote a set of conditioning variables. In this case, *y* denotes adaptation options or categories and *X* contains household attributes like age, education, income levels, and so forth. The question is how citrus paribus changes in the elements of X affect the response probabilities, $P(y = j \mid X)$, $j = 1, 2...J$. Since the probabilities must sum to unity, $P(y = j / x)$ is determined once we know the probabilities for $j = 2...J$.
Let X be a 1 x *K* vector with first-element unity.

The MNL model has response probabilities:

$$P\left(y = j \middle| X\right) = \exp\left(X\beta_j\right) \Big/ \left[1 + \sum_{k=1}^{j} \exp\left(X\beta_k\right), j = 1...J\right] \tag{1}$$

Where β_j *is* Kx1, j=1.....*J*.

For this study, the households were asked to respond to the adaptation strategies they are using mostly to overcome the impacts of water shortage. Accordingly, the adaptation strategies mostly used by the farm households against the impacts of the dried Lake are:

0 = No adaptation
1 = Using ground water
2 = Using ground water and rain water harvesting
3 = Using ground water, rain water harvesting and importing water from other places

4 = Diversifying from farm to non farm income

Unbiased and consistent parameter estimates of the MNL model in equation (1) require the assumption of independence of irrelevant alternatives (IIA) to hold. More specifically, the IIA assumption requires that the probability of using a certain adaptation method by a given household needs to be independent from the probability of choosing another adaptation method (that is, P_j/P_k is independent of the remaining probabilities). The premise of the IIA assumption is the independent and homoscedastic disturbance terms of the basic model in equation (1). The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable, but estimates do not represent either the actual magnitude of change nor probabilities. Differentiating equation (1) with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\partial \mathrm{P}_j}{\partial x_k} = \mathrm{P}_j \left(\beta_{jk} - \sum_{j=1}^{j=1} \mathrm{P}_j \beta_{jk} \right) \tag{2}$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Green 2000; Koch 2007).

Definition of variables and hypothesis

Dependent variable

The dependent variable in this study is a categorical variable referring to the adaptation strategies mostly used by the farm households to overcome water shortage problems due to the dried Haramaya Lake. Therefore, the dependent variable for the multinomial logit has five categories defined as:

Y=0 No adaptation strategy
Y=1 Using ground water
Y=2 Using ground water and rain water harvesting
Y=3 Using ground water, rain water harvesting and importing water from other places
Y=4 Diversifying from farm to non farm income

Independent variables

The independent variables of this study were those which expected to affect the adaptation strategies of farm households towards water shortage problems. Accordingly, the variables and their hypothesized sign shown in (Table 1) below.

Table 2. Summary of the independent variables used in the model

Variables	Type	Description (value)	Hypothesis
Livestock	Continuous	The total livestock owned by HHs in TLU	+
Farmer group	Dummy	Takes 1 if a farmer is a members of farmer group 0 if not	+
Average size	Continuous	Total average size of the household in (ha)	+
Family size	Continuous	Total family size of the household	+
Age	Continuous	Age of the household in (years)	+
Education	Continuous	Grades completed by the household in formal education	+
Water distance	Continuous	Distance of water source from households home in KM	-
Sex	Dummy	Sex takes 0 if female and 1 if Male	+
Extension	Continuous	Number of contacts with extension agent	+
Iddir	Dummy	Takes 1 if a farmer is a members of *iddir* 0 if not	+
Credit	Dummy	Takes 1 if a farmer get credit access or 0 if not	+
Training	Dummy	Takes value 1 if farmer participate in trainings & 0 if not.	+

Results and discussion

Descriptive statistics of continuous variables

To test whether or not there is a significant mean difference between farm households using different adaptation strategies and who don't use adaptation strategies in terms of continuous explanatory variables, one-way ANOVA was used and the result was presented in (Table 2).

From table 3, the result of one way ANOVA test shows only educational level and extension contact were significant. This indicates that the level of education of households that use different adaptation strategies was higher than that of households who don't use adaptation strategies and also households with better extension contact found to use different adaptation than households that have less extension contact. However, the remaining variables were found to be insignificant. This leads to the conclusion that there is no significant difference between farm households that use different adaptation strategies and who don't use adaptation strategies in terms of age, family size, distance of water source, average size and livestock holding.

Table 3. Descriptive statistics of continuous variables

Variables	No adaptation Strategy		Ground water		Ground and RWH		Ground +RWH and IW		Diversifying income		F-Value
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	
Age	39.76	8.47	44.61	8.72	45.04	8.02	41.94	6.96	43.21	8.07	1.04
Education	1.24	1.47	1.43	1.10	2.04	1.24	1.78	1.16	2.07	1.44	2.34*
Family size	6.95	2.73	7.18	3.39	6.95	2.58	6.11	2.52	6.57	2.90	1.21
Water distance	2.02	1.5	2.4	1.3	2.1	1.0	2.3	1.6	1.7	1.1	0.37
Average size	2.92	0.83	0.72	0.38	0.82	0.40	0.79	1.28	0.72	0.34	1.36
Extension	0.70	0.48	3.07	1.08	3.35	0.88	2.78	0.94	3.43	1.08	2.64**
Livestock	1.51	1.56	2.02	1.22	2.23	1.09	1.72	1.48	2.78	3.97	0.84

*, ** and *** are statistically significant at 10%, 5% and 1% level of significance respectively
Source: own survey results, 2013.

3.2. Descriptive result for dummy variables

To check if there is a significant difference between households who use different adaptation strategies and who don't use adaptation strategies in terms of this dummy variables, chi-square test was conducted (Table 3). As it can be seen the test was found to be significant for all variables which leads to the conclusion there is a statistically significant different between households in terms of these all variables.

Table 4. Descriptive statistics of dummy variables

Variables	No adaptation Strategy		Using ground water		Using ground and RWH		Using ground, RWH and importing water		Diversifying income source		$\chi 2$
	No	%	No	%	No	%	No	%	No	%	
Sex											
Female	10	27	1	3.6	3	13	3	16.7	1	7.1	7.85*
Male	27	73	27	96.4	20	87	15	83.3	13	92.9	
Farmer group											
No	18	48.6	6	21.4	6	26.1	9	50	3	21.4	9.01*
Yes	19	51.4	22	78.6	17	73.9	9	50	11	78.6	
Credit											
No	29	78.4	12	42.9	11	47.8	8	44.4	6	42.9	11.96**
Yes	8	21.6	16	57.1	12	52.2	10	55.6	8	57.1	
Training											
No	19	51.4	5	17.9	4	17.4	2	11.1	4	28.6	15.15***
Yes	18	48.6	23	82.1	19	82.6	16	88.9	10	71.4	
Iddir											
No	20	54.1	10	35.7	2	8.7	3	16.7	5	35.7	15.79***
Yes	17	45.9	18	64.3	21	91.3	15	83.3	9	64.3	

*, ** and *** are statistically significant at 10%, 5% and 1% level of significance respectively
Source: Compiled from survey data, 2012

Major Adaptation Choices and Constraints in the Study Area

Major adaptation choices by the households

The adaptation strategies of this study are based on asking the households which of the adaptation methods they were practicing among the given alternatives to counteract the negative impacts they are facing due to the disappearance of the Lake. The adaptation methods that farmers reported were, no adaptation, using round water, using ground water and rain water conservation, using ground water, rain water conservation and importing water from other place and diversifying from farm to non-farm income source strategies (figure 1).

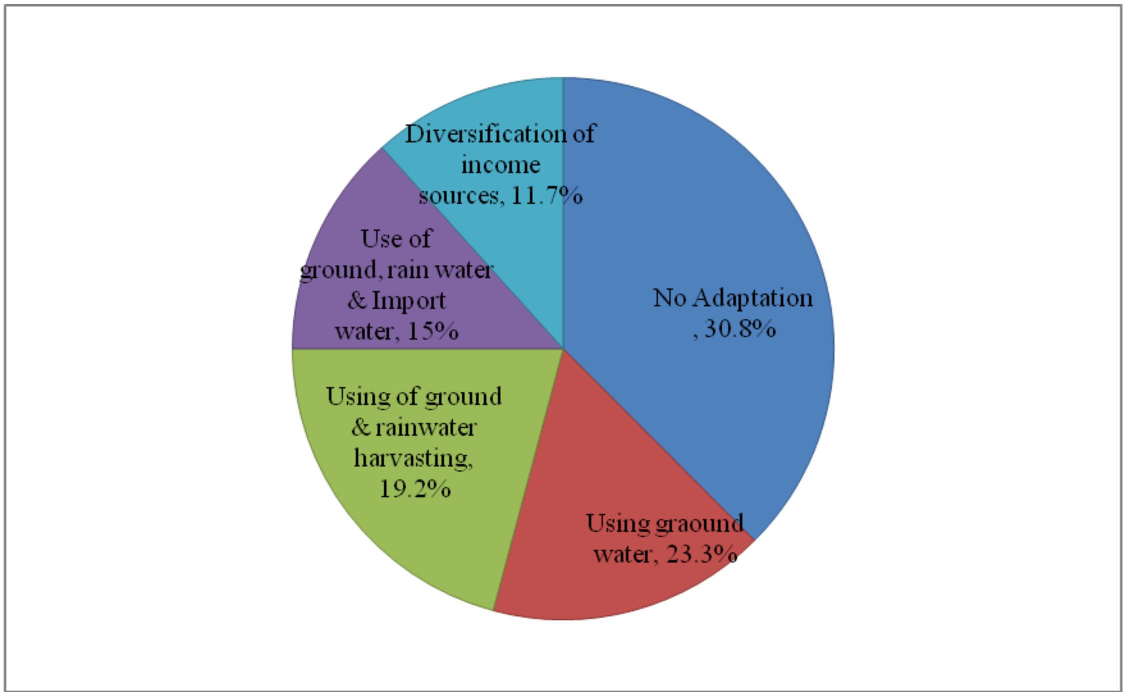

Figure 2. Adaptation strategies of the sample households

As indicated in the above figure 1, using ground water, and using ground water and rain water conservation are the most commonly used adaptation methods, used by 23.3% and 19.2% of households. Moreover, using ground water and rain water harvesting and importing water from other place and diversifying income source are used by about 15% and 11.7% of the households, respectively. From this we can conclude that using ground water and using ground water and rain water harvesting like ponds are among the major methods exercised by the communities for irrigation purpose and family need. On the other hand, importing water from other place requires labor force while diversifying income source requires budget. About 30.8 percent of the sampled households reported not to have taken any adaptation method for a number of constraints.

Constraints to adaptation choices

The analysis of constraints to adaptation of the study area indicates that there are five major constraints to adaptation. These are lack of knowledge, information, money, shortage of labor and limited of training. Most of these constraints are associated with capacity of the households. For instance, lack of knowledge means low level of education which in turn cause them not to use adaptation, lack of information on appropriate adaptation options could be attributed to the dearth of research on water shortage and adaptation options in the region in general and in the study area in particular. Lack of money hinders using irrigation and financial means to hire labor and limited training means less participation on different natural resource conservation and field days trainings which in turn cause them not to get information related to adaptation (Figure 2).

As it can be seen from the figure below, about 25.83% of households had lack of information and this shows that there was information gap in the study area.

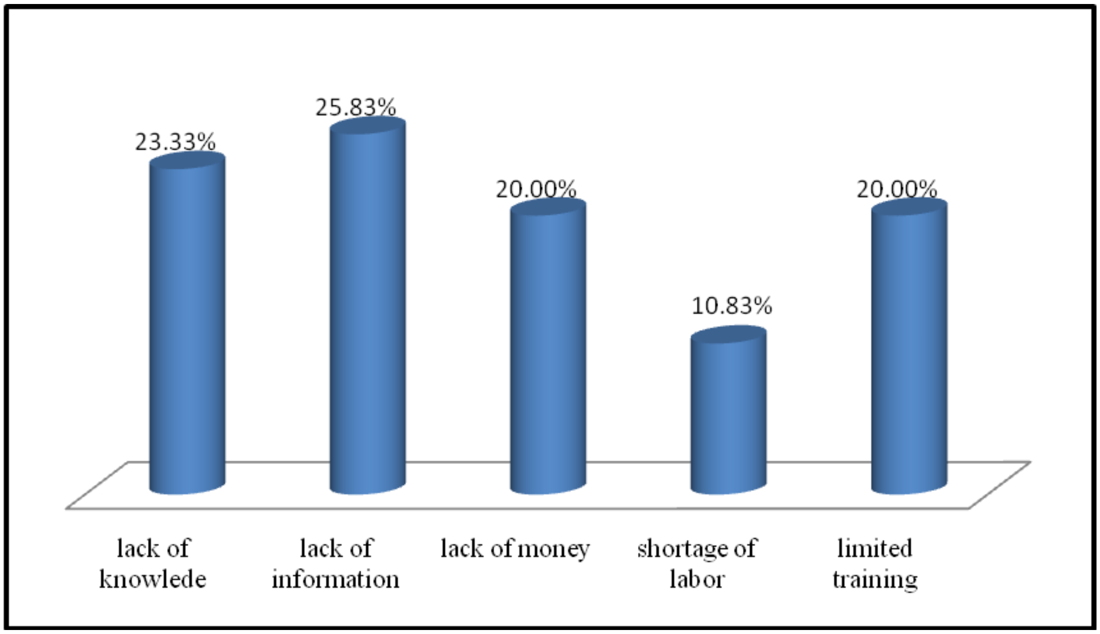

Figure 3. Constraints to adaptation choices

4. Econometric Results Interpretation

Table 5. Parameter estimates of the multinomial logit model

Explanatory variables	Ground water		Ground water & rain water Harvesting		Ground water, rain water Harvesting & importing water		Diversifying income source	
	Coef. (Std. error)	Marginal effect	Coef. (Std. error)	Marginal effect	Coef. (Std. error)	Marginal effect	Coef. (Std. error)	Marginal effect
Constant	-13.229 (3.192)		0-19.993 (4.096)		-12.193 (3.457)		-14.336 (3.851)	
Age	0.179*** (0.055)	0.011	0.232*** (0.064)	0.013**	0.171***(0.061)	0.005	0.155 ** (0.063)	0.001
Sex	2.075* (1.270)	0.261**	0.818 (1.151)	-0.017	0.665 (1.021)	-0.051	1.661 (1.384)	0.070
Education	0.549** (0.285)	-0.010	1.061***(0.344)	0.073**	0.650** (0.314)	0.012	0.919***(0.345)	0.043
Family size	-0.296** (0.142)	0.013	-0.546***(0.177)	-0.032*	- 0.537***(0.184)	-0.036*	- 0.429***(0.172)	-0.012
Water distance	-0.161 (0.265)	0.047	-0.591* (0.326)	-0.043	-0.295 (0.304)	0.001	-0.836 ** (0.417)	-0.067*
Farmer mem.	1.786 ** (0.849)	0.186	1.645* (0.933)	0 .067	0.499 (0.833)	-0.118	2.423 ** (1.101)	0.133*
Average size	-0.211 (0.893)	-0.186	1.508* (0.914)	0.177*	1.208 (0.867)	0.156	-0.261 (1.180)	-0.076
Extension	0.352 (0.365)	-0.052	1.263***(0.443)	0.115***	0.359 (0.409)	-0.026	1.027** (0.461)	0.066*
Iddir	1.564** (0.807)	-0.068	4.604***(1.215)	0.291***	3.086***(1.061)	0.159**	2.608** (1.051)	0.073

Training	2.767*** (0.907)	0.193*	3.652***(1.111)	0.165**	3.748 ***(1.135)	0.205***	2.126** (1.078)	0.017
Credit	1.944***(0.738)	0.173*	1.352 (0.848)	-0.009	1.674 ** (0.821)	0.044	1.948** (0.888)	0.065
Livestock	-0.105 (0.301)	-0.019	0.011 (0.321)	0.008	-0.202 (0.340)	-0.027	0.182 (0.322)	0.029
Outcome		0.335		0.152		0.181		0.126

Base category	No adaptation
Number of observation	120
LR chi-square	113.25
Prob > chi^2	0.0000
Log Likelihood	-129.87
Pseudo-R^2	0.3036

*, ** and *** are statistically significant at 10%, 5% and 1% level of significance respectively

Source: model output, 2013

The results presented on Table 5 show that, age, education, family size, average size, extension contact, *Iddir* membership, training participation, sex of household, distance from water source, member of farmer group and credit access are variables that affect adaptation strategies of the sample households. Livestock ownership was found to have no relationship with choice of adaptation strategies. Last row of table 5 above shows the outcomes of the four adaptation options used by farm households to overcome the impact of water shortage in the study area. As it can be seen from the table about 33.5, 15.2, 18.1% and 12.6 percent of households use ground water, Ground water and rain water harvesting, ground water, rain water harvesting and importing water and diversifying from farm to non-farm income source adaptation strategies respectively. This leads to the conclusions that using ground water was the most adaptation strategies followed by using ground water, rain water harvesting and importing water from other places, using ground water and rain water harvesting and diversifying income source from the most to the least.

Age of the household head: Age of the household head affects adaption strategies of households' positively as expected. From the result on Table 5, as age of household head increases by one year compared to the non-adaptation strategies, the probability of using underground water and rain water harvesting increases by 1.3 percent. The possible explanation for this is that as household's age increases, the farm household may get better experience which in turn help him to use the better adaptation strategies among the existing alternatives. At the same time this strategy is preferable than other as farm households can harvest rain water in simple way.

Education: Education was positively related to adaptation strategies as expected. The result shows as farm household's educational level increases by one extra year compared to non-adaptation strategies, the probability of using ground water and rain water harvesting increases by 7.3 percent. The possible explanation is that, more educated farmers were in a better position to use the best adaptation strategy than other uneducated farmers.

Family size: Family size negatively related to adaptation strategies. The result of this study shows that, family size affects the adaptation strategies towards the impacts of dried Lake negatively. Accordingly, an increase of the household size by one extra person, compared to non-adaptation strategies decreases the probability of using ground water and rain water harvesting and using ground water, rain water harvesting and importing water by 3.2 and 3.6 percent respectively. A possible explanation for this is that households with higher family size faces problem to sustain all household members during harsh condition as well as in the large family the probability of dependency ratio is high.

Sex of the household: sex of households affects adaptation strategies of farm households positively. From the result of this study being male household increases the adaptation strategy of farm households towards water shortage problem. Accordingly, being male household increases the probability of using ground water by 26 percent. The possible explanation for this is that, male households have batter experiences than female which in turn help them to use this strategy. At the same time most of farm activities performed by male households in the study area and using ground water also the common practice to get water for their farm as well.

Extension contact: Extension contact positively related to adaptation as expected. Households that have extension contact expected to have more information and knowledge compared with those have no extension contact. As the household number of contacts with extension agent increases, it is expected that he would get more information. The result of this study shows that as households contact with extension increases compared to non-adaptation strategies, the probability of using ground water and rain water harvesting and diversifying income sources increases by 11.5% and 6.6% respectively. Possible explanation for this is that farmers with high contact with extension will get better information that support them to use ground water and rain water harvesting and diversifying their income from farm to non- farm source.

***Iddir* membership**: *Iddir* affects adaptation strategies positively as expected. The result of this study shows that households who are a member of *iddir* have 29.1 and 15.9 percent more probability compared to non-adaptation strategies, of using ground and rain water harvesting and using ground water and rain water harvesting and importing water from other places respectively. Possible explanation for this is that, household who is *iddir* membership may get financial support in case of death and also may get information on various issues during contact with his member. Therefore this will help him to use different adaptation strategies.

Training: Training affects adaptation strategies positively as expected. It is one of the extension events through which farmers get practical skill and technical information on adaptation options. Results of this study indicated that the households who participated on training compare to non-adaptation strategies, have 19.3, 16.5 and 20.5 percent more probability of using ground water, using ground and rain water harvesting, using ground, and rain water harvesting and importing water respectively. Possible explanation for this is that household who participated on natural resource conservation and different field day training expected to get more information which in turn help them to use different adaptation strategies towards water shortage impact.

Membership of farmer group: Membership in local farm organizations had a positive impact on adaptation. From the result of this study being membership in farmer group has more probability of Diversifying from farm to non-farm income. Accordingly, being membership of farmer group compared to non adaptation strategies increases the probability of Diversifying from farm to non-farm income by 13.3 percent. A possible explanation is that, being farmer membership would help the household to get information related to trade and also my get financial support from his fellow friends which in turn help him to perform off farm activities.

Average size of holding: Average size of holding is associated with grater wealth and this is because of the fact that as average size of holding increases the farmer's ability to tolerate risk and uncertainty also increases which in turn true for adaptation. From the result of the this study total average size of holding affects using ground water and rain water harvesting strategy positively and significantly. Accordingly, as the average size of holding of the household increases by one hectare compared with non-adaptation strategies, the probability of using ground water and rain water harvesting as adaptation strategy increases by 17.7%. Possible explanation for this is that farm households can get ground water and rain water relatively in simple way.

Distance from water source: Distance from water source expected to affect adaptation choices of farm households negatively. This is because as the distance of water source increases from the residence of farm households the probability of using different adaptation strategies expected to decrease. From the result of this study a kilometer increase by the distance of water source from the home of farm households compared to non adaptation strategies, the probability of diversifying income source decreases by 6.7 percent.

Access to credit: Access to credit has positive relation with adaptation. This result implies the important role of institutional support in promoting the use of adaptation options to reduce the negative impact of water shortage problems. From the result of this study households with credit access compared with non-adaptation strategies have 17.3 percent more probability in using ground water. Possible explanation for this is that credit is the source of finance which helps the farm households to buy generators for pumping water from ground and at the same time, credit will help the farm households to pay a wage for labor to dig for ground water.

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Constraints of Rural Women to Utilize Microfinance Institutions: the case of Members of Microfinance Institutions in Rural Districts of Dire Dawa Administration, Ethiopia

Developing Country Studies, ISSN 2224-607X, ISSN 2225-0565 (Online) Vol.3, No.7, 013, 24-28. (Puplished article)

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Funded by HrU Government Research Grant

Summary of the Results and Recommendations

Microfinance institutions mainly give services to those who are very poor especially women. This is because it has been a means that poor people have in their own businesses so that their livelihood can be improved. There were microfinance institutions that were working in rural districts of Dire Dawa Administration. The study conducted in these areas identified that microfinance members have been changed for better. It was, however, there were constraints that became a bottle neck that challenged them not to utilize the services effectively. Insufficient loan amount, lack of training, and follow up, unavailability of nearby market and high cost of inputs, and animal diseases were the major constraints of members. Thus, the study recommended that the microfinance institutions have to consider the loan size, training, and follow up. The microfinance institutions have to also look for ways that the members could get market for what they produce and have to schedule programs on the time that debts are collected and the clients should be aware of it.

Determinants of women's participation in microfinance services: empirical evidence from Rural Dire Dawa, Ethiopia,

African Journal of Agricultural economics and Rural Development, Vol 1 (1) 2013, 1-7, International Scholars Journals

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Funded by HrU Government Research Grant

Summary of the Results and Recommendations

The result of the study showed that the mean difference among microfinance users and non-microfinance users in terms of age, land holding, livestock holding, and monthly saving were statistically significant at 1%, 10%, 1% and 1%, respectively. Whereas, marital status, land access, and family size of the respondents were statistically insignificant except religion and educational variables. The econometric results of the study also revealed that the saving experiences of sample respondents were positively and significantly affected probability of

women’s participation on microfinance services. This could be due to the fact that the amount of monthly saving of the respondents capacitates individuals to search for further micro saving services in microfinance institutions. The coefficient of the variable also confirmed that a unit changes in the amount of monthly saving changes the probability of women’s participation in microfinance services by 1.804. The result of the study revealed that family size of the respondents significantly, but negatively affected probability of women’s participation in microfinance services. This can be justified by the fact that the household size of each sample respondent lacked productivity and generates limited household income. The study also revealed that the households’ access to land positively and significantly increased the probability of participation by 1.934. A woman facing the problem of low level of production due to shortage of farm land and limited use of modern farm technologies would increase her productivity through the use of fertilizer and other improved farm inputs. This forces women to search for credits and saving institutions or individuals and groups. Therefore, the study concluded that creating enabling environment for access and utilization of farm land and saving institutions in rural areas fosters women’s participation in microfinance service. In controlling family size and enhancing family productivity, the study also recommended that family planning services must be further strengthened in the study area as an important option. Furthermore, research must be conducted on the link between rural microfinance services and family size.

Roles and Challenges of Microfinance Institutions in Economic Empowerment of Women: the Case of Rural Districts of Dire Dawa Administration

By

Dereje Kifle, Sisay Belay, Yenenesh Taddese, Jemal Yousuf

Funded by HrU Government Research Grant

Abstract: *In countries like Ethiopia where the per capita income is 370 USD and more than 30% of the people live under poverty, the significance of microfinance institutions is unquestionable. It becomes more important when it has been given to rural women. In the efforts made to empower women, microfinance institutions are facing various challenges. Thus, the study was conducted in order to find out the major roles that microfinance institutions play in economic empowerment of rural women and the challenges they faced in rural kebeles of Dire Dawa Administration. The result of study revealed that the microfinance institutions significantly assisted rural women of the study area to increase their income, improve their power of decision making and their access and control over resources, and the saving habit of them were also showed significant improvements. It was also found out that the effort of microfinance institutions were hindered due to various challenges. The attitude of members towards the government funded microfinance institutions, religious beliefs to loan that involve interest, lack of fund, attitude towards females and problems of giving loan and collecting from members were the challenges investigated through the study. The study, therefore, concluded that the microfinance institutions have to be strengthened so that the rural women can benefit more.*

Moreover, to come up with the desired changes, the various challenges that microfinance institutions face have to be mitigated. It is recommended that first of all the rural people must be aware of the purpose of microfinance institutions. There is also a need to work on that rural people so that they believe in the role of women that if they are supported, they could bring much change. It is also recommended that microfinance institutions have to look for alternative sources of funding so that they can serve their clients better.

Keywords: Roles, Challenges, Microfinance Institutions, Empowerment, Women, Dire Dawa

Introduction

Ethiopia is one of the least developed countries. The per capita annual income of the country, though it showed improvement in recent years, is only 370 USD (World Bank, 2013). Several studies noted different causes for poverty in a country. Some argued that the cause of poverty in developing economies among other things is that the poor does not have access to credit for the purpose of working capital as well as investment for its small business (Jean-Luc 2006).

Although the development of microfinance institutions in Ethiopia started very recently, the industry has shown a remarkable growth in terms of outreach particularly in number of clients (Wolday, 2000). To this end many developing economies have designed and have been providing credit to the poor through microfinance schemes. Micro-finance programmes not only give women and men access to savings and credit, but reach millions of people worldwide bringing them together regularly in organized groups.

Microfinance is now a proven strategy for reaching poor women. There are good reasons to target women. Gender equality turns out to be good for everybody. The World Bank reports that societies that discriminate on the basis of gender have greater poverty, slower economic growth, weaker governance, and a lower standard of living. Women are poorer and more disadvantaged than men (Margaret, 2001).

Women in Ethiopia have not been exposed to the economic opportunities that would enable them practice alternative income-generating activities. But recently, many scholars, policy-makers and development planners have started advocating the important role of the emerging new phenomenon, microfinance program, for the advantage of poor Ethiopian women. Microfinance institutions in the country are formed with major objectives of poverty alleviation and women empowerment to mention few (Haimanot, 2007)

Statement of the problem

Following the Agricultural Development Led Industrialization (ADLI) strategy of the government of Ethiopia, rural finance has been considered as an important tool for agricultural and food security (Belay, 2001). The importance of the micro and small enterprises sector in Ethiopia, particularly for the low-income, poor and women groups, is evident from their relatively large presence, share of employment and small capital requirement. These are sufficient reasons for governments and other stakeholders in development to be interested in micro and small enterprises (Gebrehiwot and Wolday, 2001). In line with the development of micro-finance institutions, the Government of Ethiopia set up participatory rules and policies which gave space for women's productivity

Women constitute about 50 percent of the Ethiopian population and they involve in different sectors of the economy. Although poor women are engaged in heavier and highly time-consuming work load, they never obtain the commensurate earnings. This leads them to be highly dependent on their male counterparts. The burden is worse in rural Ethiopia where peasant women have no alternative to generate their own income and to be self-reliant (Haimanot, 2007).

Padma and Swamy (2003) noted that government has formulated and issued the Ethiopian Women's Policy to speed up the economic and social advancement of women. This policy gives special emphasis to rural women by 'facilitating the necessary conditions whereby they can have access to basic services and to ways and means of lightening their workload'.

There are different microfinance institutions in Dire Dawa Administrative region that are working to empower women and eradicate poverty. In spite of the presence of microfinance institutions, studies that critically assess the impact of micro-finance on women's economic empowerment are so far limited. This is perhaps due to the fact that both micro-finance development and priority attention to women's economic empowerment are new, and are now currently recognized as important strategies in the process of policy development in Ethiopia. However, the microfinance institutions are playing a great role in empowering women. In the efforts of empowering women through saving and credit services, they have also faced various challenges. Thus, this study is proposed to assess the roles and challenges of microfinance institutions in empowering of women economically.

Objectives

The study was proposed to

- assess the role of microfinance institutions in economic empowerment of women
- identify challenges faced by microfinance institutions to operate efficiently

Methodology

Description of the study area

Dire Dawa Administration (DDA) is one of the two federally administered regions located 505 km from Addis Ababa and 311km to the South East of Djibouti. It is located on the Ethio-Djibouti Railway between Addis Ababa and Djibouti (Dereje,2008). It was founded in 1902 after the Addis Ababa – Djibouti Railway reached the area. Dire Dawa administrative council consists of the city of Dire Dawa and the surrounding rural areas.

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), Dire Dawa has a total population of 341,834, of whom 171,461 are men and 170,461 women; 233,224 or 68.23% of the population are urban inhabitants. For all of Dire Dawa 76,815 households were counted living in 72,937 housing units, which results in an average of 4.5 persons to a household, with urban households having on average 4.2 and rural households 4.9 people. Ethnic groups in the region include the Oromo (45.9%), Somali (24.3%), Amhara (20.17%), Gurage (4.55%), Tigray (1.23%), and Harari (1.09%). Languages spoke include Oromiffa (47.95%), Amharic (26.46%), Somali (19.7%), Gurage (2.78%), and Harari (1.04%). The religion with the most believers in Dire Dawa is Muslim with 70.8%, 25.71% are Ethiopian Orthodox, 2.81% Protestant, and 0.43% Catholic.

There are two major climatic zones in the DDA. *Kola*, areas with altitude ranging from 500-1500 m a.s.l. covering 1173 sq. km; and *Weyna dega*, areas with altitude ranging between 1500-2300m a.s.l. covering 160 sq.km. *Kola* has an average annual temperature of 20-27.5 ºc and *Weyna dega* with 17.5-20ºc. The average annual rainfall is 640.3mm with highest 1257.7mm and a minimum of 357.3mm.

Sampling technique

Dire Dawa Administration has 9 urban *kebeles* and 38 rural Peasants Associations. For the purpose of the project, from the total kebeles, 3 rural *kebeles* were selected using random sampling method. Three microfinance institutions operating in these rural kebeles were selected. These institutions were getting the financial support from Dire Dawa Women, Children and Youth Affairs Bureau. The total sample size was 203, and of which 151 were members of the microfinance institutions and the other 52 were not members. They were selected using probability proportional random sampling technique. There were also key informants from the office of Dire Dawa Women, Children and Youth Affairs Bureau and coordinators of the selected microfinance institutions. These people were selected purposefully based on their experiences in microfinance institutions.

Methods of Data Collection and Analysis

Structured interview schedule, focus group discussion, in-depth interview were used to collect data from primary source which mainly comprised of target households and microfinance service providers followed by review of the available secondary data source. The quantitative data that were collected from primary sources were analyzed using descriptive statistics such as frequency, percentage and Chi-square. The analysis of the qualitative data started during collection of data. Each and every day the data recorded in the field note were expanded. The data was then divided into categories. The categorized data were interpreted and explained, and generalizations were made to write the report.

Result and Discussion

The Roles of Microfinance Institutions to empower rural women: users before/after projects analysis

In spite of variations in the extent of its impact, many scholars are in favor of the role microfinance plays to the economic empowerment of women. Bansal (2010) indicated that the contribution of women in household income, access to and control over resources, participation in household financial decision and saving as indicators of economic empowerment. In line with this, members of microfinance institutions in the study area showed improvements in these regards.

Income Increased

The microfinance institutions in the study area helped the members to increase their income. Among the users 117 of them gave responses whether their income increases because of the business they engaged with the loan or not. According to their response, 88% of them indicated that their income increased because of the microfinance institution. (see Appendix, Table B). In the focus group discussion held with members, discussants also indicated that their income increased because of the program. A women who was a member of microfinance institution stated that,

Though I do not know the exact monthly income I earn, I have not faced scarcity

of money to buy what I need since I joined the microfinance institution. Earlier, I was suffering because I could not have money to cover even minor expenses.

Another woman also said that

After the loan, I did not request my husband for minor household expenses. I can

get money for school fees, cloth, and food item by selling the livestock I have. This *is because of the business I am involved with the loan.*

It could be generally concluded that the program assists in increasing the income of the clients. However, the changes that resulted because of the saving and credit program were not similar among members. Some of the members indicated that their income did not increase as they expected. A woman who was member of a microfinance institution mentioned that, 'Even though it is not that much satisfactory, at least I do not wait till my husband gives me the household expenses'. The other woman supported the above idea by saying that, 'Though the change is not that much, at least we can get money to cover school expenses like to buy exercise books, pens, and uniforms for our children'.

Asset holding status and saving habit

Table 3: Micro Finance users' asset holding status (N=151)

Variables		Before		After		χ^2 -test
		Freq	%	Freq	%	
Kind of house	Grass roofed	10	66.9	6	46.9	
	Corrugated roof	129	84.9	146	96.6	309.8***
Saving account	yes	39	25.7	67	84.7	59.4
	no	110	72.4	33	16.3	
Savings at MFI	Yes	45	29.6	71	88.9	1.7
	No	63	41.4	29	12.1	

*** Significant at 1%

Source: Survey result, 2013

The result of the study shows that 96.6% of the MF users owned house with corrugated roof after the program as compared to 84.9 % before the program and which was also statistically significant at 1% level. The result on table 3 revealed that, from the total respondents 84.7% of them have saving account after the program as compared to 25.7% before the program. Furthermore, 88.9% of the respondents deposited money in MF institutions after the program and 29.6% of the MF users deposited money in MF institute before the program (*Table 3*).

The information obtained from the focus group discussion also confirmed this fact. Because of the saving and credit program, the members either started to save or increased the saving amount. A woman indicated that, 'The business I am engaged in is profitable so that my income increases. Thus, I save 10 birr per day'. There were also other members who said that they save 300-400 birr per month. This indicated how the program helped the microfinance members to develop saving habit. However, key informants form the bureau (Dire Dawa Women, Children and Youth Affairs) that funds the microfinance in the study area that the saving habit of clients did not developed as they expected in view of their goal because of lack of organized efforts.

Decision making status

The participation of women in household decision-making is the overriding indicator of women's economic empowerment. Ashraf *et al*. (2006) as cited in Rahman et al (2009) have also taken decision making in defining women empowerment. The researchers in this study used different indicators such as sale of animal, loan decision making, expense, saving decision, decision on reinvestment activities before and after participation in microfinance program to examine the impact of the MF program on women's participation of women in decision-making at the household level. Accordingly, from the total respondents, 45.4% women were involved in loan taking decision after participating in the MF program as compared to 10.5% before their participation. Similarly, among the women respondents, 48% of them mostly involved in saving decision after the MF program and 27.1% before the participation (*Table 4*).

As the result indicated in Table 4, 9.2% and 20.4 of women were involved in decision making by themselves on school expenses before and after the program respectively. Decision making for health expense was mainly done by both men and women equally (43%) before the MF program participation and only 15% after the MF program participation. From the total respondents, 13.8% and 44% of women were involved on health expense decision making before and after the program, respectively. Reinvestment decision was mostly made by both women and men equally (14.4%) at the household level before the MF program participation and only (7%) both of them were equally involved after the MF program participation. Greater percent (11.5) of women were involved for reinvestment decision after the MF program participation and only 6% before the program participation.

Moreover, 48% of the sample responded that men were involved in decision making for animal sale before the MF program participation and only 20% after the MF program participation. A significant percent of (87%) the sample responded that the animal sale decision was made by mostly women as compared to 12.5% before the MF program participation (*Table 4*). Therefore, there was an improvement in the participation of women in decision making at the household level after getting the service from the microfinance institution.

Table 4: MF user's decision making on access to loan

Variables		Before		After		χ^2 -test
		Freq	%	Freq	%	
Loan decision	Mostly myself	16	10.5	48	45.4	147.7***
	Both equally	109	71.7	34	32	
	Mostly Spouse	6	3.9	27	25.4	
Saving decision	Mostly myself	17	27.1	73	48	144.7***
	Both equally	85	55.9	28	18.4	
	Mostly spouse	5	3.3	3	2	
School expense	Mostly myself	14	9.2	31	20.4	46.17***
	Both equally	25	16.4	7	4.6	
	spouse	5	3.3	7	4.6	
Health expenses	Mostly myself	21	13.8	72	44.4	99.7***
	Both equally	66	43.4	24	15.8	
	Mostly spouse	11	7.2	10	6.6	
reinvestment	Mostly myself	6	3.9	18	11.8	24.06***
	Both equally	22	14.4	15	9.9	
	Mostly spouse	16	10.5	13	8.6	
Sale of animals	Mostly myself	19	12.58	87	57.6	123.55***
	Both equally	17	11.3	23	13.5	
	Mostly spouse	72	48	20	12.8	

*** significant at 1%

Source: Survey result, 2013

The data obtained from the focus group discussion also supported the above argument. According to a woman in a focus group discussion held, the decision in the household is made with the consultation of her. She further noted that, ‘I have involved in decision regarding the use of resources and selling of any products. It also made me air my view and opinions in related to household affairs’. Another discussant said that, ‘The service provided by the microfinance institution assisted me to have the right to give any kind of contribution to those who are in problem, throwing party and for those who lost their family members of relatives’.

Challenges MFI face in their performances

When microfinance institutions are working to empower rural women, they are facing many challenges. These challenges have always become a bottle neck in the efforts made to achieve their objectives. Kulkarni (2011) stated that ‘While the empowering potential of microfinance programmes remains strong, the evidence of challenges, ineffectiveness and limitations of the potential is equally compelling.

Attitude of the community towards government supported MFIs

People in any community have different attitudes towards microfinance institutions depending of the orientations they have. Due to the changes microfinance institutions brought, studies show that in many parts of the world people see them as an important intervention to empower poor people especially women. The situation is not different among women of rural districts of Dire Dawa. In an interview made with the coordinator of microfinance in the study area it was stated that the attitude of people in the area was good as those who were members of the institution started earning their own income so that the women solved their economic problem through it.

In spite of the significance that microfinance institutions play in empowering women, there have been various negative attitudes people have towards them. In the study area the money distributed to the clients came from the government office (Dire Dawa Administration Women Children and Youth Affairs Bureau). According to the information from the informants there was a tendency to see government’s money (loan) could be taken for free and it would not bring any punishment if they did not pay their debt. This attitude might be developed, as to an informant, because of the fact that no measure were taken to those defaulters who did not pay the loan. Another informant mentioned that, ‘I did not see any measure taken to those who had not paid their debt’. Among the interviewed, most of them said that the penalty that they came across was simply denying the defaulters not to take loan other time or from other institutions.

Challenges to give loan and collect the debt

In the process of rendering their services, it has been common to see challenges of collecting the debt from the clients. It was also found out that microfinance institutions came across various problems to give the loan to their members. In an interview conducted with the coordinator of a microfinance institution it was found out that some members do not pay the money on time and it was stated that mostly the clients did not pay because they used the money for other purposes. It was also indicated that some of the members could not pay because the business they engaged was not profitable and the time they requested to pay was not appropriate as most of the rural people are engaged in farming which is a seasonal business.

The clients of microfinance institutions in the study are shared the view of the officials that sometimes they found it difficult to pay the loan. Though most of the clients (66.9%) reported that they did not face any difficulties in paying the loan, it was a headache for 50 (33.1%) of them (see Appendix, Table A). The clients gave their own reasons for not settling their debt on time. Among the reasons they mentioned, using the money for personal consumption took the lions share. From 50 defaulters, 23 (46%) of them spent to cover household expenses including family celebrations. This result was also consistent with a focus group discussion held with members. It was stated that, ‘At the beginning I used the money to throw a wedding party of my son.’ Unsuccessful business (20%), lack of market 18%), sickness of family member i.e. medical expense (14%) and disaster (natural. theft, fire, etc) (2%) were mentioned as the other reasons for not paying. (see Appendix, Table C)

The data obtained from focus group discussion also indicated how the clients spent their money so that they found it difficult to settle their debt. A participant in a focus group discussion indicated that ‘I used the money to cover medical expenses because my husband was sick’. When the other discussant asked about why she did not pay, she stated that ‘I did not pay because I feel that as there is no interest so that it does not matter whether I paid it or not, but I am paying the saving money’

The challenges microfinance institutions faced were not limited to collect the loan from the members but also to give them the loan. As one of the goals of microfinance institutions is encouraging rural poor to develop saving habits, the data gathered from those who work in the office showed that the saving habit of the women in the study area was not promising though there were improvements after the intervention. Thus, lack of saving habit of members was considered as one challenge that microfinance institutions faced. The other challenge, as indicated by informants, was that some of the clients were not ready to take loan and engage in business that could change their life. Moreover, some women took loan without any real plan simply because others did it. This hampered the effort of the microfinance institutions to empower those women who were ready to work and be changed.

Religious Outlooks

People in any society need their norms to be respected and followed. Especially rural people are very sensitive in any issues related to their religion. Those who behave against the religion of the particular society could be cursed and out casted. The religion of the clients in the study area was one of the factors that influenced the business of microfinance institutions. As microfinance institutions need capital to run the program, interest was collected depending on the amount of money lent. It is however, working with the money that involves interest was considered as *haram* (forbidden) among Muslims. A member of a microfinance institution during the group discussion mentioned that, ‘At the beginning there was a problem of attitude towards it because in *sheria* interest is taken as sin- taking or giving money with interest is forbidden.

The above argument is supported by a research conducted in other places. Muleta (2008) indicated that among the Muslims it is forbidden *(haram*) to take interest from loan and pay interest to loan. Moreover, in a study conducted in Pakistan, the result showed that 80% of respondents were positive that financial intuitions are largely perceived as non-Islamic. (Jaffari et al, 2011). In order to solve the problem, MFI in the areas gave up calculating interest on the money they lend. Instead, they request the clients to pay some administrative costs.

Lack of fund (Scarcity of loan money) and problems of logistics

The other bottleneck that affected the effort of microfinance to empower rural women in the study area was scarcity of money to be given to clients. It was mentioned that as the money was scarce it was difficult to give the credit service to all need. Furthermore, it was indicted that the amount of loan given to the clients was not enough to engage in a business that may bring sustainable change. In an interview with a person, it was stated that increasing demand of loan money and scarcity of money became a head ache to the microfinance institutions. A person who works in a district microfinance office shared this view and argued that it was difficult to give loan to all because the budget allocated was limited.

Literatures also show that this problem was not peculiar to the study area. Ashcroft (2008*)* stated that lack of funding has been a challenge for African microfinance institutions. Moreover, microfinance institutions in the area were challenged because of lack of logistics such as per diem, transport and equipments for those who work in awareness creation and give training. It was indicated by a coordinator at a microfinance that,

> *We are facing transportation problem to take the money from the bank and to deposit the money collected from the clients. Moreover, we do not have safe place to keep both the money taken from the bank or collected from the clients*

It was also argued that, ‘A main constraint to the provision of financial services to all in Africa is the high cost operating environment’ (Aschoft, 2008). In support of this Befekadu (2007) asserted that shortage of logistics became a problem in microfinance service delivery.

Attitude towards female

In a patriarchal society females have been given lower status than their counterparts. The situation was not different in the areas where the study was conducted. Mainly as the decision maker and the breadwinner is the husband so that the rural women hardly air their views and opinions in related to household affairs. Nevertheless, the participation of women in microfinance institutions brought some changes in the attitude of people regarding the status given to women. It is, however, argued that access to financial services alone cannot guarantee empowerment or poverty alleviation, especially for women in a society dominated by male (Skarlatos, 2004). It was further notes that the biggest constraint to empower women through microfinance was the culture of patriarchy (Kulkarni, 2011).

The data gathered from the informants proved this issue, and this low status that is given to women challenged the microfinance business to empower women. Though this situation has been changed for better, as most husbands understood the importance of empowering women economically, there were partners who were against the saving and credit services given to women. An informant indicated that some husbands did not want their wives to take loan. It was also indicated that ‘Men farmers are complaining that how loan is given to women when the man is there’. Studies conducted in other part of Ethiuopia supports this finding**.** In a study that was conducted in Hitosa Woreda, Arsi Zone by Muleta (2008) a key informant lady who is the deputy chairperson of woreda women’s affairs office, noted that ‘He [the husband] would never allow his wife to work outside. The husband also thinks and says how come that while I am alive my wife works outside.’

Summary, Conclusion and Recommendations

Microfinance institutions have been playing a significant role in poverty alleviation and women empowerment. In rural districts of Dire Dawa where the study was conducted women members of microfinance institutions have benefited so that their lives have been changed for better. Since the income of the clients increased, their livelihood has been improved. They had also developed saving habit which they did not think of before they became member of microfinance institutions. The decision making status of the members had also been improved. Even though the contribution of microfinance institutions in empowering women has been immense, they were not free from challenges. The study revealed that attitude of the people towards government supported microfinance institutions has been one of the challenges faced. There was a tendency to think that there would not be penalty if loan that came from government had not been repaid. Microfinance institutions had also faced challenges in order to give the loan and collect the debt from clients. The religious belief of the people in the study area about loan that involves interest and scarcity of fund were also considered a bottleneck. Moreover, there were husbands in the study area who did not see the involvement of women in outdoor cash earning activities as normal. Thus, it has been recommended that first of all awareness has to be created among the rural people regarding the role of microfinance institutions and the importance involving women in cash earning activities. Microfinance institutions should also look for possible source of fund so that they can gave effective services for those who need to be member. Moreover, microfinance institutions have to be well organized in terms of giving loan and collecting debts

Acknowledgements

We would like to thank Haramaya University, Vice President for Fesearch Affairs Office for funding this study. We are also indebted to the rural women in the districts where the study was conducted for their time committed to give us the information for the research. Last but not least, we would like to extend our gratitude to those who work in Dire Dawa Administration Children, Youth, and Women Affairs Office and development agents of the study site.

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Appendix: Tables

Table A

Difficulties faced in repaying loan

	Frequency	%
Yes	50	66.9
No	101	33.1
Total	151	100

Table B

Income increased because of the program

	Frequency	%
Yes	103	88.0
No	14	12.0
Total	117	100

Table C

Reasons for not paying debts

Variables	Frequency	%
Used the money for consumption	23	46
Unsuccessful business	10	20
Lack of market	9	18
Sickness of family member		
i.e. medical expense	7	14
Disaster (natural, theft, fire, etc)	1	2
Total	50	100

Gender Dimensions of Access to and Utilization of Information related to Water, Sanitation, and Livestock Management in Haramaya and Dire Tiyara Woredas, Eastern Ethiopia

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Funded by HrU Government Research Grant

Abstract: *Gender dimension has become a typical concern in planning and facilitating development interventions meant for addressing the needs of both male and female members of gendered societies. Information interventions, like the other development endeavors, spur improvement in livelihood capacities of people if they are wisely and fairly made accessible and utilizable to both sexes. With an aim to provide the gender dimensions of information in the study area, this paper investigated the differences that occur between male and female members of the communities in terms of access to and utilization of information specifically related to water, sanitation, and livestock management. It also suggested certain strategies to fill the gender gaps of information by capitalizing on constraints and opportunities in accessing and utilizing the information. According to the field survey, review of documents, and personal observations, access to and utilization of information related to water, sanitation, and livestock management was found to be very limited in the study area, though, certain parameters were still found significantly different for males and females. However, many respondents do not have a felt need* *for water and sanitation information in particular and hence it was challenging to obtain aggregate data for many of the parameters that lead to different results between male and female respondents. Generally, the study reveals that there are gender differences in access to and utilization of information even with the limited amount of information available and hence appropriate media and strategies should be utilized to address such a gap. Moreover, studies and interventions related to information support should build on the information behavior and feelings of people prior to any other information related supports.*

Key Words: Gender Dimensions of Information, Need, Access, Utilization, Constrains, Opportunities

Introduction

Water and sanitation disease burden contribute 4% of the world death and 5.7% of the disease burden occurring in the world (Pruss *et al*., 2002). The population in the rural areas, especially, women and children are disproportionately affected by this problem. A large number of community based organizations, governmental and non-governmental organizations have continued to invest on projects related to capacity building and information provision on water, and livestock management. For example, 15% of the population of third world countries is malnourished or hungry, more than 100 million children under five are underweight and more than 870 million people are food insecure (FAO, 2012). Another study also indicated the importance of investing on improvements offering positive externalities, and that programs must encourage the safe disposal of children's feces in order to produce maximum health gains (Buttenheim, 2008).

Consequently, Sub-Saharan African countries like Ethiopia have kept struggling to achieve reaching rural and urban population with adequate information on their new packages of products and services. However, the existence of a differential level of access to and utilization of development information across members of the society has contributed to impartialities in the benefits of interventions reaching the various segments. Women are the main constituents of these disadvantaged segments. With lower rate of literacy and lesser exposure to mass media by women who live in rural and peri-urban areas of Ethiopia in general and in the study areas in particular, achieving equitable and progressive distribution of development information become challenging.

The level of success in development interventions depends on multiple variables among which quality and amount of information accessible to and utilizable by the population remains to be an important determinant. Information has increasingly become an important instrument in transforming social, economic, and environmental affairs both at global and local levels. It is the lifeblood of any society and vital to development of public as well as private sectors. If a nation is expecting meaningful growth, then it has to make maximum effort possible to establish a support system that helps communities to get access to and utilize development information.

More importantly, women play a critical role in production of food and cash crops for the household in post harvest activities and in livestock care in Ethiopia. Men and women perform different tasks that can be substituted by one another only to a limited extent and this limitation creates different demands for extension information. Furthermore, men leave farms in search of paid employment in urban areas. Women are increasingly managing and operating farms on a regular and full-time basis. Consequently, women are becoming a constituency for extension and research services in their own right (World Bank, 1995, as cited in Asres, 2006).

Though women play a potentially transformative role in agricultural growth, but they face persistent obstacles and economic constraints limiting their inclusion in agricultural growth (IFPRI, 2012). However, in many parts of the world, women in agriculture operate under greater constraints than men (Prakash, 2003). Since any extension system must target particular categories of clients to meet their needs, gender specific problems of the clients need gender specific solutions: women in agriculture need special help (Van den Ban and Hawkins, 1996). Despite their contribution in water collection, and management of small-ruminants, poultry and cattle, but female heads of households are less likely to get extension services and less likely to access quality services than their male counterparts (Ragasa *et al*., 2012) and they face serious limitations in access to adequate information in services provided by agricultural and health development agents. In addition to their involvement in productive activities such as selling “khat”, the women are often responsible for making water available to the household as well as manage especially small-ruminants in and around homesteads.

Access to and effective utilization of development information by people who are living in developing countries provides a substantial merit to the entire population. However, there is always a challenge in addressing targets with substantial information particularly in this part of the world. In this regard, improving extent of access to and utilization of development communication requires intervening with the personal, socio-psychological and situational factors so that such an intervention could lead empowerment of population in general, and a woman’s in particular (Asres, 2006). Such an intervention should begin with the understanding of the levels of access to and utilization as less as related dimensions of information in a given area. In this regard, there is no previous systematic study conducted to analyze access to and utilization of information related to water and sanitation as well as livestock management.

Hence, this project is initiated to fill the gap with an overall objective of analyzing the gender dimensions of access to and utilization of water, sanitation and livestock management related information in the study areas. The study specifically aims at assessing the difference between males and females in the extent of access to water, sanitation and livestock management related information; analyzing the levels of utilization of water, sanitation and livestock management related information by women and men; and identifying the constraints and opportunities for women in accessing and utilizing water, sanitation and livestock management related information.

Research Methodology

Description of the study area

Haramaya Woreda

Haramaya woreda is one of the eighteen woredas (CSA, 2007) in East Hararghe Zone with an estimated size of 52,163 ha. It is situated in the semi-arid tropical belt of eastern Ethiopia and characterized by a sub-humid climate with an average annual rainfall of about 790 mm, annual mean temperature of 17c with minimum and maximum temperatures of 9.4 and 242c, respectively. The woreda experiences biannual type of rainfall classified as short and long rainy seasons. The short rainy season usually occurs from end of February to mid May and the long rainy seasons occurs from July to end of September. Its altitude ranges from 1600 to 2100 m.a.s.l.

The total population of Haramaya woreda is 271,394 (50,986 Urban and 220,408 Rural) (ibid). The rural people in the woreda are Oromo in ethnicity and Muslim in religion. Concerning household size, a rural household has an average size of seven while the urban one has six individuals. The farming systems practiced in the woreda is based on a mixed type of agriculture that is subsistence in nature. Sorghum, maize and khat are the most important agriculture crops in the area and dominantly consumed by the rural community.

Dire Tiyara woreda

Harari region is located in eastern Ethiopia, 525 kms away from the capital city Addis Ababa. The region is located between 42.04° and 42.22° East longitudes, 1 00 and 25° North latitude and contains a total of six woredas, 19 urban and 17 rural kebeles and 1 83,344 residents of which 99,321 people live in the urban areas and the rest in rural (CSA, 2007). According to the regional finance and economic development bureau, out of the total area of the region 53% of the land is used for cultivation of crops, 21% serves for grazing and the rest 26% is allotted for infrastructures and investments and the region is delineated with Oromia regional state. The Harari region is well known for its cash crop production especially khat, coffee, vegetables and fruits.

According to the regional bureau of agriculture, the average annual rainfall of the region is estimated to be 600-800 ml per annum and the average temperature is 28°c. Hence, 90% of the region's weather condition is *"woina dega"* and the rest 10% is *"kola"*. The region is well equipped with infrastructures like roads, electricity, telecommunications, schools, colleges, banks and insurance companies, hospitals, etc and currently the regional government is striving to alleviate the shortage of clean drinking water which was the major limitation for the development of the region.

Sampling procedures

Haramaya and Dire Tiyara woredas were selected purposively, since both are within closer reach of Haramaya University. Four Rural Kebeles (RKs) were selected randomly from each woreda, among which two are closer to woreda towns and two are far from the towns. The sampling frame was the list of all households obtained from Kebele Administration offices. From the sampling frame, a total of 400 households were selected based on probability proportion to sample size of the list households. Among the sampled respondents were also included 32% female spouses and female heads of households.

Methods of data collection and analysis

Both primary and secondary data (of qualitative and quantitative nature) was collected for the purpose of the study. Primary data were collected using semi-structured and prê-tested interview schedules from sampled respondents. Checklists were also used to collect information from four male and female focused group discussions (FGDs) in each woreda and from key-informant interviews (KIIs). Secondary data were collected by reviewing published and unpublished sources, documents of various bureaus and records. The collected quantitative data were analyzed using descriptive statistics, such as mean, frequencies, and percentages, as well as inferential statistics like Chi-Square Test (x^2-test). Qualitative data were analyzed through interpretations and meaning categorizations.

Results and Discussion

This section briefly presents key findings pertaining to gender dimensions of access to and utilization of information related to water, sanitation and livestock management in the study area. In doing so, access to and utilization of information related to water and sanitation, access to and utilization of information related to livestock management, as well as constraints in access to and utilization of information under consideration are summarized in great depth. Parallel to the abovementioned, reflections on findings regarding opportunities in access to and utilization of information related to water and sanitation as well as opportunities in access to and utilization of information related to livestock management also constitutes part of the discussion of this section.

Need for water and sanitation related information: Is it a felt or unfelt one?

Prior to attempting to understand and explain access to and utilization of information by rural people, it is important to look into the level of targets' need for the information itself. People will not obviously inquire about information and intend to use, on one hand, if they do not have a felt need for the information. In this study, majority of the sampled respondents perceive that they are well doing in terms of their level of access to such functionalities as, for instance, substantial access to chlorine cleaned potable water. While 80% believe that they have access to clean potable water, over 95% of the respondents perceive that the cleansing is made by treating the water with chlorine. Respondents' view, based on researcher's personal observations, also reflected much of infrastructural lacunae related to water and sanitation rather than urgency of information needs at local level.

The later finding, however, contradicts with responses from discussants' of FGDs, KIIs, and researchers' participatory observation which reveal the persistence of shortage of potable water and sanitation functionalities in Haramaya and Dire Tayara woredas. Prevalence of such a problem holds true for studies on water and sanitation issues typical to eastern Ethiopia (see among others on Bizatu and Nega, 2010; Degefa and Tesfaye, 2008). This simply shows that respondents are less considerate of the need for water and sanitation related interventions in general, and information in particular.

Access to information related to water and sanitation

Despite the fact that the need for water and sanitation related information in the study area is somehow unfelt to the respondents and, therefore, rarely demanded, the results of the study indicated that there are still gender concerns for certain parameters used to measure access to and utilization of information related to water and sanitation. The results become more statistically sound going down along the tables in this sub-section.

Table 1. Gender differences in access to information related to safe excreta disposal and safe water collection, storage and use

Access to information on	**Sex of Respondents**	**Have access to information**	**Have no access to information**	**Total**	**x^2-test**	**df**	**Cramer's V**	**P-Value**
Safe Excreta Disposal	Female	93 72.7%	35 27.3%	128 100.0%				
	Male	221 83.1%	45 16.9%	266 100.0%	5.806	1	.121	.161
Safe water collection, storage and use	Female	105 82%	23 18.0%	128 100%				
	Male	237 87.1%	35 12.9%	272 100%	5.950	4	.122	.203

Source: Own Survey Data, 2013

As evidenced by the above table, 72.7% of the sampled women have information regarding safe excreta disposal while 83.1% of the sampled men respondents found to be with access to information regarding safe excreta disposal. In terms of percentage, though men have better access to information than women with narrow margin, the difference is statistically insignificant. This clearly demonstrates that there is no appreciable gender difference in terms of access to information between men and women regarding this issue. Based on data generated from FGDs and participatory observation in the research areas, the prevailing equal access to information between men and women is attributed to a lifelong experience and tradition of the people in the disposal of household excreta. In addition, the advent of health extension workers in the area has further strengthened the existing knowledge and experience of the community.

When we look at access to information regarding safe water collection, storage and use, the same scenario happens to be applicable like the above mentioned one. Women with positive response constitute 82% of the sampled population while men constitute 87.1%. The statistical test tells us that there is no statistically significant difference between men and women pertaining to access to information on safe water collection, storage and use. Data generated from KIIs from the Woreda office and from FGD how that the limited nature of the area of intervention in this regard, is what has brought about equal access to information between men and women. In addition to that, the presence of house to house health extension workers in the Woreda is what has also narrowed up the existing margin of gender differences of access to information on this matter.

The study reveals that males have greater tendencies to get access to information on safe solid waste disposal while females do have better access to information on disease causing vectors compared to their spouses respectively. Safe solid disposal i.e. the collection of litters, cow dung, and other waste products and to burry, or burn, or use them for compost making is an important indicator for local level solid disposal. In line with this, respondents have commonly indicated that they do have limited information on collection and burning of solid waste products, such as litters, away from their households. The better accesses to safe solid waste disposal information for the male indicated in the table below, therefore, is resulting from the fact that development agents usually target male household members better than the female ones when they come with information particularly related to compost making.

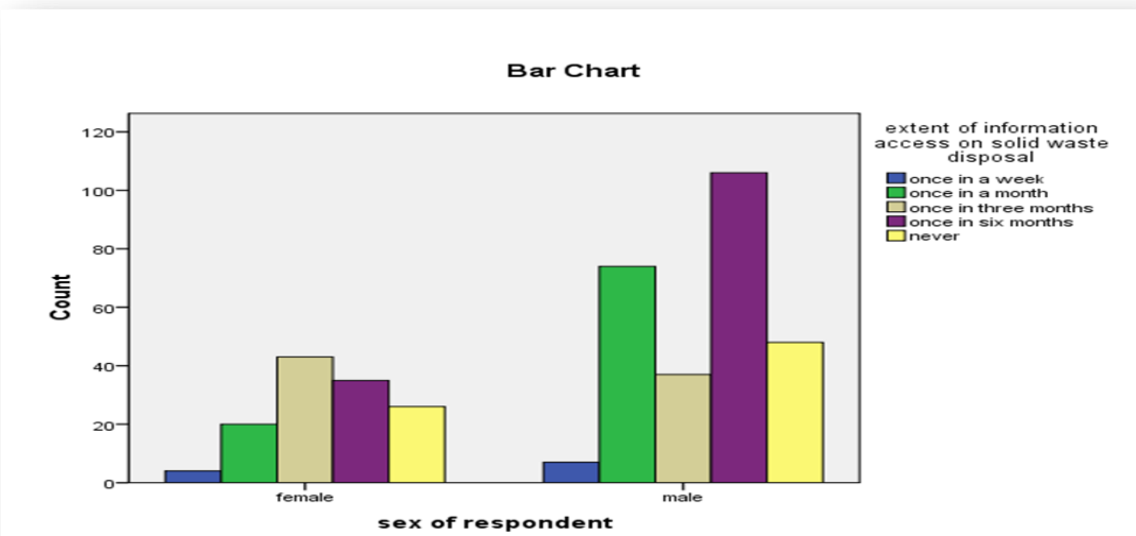
Table 2. Gender Differences in access to information related to safe solid waste disposal

Access to information on	**Sex of Respondents**	**Have access to information**	**Have no access to information**	**Total**	**x^2-test**	**df**	**Cramer's V**	**P-Value**
Safe Solid Waste Disposal	Female	102	26	128				
		76.7%	23.3%	100%				
	Male	224	48	272				
		82.4%	17.6%	100%	26.128	4	.256	.000***

*Source: Own Survey Data, 2013; *** significant @1%*

A considerable difference is shown between male and female respondents particularly on a monthly and biannually access to information related to safe solid waste disposal. Males have better access to monthly and biannually information on safe solid waste disposal as seen in the graph below.

Graph 1. Gender differences in extent of access to information related to solid waste disposal



Source: Own Survey Data, 2013

Much of this information was indicated by participants of FGDs and KIIs to be related to management of solid waste products for compost making. Discussants indicated that the females' role basically rests on collection and disposal of waste products while the males are often responsible to select and recycle the waste products for compost makings. It should be noted,

Table 3. Gender differences in access to information related to disease causing vectors

Source of information	**Sex of Respondents**	**Have access to information**	**Have no access to information**	**Total**	**x^2-test**	**df**	**Cramer's V**	**P-Value**

Access to information on	**Sex of Respondents**	**Have access to information**	**Have no access to information**	**Total**	**x^2-test**	**df**	**Cramer's V**	**P-Value**
Disease causing vectors	Female	97	31	128				
		75.8%	24.2%	100%				
	Male	179	93	272				
		65.8%	34.2%	100%	20.181	4	.225	.000***

however, that collection and disposal or sometimes even recycling of solid waste

products such as cow dung – into fuel is traditionally accepted to be the role of female members' households and urges for availability and accessibility of related information to the females. On the other hand, females have better access to information related to prevention and controlling disease causing vectors such as mosquito and flies. The difference is shown in table below.

Respondents from both Haramaya and Dire Tayara woredas have commonly indicated that malaria and diarrhea are prevalent diseases caused by vectors that are coming from marshy and

dirty areas of the surroundings respectively. Though there is limited information available to the area on management of such areas and prevention of the disease causing vectors, females have better exposure to knowledge of, for instance, prevention of malaria since they are somehow in better contact with community health extension workers than their male counter parts. The gender difference, seen from the point of interventions made through radio and health extension agents, is statistically significant @ 1%. See the Table below.

Table 4. Gender differences in sources of information related to water and sanitation issues

Radio	Female	78	50	128				
		60.9%	39.1%	100%				
Access to information	Male **Sex of**	203	69	272	***x^2*-**			
		74.6%	25.4%	100%	21.266	4	.231	.000***
Health	Female	95	33	128				
Extension		74.2%	25.8%	100%				
Workers	Male	135	137	272				
		49.9%	51.1%	100%	31.249	4	.280	.000***
Religious	Female	53	75	128				
places		41.4%	58.6%	100%				
	Male	106	166	272				
		38.3%	61.7%	100%	10.542	4	.163	.132

*Source: Own Survey Data, 2013; *** significant @1%*

Respondents have, however, found other sources of information such as religious places as equally accessible to both sexes for water and sanitation related information. Generally, gender differences in access to information on water and sanitation in the study area are characterized with simple tendency of males or females exposure to very limited information related to the issues in consideration rather than a clear and detailed understanding of the information by both sexes. This is also linked to the fact that the respondents have an unfelt need for information related to water and sanitation and hence they were able to respond to very few parameters in this study.

Access to information related to livestock management

Data generated from the research shows that for every category presented, male and female have very limited access to information. However, if we take a closer look at of the percentage of male and female who have better access to information for the different categories, we witnessed a 10% statistically significant level of differences between the two. For instance, for the first category that deals with access to information on local breed livestock women with positive response constitute 10.2% where as male constitute 18%. On the contrary, the percentage of female and male who have no access to information constitutes 89.8% and 82.0% respectively.

Table 5. Gender differences in access to information related to livestock management

on	Respondents	Have access to information	Have no access to information	Total	test	df	Cramer's V	P-Value
Local Breed Livestock	Female	13	115	128				
		10.2%	89.8%	100%				
	Male	49	223	272				
		18.0%	82.0%	100%	4.104	1	.101	.043
Local Breed Shoat	Female	28	100	128				
		21.9%	78.1%	100%				
	Male	84	188	272				
		30.9%	69.1%	100%	3.503	1	.094	.061
Local Poultry Breed	Female	61	67	128				
		47.7%	52.3%	100%				
	Male	93	179	272				
		34.2%	65.8%	100%	6.665	1	.129	.010*

Source: Own Survey Data, 2013 * *significant @ 10%*

The latter figure clearly demonstrates that both have very limited access to information. Despite of the limited access to information both have on this category, with small percentage, male's are better placed in terms of access to information on local breed livestock. This leads us to the generalization that even if those who have access to information are small in percentage compared to those who have no access to information, the result on differences between male and female is statistically significant at 10% level.

For the second category also, female and male respondents who have no access to information still over weighs those who have access to information. The percentage of female without access to information is 78.1% while 69.1% goes to male. On the contrary, the female-male percentage with access to information constitutes 21.9 % and 30.9% respectively. Similar to the above mentioned category, the figure clearly depicts that there is a 10% statistically significant level of differences between the two sexes regarding access to information on local breed shoats. This case also clearly shows that males are relatively privileged in access to information for this category as well.

Similar to the above two cases, the third category that deals with access to information on local poultry breed represents higher percentage of respondents without access to information and the statistics shows that there is still 10% statistically significant level of differences of access to information between the two sexes. However, what is unique about this category is female portions of the target respondents appears to be with better access to information than male representing 47.7% while male constitutes 34.2%. Based on an exclusive interview and FGDs conducted with women, Woreda officials and development agents, the existing disparity in access to information is attributed to the fact that traditionally it is believed that females are responsible for raring and taking care of poultry while big animals are the responsibility of males. As a result males are relatively insensitive to information regarding this issue than female. Development agents and extension workers are also more interested to provide information to women than male due to inbuilt inertia.

In all of the above mentioned categories, it is evidenced that access to information on livestock production and management appears to be limited across the two sexes. Qualitative information generated from different actors revealed that the limited access to information is attached to the lack of need displayed by the community. Though lack of need for information on livestock issues is brought forth as a reason for the limited access to information, different actors, including, community members stress that the lion's share of the blame should go to the Woreda office of the livestock sector for failing to create demand for information on the subject.

According to the responses obtained from FGDs and KIIs most of the information on improved livestock management is obtained through participation in extension events such as individual contacts with agricultural development agents at homesteads or by paying a visit to their offices. In this regard, the study reveals that there is a better tendency for the males to participate in extension events than the females. The difference is depicted in the table below.

Table 6. Gender differences in extent of participation in agricultural extension events

Sex	**participated in extension**						
	no	**yes**	**Total**	**x^2-test**	**df**	**Cramer's V**	**P-Value**
Female	84	44	128				
	65.6%	34.4%	100.0 %				
Male	135	137	272				
	49.6%	50.4%	100.0 %				
Total	219	181	400				
	54.8%	45.2%	100.0 %	8.986	1	.150	.003**

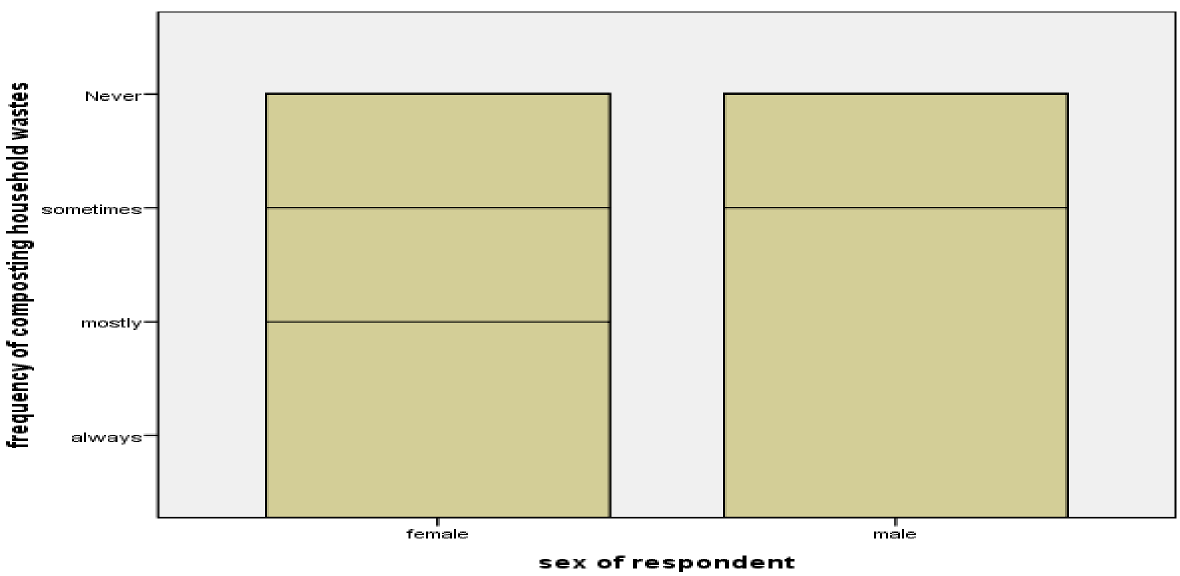
Source: Own Survey Data, 2013 *** significant @5%*

Linking the results in the above table with access to information by the two sexes, therefore, implies that the extension events provide more information on cattle and shoat than poultry since males are more exposed to cattle and shoat related information than females who are more exposed to poultry information than their counterparts and vice-versa. Participants of FGDs indicated that the information provided on cattle and shoat through various extension events is quite limited and merely focuses on local breeds. Considering the results again, the information provided through extension events to participants on poultry becomes even negligible and hence women would hardly benefit from.

Utilization of Information related to water, sanitation and livestock management

The study reveals that there is a 1% statistical significance level of differences between male and female respondents for utilization of information related to safe solid waste; such as excreta disposal and composting in particular. The graph below shows that male tends to implement the composting more frequently than their female counterparts. Here, note that the result is analyzed based on responses on the frequency of individual's implementation of compost making related information accessible to him or her.

Graph 2. Gender differences in frequency of using household waste products for compost



Source: Own Survey Data, 2013

On the other hand, females have been found to utilize information related to disease causing vectors better than male respondents. For this study, utilization of such information is measured through application of insecticide chemicals and detergents during incidences of disease causing vectors and major pro-active responses too. Male and female respondents have been observed to utilize water collection, storage, cooking, washing, canning and related information on water and sanitation with a statistically insignificant level of differences. The finding is actually a result of the fact that the information under consideration is lacking in the study area- as seen in the previous discussion and hence both sexes tend to exhibit a similar level of utilization.

Results on utilization of livestock management related information by male and female respondents simply correspond with their differences in access to the information itself i.e. males have better access to cattle and shoat management information while females are more advantaged than males in terms of access to poultry information. Accordingly, females have shown better tendencies to utilize information related to improved poultry management while males have utilized information on improved cattle and shoat management better than their male counter parts.

Constraints and opportunities in access to and utilization of information related to water, sanitation, and livestock management

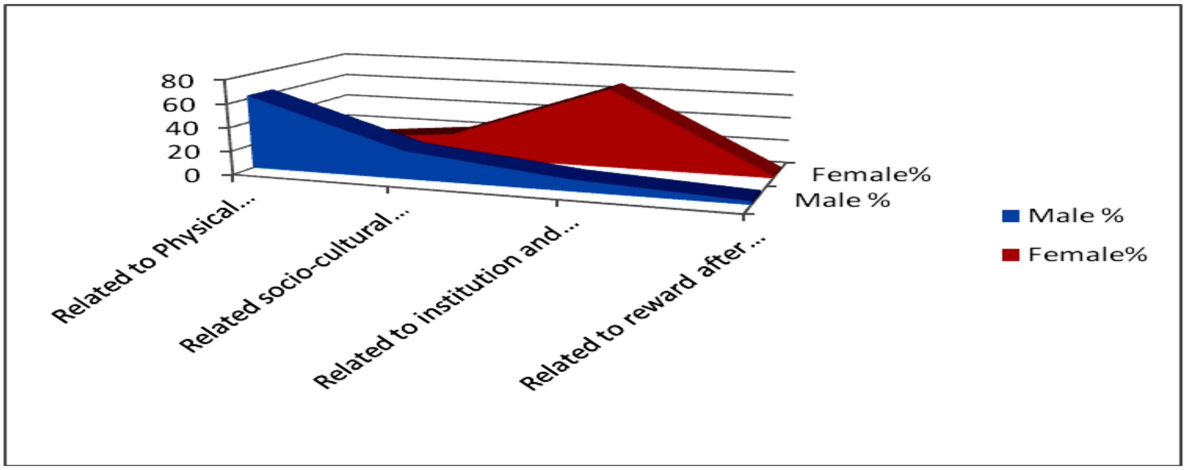
Constraints in access to and utilization of information related to water, sanitation and livestock management

There are various constraints in access to and utilization of information in the study area. According to the sampled respondents, much of these constraints are related to lacunae in institutional capacities and farmers capabilities. These include; limited organizational interventions related to information on water and sanitation, shortage of knowledge, enthusiasm, and skills of local people to utilize the limited amount of information available. Besides, respondents have also indicated that the limited amount of information on water sanitation issues was not fully taped and utilized because of shortage of chemicals and sanitation materials. The later has been highly pronounced by female respondents (60%) compared to the male (20%) ones. Male tended to be silent on other constraints in this regard.

In relation to access to and utilization of information related to improved livestock management, both sexes equally valued lack of institutional capacities, and personal capabilities, as well as technical equipments as the most important constraints. However, lack of range land is more important constraint that hindered enthusiasm towards informed livestock management for male respondents in the study area while females prioritized socio-cultural and economic incompatibilities of rearing livestock as the major constraints. Female respondents indicated that rearing livestock is less responsive to their homestead needs and social values compared to other enterprises such as khat production. Furthermore, females emphasized that they are less responsible for cattle and shoat fattening and hence their demand for information also accords with the same.

Opportunities in access to and utilization of information related to water, sanitation, and livestock management

The opportunities available in relation to improving access to and utilization of information on water and sanitation issues in the study area involves, once again, both institutional and personal capabilities as well as capitalizing on the existing limited physical resources to be able to furnish the ground on which the information can be utilized.



Source: Own Survey Data, 2013

Graph 3. Gender differences in opportunities for improving access to information related to water, sanitation, and improved livestock management

Females rose that institutional capacities and personal capabilities are the major opportunities on which various stakeholders should aim at improving while males focused more on the necessity of amending the physical resources available as an opportunity to access information related to water, sanitation, and improved livestock management. Physical resources and assets refer to infrastructural facilities and the size of livestock available. Majority of the sampled males respondents and key informants stressed on the point that the area is favorable for livestock fattening and hence they also derive farmers to partly involve in fattening enterprises which would interest them to get access to and utilization of information related to improved livestock management. Females view that institutional capacities and personal capabilities are the major opportunities in terms of improving access to and utilization of improved livestock management information. These include high market price for livestock, accessibility of development professional with animal science background, and availability of strong informal social networking.

Summary

Water and sanitation related information for most of the issues raised in this study is not a felt need for people living in the study area. Respondents preferred to direct their attentions towards, for instance, infrastructural problems of water and sanitation rather than information needs in response to the inquiries made during the field survey. FGDs, KIIs, and researchers' observations, however, justified that the study area is lacking proper water and sanitation use and management strategies. The same has also caused methodological challenges to the research particularly during the analysis of responses aggregate to gender based information need (i.e. very few parameters were found statistically significant in that regard). The reasons for the existing dwindling access to information in this regard, rests on the lack of information need displayed by the community for the past years due to a change in the course of lifestyle and the lack of persistence and coordinated action by the woreda's bureau of livestock sector to create demand on the gradually dwindling and latent information need of the people.

There are, however, certain parameters that are found different between male and female respondents. Pertaining to access to and utilization of water and sanitation related information, males are better off than females in terms of access to and utilization of information related to safe waste disposal, composting and recycling of waste products in particular, while the reverse is true for responses on disease causing vectors. The results might be seen in correspondence with the finding that males have higher exposure to media such as radio and development agents while females are in better contact with health extension workers. Utilization of information is found to accord with the level of access to information that the individuals possess. Therefore, utilization of information related to water, sanitaion, and improved livestock management is not a gendered matter. This implies also that addressing gender gaps in access to information would simply respond to the gender gaps in utilization of the information.

The research findings unambiguously show that male and female have scant access to information related to improved livestock management, particularly on exotic breeds, though male are found to be relatively privileged in access to information on the subject within the course of the prevailing scarcity on the areas of access to information on local breed livestock and information on local breed shoats and females having better poultry production related information.

Gender dimensions in constraints and opportunities of access to and utilization of water, , and improved livestock management information are related to physical, socio-cultural, economic, as well as institutional capacities and personal capabilities of the area and respondents. Females tend to pronounce shortage of chemicals and saniataion materials as hindrances of searching for information related to water and sanitation. They say there is no use to search for information if the materials on which to apply the information are not available. Regarding constraints in access to and utilization of livestock management information, males have found shortage of forage-responding more enthusiastically than female respondents. Eventually, females have found institutional capacities such as availability of untapped media and professionals as to improve their capabilities as the major opportunities to improve access to and utilization of information related to water, , and livestock management while males gave more value for physical resources such as availability of infrastructures.

Therefore, institutional arrangements should be put in place to convert the unfelt water and sanitation related information needs of people by utilizing local radio stations, informal social networks, FTCs and other local organizations, as well as home visits. On the other hand, researchers should be able to settle methodological issues of inquiries related to felt and unfelt needs of information while studying about information behavior of people.

In the context of the limited information available itself, the type of communication media and contents used for interventions related to improved water and sanitation management deters the extent to which female and male differ in terms of getting access to and utilization of information. The same thing also holds true for gender dimensions in access to and utilization of improved livestock management related information.

Moreover, contents and strategies of agricultural extension programs should be able to address gender dimensions of information related to improved livestock management in the study area. Planning such programs should start with a thorough study of information seeking behavior of both sexes. Besides, contacting females through agricultural development agents should be able to utilize home and farm visits as well as market place where, females can be mostly spending their days.

Finally, stakeholders who are working on improving institutional capacities, farmers' personal capabilities, and infrastructures related to information should be able to closely work with the local people on designing ways to bridge the gender constraints of information related to water, , and livestock management. Finally, stakeholders should understand and tap the sex aggregated results of opportunities to solve gender gaps in access to and utilization of information related to water, , and livestock management. These opportunities, for males, are more of availability of physical resources such as roads that encourages cattle fattening and sending to market spots, for instance, while females' idea of improving their access to the already available media and informal social networking should count equally as an opportunity.

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2. College of Business and Economics

Fostering Rural Employment through Creating Rural Non–Farm Activities (RNA) and Household Jobs in Haramaya, Kersa, and Babile Woredas of Eastern Hararghe Zone, Oromia National Regional State

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Funded by HrU Government Research Grant

Abstract:*This study analyses the behavior of rural households on the involvement in rural non-farm formal and informal indigenous handcrafts in off-farm work participation decisions of farm households in three districts (Haramaya, Babile, and Kersa), from Eastern Hararghe Zone of Oromia Regional State, Ethiopia. It attempts to map the areas where rural off farm household level handcrafts are practiced, and identify the major constraints hindering the development of non-farm employment activities in the study area. It primarily focuses on the mapping of rural non- farm activities in the study area. Mainly a descriptive statistics were used to analyze the data. The results of the analysis show that while farming is the main economic activity of Eastern Hararghe zone, there is a significant difference on the practice of handcraft activities. The distribution of such handcraft skills differ from household to household because of the availability of inputs, access to markets, learning opportunities and gender differences. The diversification of some handcraft activities in the zone could be attributed to existing skill practices and inputs. In terms of their distribution, households in Kersa district indicated the largest share (52.1%) of the total handcraft distributions followed by Babile which accounts for 39% of the total distributions. Pottery is the main handcraft category reported in the survey which needs further attention of rural income diversification programs in the study apart from leather processing and carpentry. Haramaya district recorded the least in the distribution of hand crafts. Moreover, the study indicated that inter-generational handcraft skill learning is becoming an old fashioned and this caused gaps in handcraft skills among the young and the elders. Finally, the study suggested that apart from increasing agricultural output and raising agricultural productivity, complementary policies and programs must be developed to strengthen the link between farm and non-farm activities. The current agricultural extension program should encompass both farm and non-farm activities and encourage the growth of small-scale businesses and create non-farm employment opportunities in rural areas.*

Keywords: *nonfarm employment, nonfarm jobs, rural households, Eastern Hararghe zone*

INTRODUCTION

Non-farm income is important to farm households in developing countries. In a review of about 100 farm-household survey studies from the 1970-1990s, Reardon *et al.* (1998) find an average share of 42 per cent of non-farm income in total rural household income in Africa, 40 per cent in Latin American and 32 per cent in Asia. There is also evidence that the importance of non-farm income has been increasing over the past few decades (Reardon et al., 2000).

Given the importance of non-farm income, the question of whether and under what conditions rural non-farm employment increases or decreases overall rural inequality is critical in the many situations in the developing world where inequality causes or exacerbates social tensions and instability. In turn, inequality could have a strong bearing on the operation of rural institutions and the impact of policies.

Decentralisation provides an example. In India, widening village-level inequality may well be undermining the effects of decentralisation policies as village governments become less representative of the communities they serve (Jayaraman and Lanjouw, 1998). The current "conventional policy wisdom" is that rural non-farm employment, and thus the microenterprise promotion programmes which aim to stimulate this sector and are currently much in vogue, will unambiguously reduce rural income inequality and, as a resuIt, social and political tensions. In the rural non-farm economy literature this position is typically presented as a hypothesis that non-farm activity reduces the Gini coefficient of total income in a given rural area and hence is "equalising" (Ahmed, 1996).

To address the food security problems, the Ethiopian government has designed and implemented different interventions to improve agricultural productivity, such as irrigation schemes, fertilizer promotion, soil and water conservation, extension services, and food security policies, among others. Nevertheless, focusing on agricultural production alone may not be enough to combat the population's vulnerability to shocks and the resulting food insecurity.

With agriculture so completely dependent on rainfall, rain rules the lives and well-being of many rural Ethiopians. It determines whether they will have enough to eat and whether they will be able to provide basic necessities and earn a living. Indeed, the dependence on rainfall and its erratic pattern has largely contributed to the food shortages and crop crises that farmers are constantly faced with. Even in good years, the one-time harvest or crop may be too little to meet the yearly household needs; as a result, the majority of Ethiopia's rural people remain food insecure (Bezabih et al., 2010).

Rainfall contributes to poverty both directly, through actual losses from rainfall shocks, and indirectly, through responses to the threat of crisis. The direct impacts particularly occur when a drought destroys a smallholder farmer's crops. Under such circumstances, not only will the farmers and their families go hungry, but they also will be forced to sell or consume their plough animals in order to survive. They are then significantly worse off than before because they can no longer farm effectively when the rains return. These impacts may last for years in the form of diminished productive capacity and weakened (Bezabih et al., 2010).

Indirect impacts are equally serious. People tend to be excessively risk-averse when faced with the threat of possible weather shock. They also tend to shy away from innovations that could increase productivity because these innovations may also increase their vulnerability or drain the assets needed to survive a crisis. Moreover, farmers face credit constraints if creditors are not willing to lend for fear that drought might result in widespread defaults —even if loans can be paid back easily most years. This, in turn, critically restricts access to agricultural inputs and technologies, such as improved seeds and fertilizers.

The threat of disaster is enough to block economic vitality, growth, and wealth generation during all years -good or bad—even though a drought (or a flood or a hurricane) may happen only once in five years. Ethiopia has experienced at least five major national droughts since 1980, along with literally dozens of localized ones (World Bank, 2008). These cycles of drought create poverty traps for many households, constantly consuming any build up of assets and increase in income.

Evidence shows that about half of all rural households in the country experienced at least one major drought during the five years preceding 2004. The evidence also suggests that these shocks are a major cause of transient poverty. That is, had Ethiopian households been able to smooth consumption, then poverty in 2004 would have been at least 14 percent lower, which translates into 11 million fewer people falling below the poverty line.

Therefore, non-agricultural or non-farm activities as sources of alternative income may be of paramount importance for people’s livelihoods in the face of climate change, particularly in drought-prone areas and the degraded highlands.

The traditional image of farm households in developing countries has been that they focus almost exclusively on farming and undertake little rural non-farm (RNF) activity. This image persists and is widespread even today. Policy debate still tends to equate farm income with rural incomes, and rural/urban relations with farm/non-farm relations. Industry Ministries have thus focused on urban industry and Ministries of Agriculture on farming, and there has been a tendency even among agriculturists and those interested in rural development to neglect the RNF sector (FAO, 2010).

Nevertheless, there is mounting evidence that RNF income (i.e. income derived in this sector from wage-paying activities and self-employment in commerce, manufacturing and other services) is an important resource for farm and other rural households, including the landless poor as well as rural town residents. Although this source accounts for only part of total off-farm income (which also includes farm wages and migration earnings), this study focuses on RNF income so as to enable a closer examination of what can be done within rural areas themselves to increase overall economic activity and employment.

There are several reasons why the promotion of RNF activity can be of great interest to developing country policy-makers. First, the evidence shows that RNF income is an important factor in household economies and therefore also in food security, since it allows greater access to food. This source of income may also prevent rapid or excessive urbanization as well as natural resource degradation through overexploitation.

Second, in the face of credit constraints, RNF activity affects the performance of agriculture by providing farmers with cash to invest in productivity-enhancing inputs. Furthermore, development of RNF activity in the food system (including agro processing, distribution and the provision of farm inputs) may increase the profitability of farming by increasing the availability of inputs and improving access to market outlets. In turn, better performance of the food system increases rural incomes and lowers urban food prices.

Third, the nature and performance of agriculture, themselves affected by agricultural policies, can have important effects on the dynamism of the RNF sector to the extent that the latter is linked to agriculture. This sector grows fastest and most equitably where agriculture is dynamic– where farm output is available for processing and distribution, where there are inputs to be sold and equipment repaired and where farm cash incomes are spent on local goods and services.

There is a rural labor shortage during the peak season and high unemployment and underemployment during the slack season. Non-farm activities have a great potential to provide employment and additional incomes during the slack season to rural households. In addition, given rising population pressure on agricultural land which results in a decline in land holding per individual, off farm activities can provide alternative employment. Off farm employment refers to employment in activities outside his/her farm. It includes employment in other farmer's farm. But non- farm employment refers to employment outside farming activities. Despite their great potential, rural nonagricultural activities account for less than three percent of the rural labor force (CSA, 1999).

As compared to other African countries, the proportion of the rural labor force engaged in non-farm activities is too low. According to ILO/JASPA (1993), in Ghana for instance 26.7% of the rural workers were engaged in rural non-farm activities, 15% in Sierra Leone and an average ranging from 10-20% in Sub Saharan Africa. According to this report the importance of the rural non-farm activities in Ethiopia is understated because of the narrow definition of the Central

Statistical Authority, and the Ethiopian definition of urban area as towns of 2000 people or more compared to the UN definition, which uses 20,000 people as a cutoff point.

A review made by Abebe Damte (2002) by referring to Mulat and Teferi (1996) classified non-agricultural activities in the rural areas of Ethiopia in to the following categories;

a) Small-scale industrial activities such as food processing: flour milling, oil processing, soap making, cottage industries: handicrafts, spinning of cotton (yarn and wool), cloth weaving and dyeing pottery leather tanning and distilling local brews (such as tej and tella).
b) Informal sector artisan activities; blacksmithing, masonry, wood work/ carpentry, house construction, repair services and fabrication of farm tools.
c) Commercial activities; trading and transportation
d) Infrastructural development activities; special public works feeder roads and irrigation works.
e) Formal employment in rural areas including professional administrative and clerical cadres.

OBJECTIVES AND RESEARCH QUESTIONS

Research objectives

The general objective of the study is to identify and document the various rural non-farm formal and informal indigenous technologies in the study area and the specific objectives of the study are the following:

- to map the areas where rural off farm household level handcrafts technologies being are practiced.
- to identify the major constraints hindering the development of non-farm employment activities in the study area (Haramaya, Babile and Kersa) particularly during off-farm seasons, and
- to identify the availability of institutional supports that help foster rural off-farm employment activities.

To come up with policy recommendations for the establishment of institutional systems to remote rural non-farm businesses and thereby bridge the gaps between agriculture and industry king the cognizance of value chain additions and market linkages.

Research questions

Research questions to be addressed are as follows taking the study area into account:

- What are the patterns of RNF income and employment in different Kebeles and Villages of Haramaya, Kersa and Babile Woredas?
- What are the various rural household jobs and indigenous technologies that can be upgraded to rural enterprise development?
- What effects do RNF income and employment have on the levels and distribution of rural household incomes, poverty incidence and food security?
- What policy and program implications can be drawn from these points?

Materials and methods

Description of the study area

The study was carried out in Eastern Hararghe Zone in three Woredas (Haramay,Kersa and Babille). Eastern Hararghe Zone is located in the Eastern part of Oromia Regional State. The Zone has 18 administrative districts (Woredas) with three municipality towns namely: Aweday, Haramaya and Deder. The Zone has a total area of about 24,248 km^2 (2,424,800 ha). It is bordered with West Hararghe Zone in the West, Bale Zone in the South, Somali National Regional State in the East and South-east, Dire Dawa Administrative Council in the North East and Harari National Regional State is surrounded by the Zone (EHZ/FEDO, 2007). Based on the summary and statistical report of the 2007 population and housing census, the Zone has a population of 2,739, 390 persons from which about 91.93% are living in rural areas and the remaining 8.07 in towns (FDRE/PCC, 2008).

East Hararghe is one of the Zones of the Ethiopian Region of Oromia. It takes its name from the former province of Hararghe and is bordered on the southwest by the Shebelle River which separates it from Bale, on the west by West Hararghe, on the north by Dire Dawa and on the north and east by the Somali Region. The Harari Region is an enclave inside this zone.

Towns and cities in East Hararghe include Alemaya, Babille and Fugnan Bira. Its highest point is Gara Muleta. Local landmarks include the Harar Wildlife Sanctuary and Haramaya University.

The Zone is characterized by three farming systems: the mixed farming (crop and livestock) production, pastoral and agro-pastoral. The mixed farming region accounts for 40% of the total area of the Zone, the pastoral areas account for 50% and the agro-pastoral areas make-up 10% of the total area of the zone. Cereals, pulses, oilseeds, vegetables, fruits and cash crops, like coffee and *“khat”* are widely grown in the Zone during the two cropping seasons. At the lower altitudes, crop cultivation is usually limited leading to more of livestock based economy. At the higher altitudes the economy is characterized by live stock activities.
Due to high population growth, the zone is not in harmony with the rate of socio-economic development which in turn resulted in high dependence on the natural resource base for sustenance. This has also aggravated the rapid environmental degradation and imbalance. Due to

these and other related factors, the zone is afflicted by recurrent drought, food insecurity and high poverty situation (EHZ/FEDO, 2007).

Data sources and collection methods

Both primary and secondary data were collected using formal as well as informal data collection process. Data to be used in this analysis will be taken from a survey of households in the Eastern Haraghe Zone low lands and high lands of Oromia Regional State. The data was collected from 350 farm households randomly selected and interviewed in 8 peasant associations, located in 3 Woredas of the Eastern Haraghe Zone.

The survey questionnaire was pre-tested before data collection and modified. Similarly, Key Informant Interview and Focused Group Discussions (FGD) were administered. Secondary data were collected from different reports, study documents, new paper clippings and websites.

Sampling Techniques

Sample households for data collection were identified using random sampling technique. In the first stage, household lists were collected from peasant associations (PAs) where handcraft activities were widely practiced. Accordingly, 8 peasant associations were indentified, three each from Babile and Kersa. 2 peasant associations were selected from Haramaya district. The households were selected randomly from villages where handcrafts were widely practiced. 3500 households have passed through a tracer study by indentifying villages in various rural Kebeles where handcraft works such weaving, woodworking and metal working, bottling, renting and/or leasing, and other off-farm employment activities are practiced.

Methods of data analysis

Because this study primarily focuses on the mapping of rural Non- Farm activities in the study mainly a descriptive statistics were used to analyze the data. Basic socio-economic and demographic characteristics of the sample households were analyzed using descriptive statistical tools including mean, standard deviation, percentage and frequencies.

RESULTS AND DISCUSSIONS

Description of household respondents

The results of the data collected through survey have been discussed in this section. Data were collected from 350 households through survey questionnaire in the three districts (Babile, Kersa, and Haramaya) of East Hararghe Zone. Out of the 350 questionnaires distributed only 310 were found to be valid and 40 questionnaires were excluded from this report. Eight peasant associations (PAs) (Kebeles) have passed through this study whereas the selection is being made based on the distribution of handcraft practices. Accordingly, been 3 PAs have been selected from Babile and Kersa districts each and only 2 PAs from Haramaya district were included. Haramaya district indicated the list in the availability of handcraft activities from the three districts in this study.   Tables 1 and 2 indicate the descriptive statistics of the household respondents.

Table 1. Descriptive Statistics of Household Respondents by their district and sex

		Sex		
		Male	Female	Total
District	Babile	91 29.4%	20 6.5%	111 35.8%
	Kersa	105 33.9%	46 14.8%	151 48.7%
	Haramaya	38 12.3%	10 3.2%	48 15.5%
Total		234 75.5%	76 24.5%	310 100.0%

Kersa district recorded the highest in terms of the distribution of various handcrafts from the three districts and as a result many households were taken from it. Soddu peasant association from Kersa district comprises of the largest size (25%) sample household respondents.

Table 2. Household Respondents' distribution in terms of Districts and Peasant Associations

			Kebeles								Total
			Bishan Babile	Yabata Lenca	Golawachu	Awusharif	Ifaa	Tiniqe	Finqille	Soddu	
District	Babile	Count	54	0	0	46	11	0	0	0	111
		% of Total	17.40%	0.00%	0.00%	14.80%	3.50%	0.00%	0.00%	0.00%	35.80%
	Kersa	Count	0	24	50	0	0	0	0	77	151
		% of Total	0.00%	7.70%	16.10%	0.00%	0.00%	0.00%	0.00%	24.80%	48.70%
	Haramaya	Count	0	0	0	0	0	23	25	0	48
		% of Total	0.00%	0.00%	0.00%	0.00%	0.00%	7.40%	8.10%	0.00%	15.50%
Total		Count	54	24	50	46	11	23	25	77	310
		% of Total	17.40%	7.70%	16.10%	14.80%	3.50%	7.40%	8.10%	24.80%	100.00%

Household respondent's off farm income contribution to household income

The respondents were asked whether or not they contribute to household's income and whether or not they engage in some off-farm activities. Accordingly, about 70% of the respondents contribute to household's income from their engagement in either on farm or off-farm activities. Women were found contributing less to the household's total income compare to men. This may be because women engage mainly in domestic activities which were not included in the computation of total household's income. Evidently, women in Eastern Ethiopia involve even in the farming activities in addition to their domestic responsibilities (Table 3).

Table 3: Contribution to Households' Income in Cash

			Do you contribute to HH income in Cash from Off Farm activities?		Total
			Yes	No	
Sex	Men	Count	154	76	230
		% of Total	50.8%	25.1%	75.9%
	Women	Count	57	16	73
		% of Total	18.8%	5.3%	24.1%
Total		Count	211	92	303
		% of Total	69.6%	30.4%	100.0%

Non-farm and off farm activities and handcrafts knowledge distribution in the household

While farming is the main economic activity of the Eastern Hararghe zone, there is a significant difference on the practice of handcraft activities. The distribution of such handcraft skills differ from household to household because of many reasons. Availability of inputs, access to markets, learning opportunities and gender differences could be a few among the many reasons to be mentioned. In terms of their distribution households in Kersa district indicated the largest share 52.1% of the total handcraft distributions followed by Babile which accounts for 39% of the total distributions. Pottery is the main handcraft category reported in the survey accounting for 23% followed by woodwork (21%). Haramaya recorded the least in the distribution of hand crafts accounting for only 9%. Pottery is the mainly done by women and this skill should be an advantageous to them if practiced with proper training and tools for increasing their productivity and marketability of their products. Table 4 indicates the various handcraft distributions in the three districts.

Some handcraft skills were practiced for years by few ancestors because there had been bad social impression for those who produce handcraft activities such as leather products, wooden equipments, metal products, and pottery products. Thus such skills were not encouraged and grown up. Even today because of uprooted bad attitude of the society such activities were left to few groups in the society and some even gradually abolished.

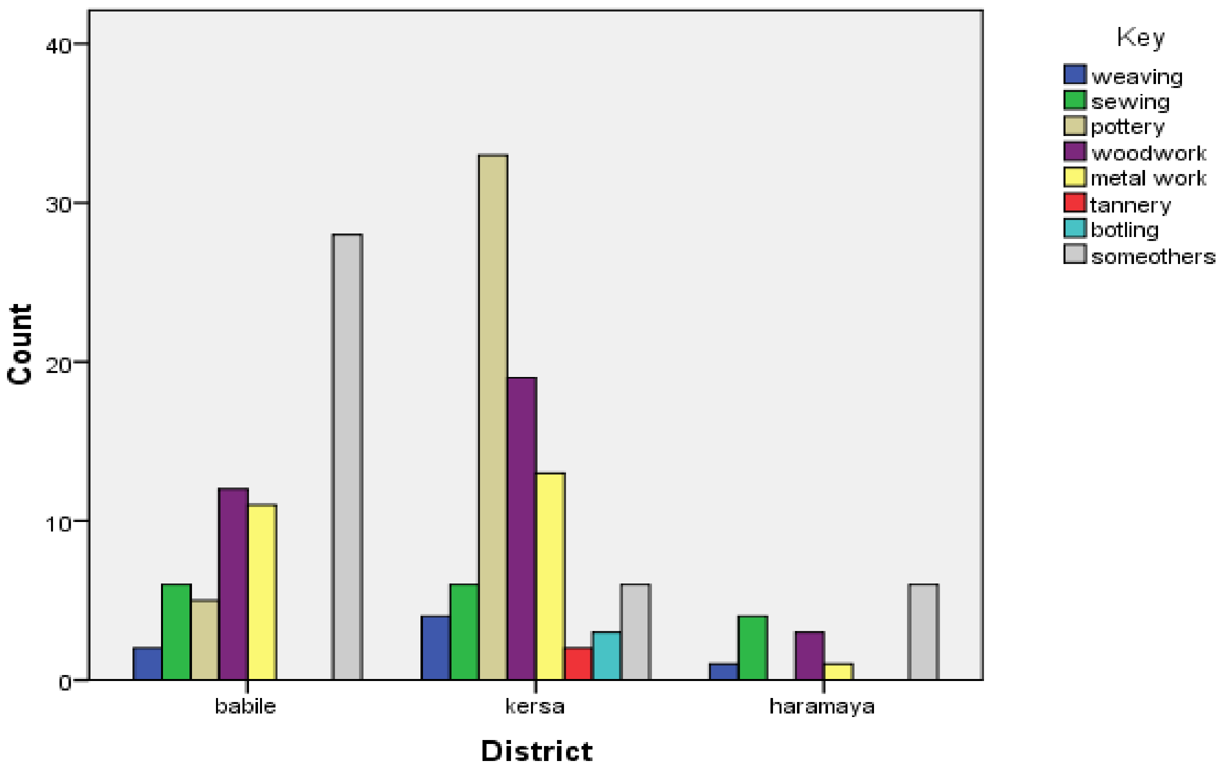
The interview and observation results indicated that weaving and metal work was widely practiced in the study area by people who migrated from Selallie area.

Table 4. Kind of handcraft type Distribution in the three Districts

		Kind of handcraft type								Total
		weaving	sewing	pottery	woodwork	metal work	tannery	bottling	Some others	
Babile	Count	2	6	5	12	11	0	0	28	64
	% of Total	1.2%	3.6%	3.0%	7.3%	6.7%	.0%	.0%	17.0%	38.8%
Kersa	Count	4	6	33	19	13	2	3	6	86
	% of Total	2.4%	3.6%	20.0%	11.5%	7.9%	1.2%	1.8%	3.6%	52.1%
Haramaya	Count	1	4	0	3	1	0	0	6	15
	% of Total	.6%	2.4%	.0%	1.8%	.6%	.0%	.0%	3.6%	9.1%
Total	Count	7	16	38	34	25	2	3	40	165
	% of Total	4.2%	9.7%	23.0%	20.6%	15.2%	1.2%	1.8%	24.2%	100.0%

While pottery is mainly practiced in the study area in the three districts, tannery is practiced only in the Kersa area. Many animal produces known in the area but the skills of using skin and hide for income earning is quite minimal in the study area. Our observation indicated that many leather products are used for making agricultural and cultural tools. For instance at Kersa and Fadis districts women make a leather product called *Gorbota* which are used for transportation and packing on donkey and camel back. Because of lack of skills related to tannery and leather processing there is acute wastage of skin and hides in the districts.

Fig 1 kinds of handcraft activities in the district



Inter family handcraft skill transfer and intergenerational continuity of handcraft skill in the household respondents

Skill transfer in the household from one member of the family to the other or from the ancestors is crucial for sustaining a typical handcraft skill in the family. If a mother does some kind of handcraft activity in the household it is highly likely that children also learn some kind of handcraft. Certain handcraft activities are gender based. For instance, women usually engage in weaving, pottery and spinning activities whereas men participate in woodwork and metal work, and carpentry.

The prevalence of handcraft jobs in the family were asked in the three districts. Accordingly, only 43% of the respondents are indicated that there was some kind of handcraft activities in their households. In specific terms, 25 % respondents indicated that Kersa district has large number handcraft activities in the household (Table 5).

Asked what relationship they had with the person who does some kind of handcraft in the family, the respondents indicated that “fathers” and “mothers” play significant role in passing skills from generation to generation(29%, and 25 % of the respondents respectively). (Table 6). As a matter of fact, focusing skill training programs on fathers and mothers in the household play significant role in sustaining handcraft skills in the family.

Moreover, some of the respondents reported that they failed to learn some hand craft skills mainly because of lack of personal interest (43.3%) followed by lack of access (28.1%). Expectedly, social norms significantly discourage the skill transfer of hand craft skills. (Table 7). This demands public awareness creation on the role of handcraft skills towards income generation and maintaining rural livelihood employment.

Table 5. Handcraft skill availability in the household

			Is there some kind of handcraft in family?			
			Yes	No	Don't know	Total
District	Babile	Count	42	65	2	109
		% of Total	14.0%	21.7%	.7%	36.5%
	Kersa	Count	74	51	18	143
		% of Total	24.7%	17.1%	6.0%	47.8%
	Haramaya	Count	12	34	1	47
		% of Total	4.0%	11.4%	.3%	15.7%
Total		Count	128	150	21	299
		% of Total	42.8%	50.2%	7.0%	100.0%

Table 6. The relationship of the person who does some kind of handcraft in the family to the respondent

			The relationship of the person who does some kind of handcraft to the respondent						Total
			Mother	Father	brother	sister	some other relative	no relationship at all	
District	Babile	Count	13	16	3	2	11	28	73
		% of Total	7.3%	8.9%	1.7%	1.1%	6.1%	15.6%	40.8%
	Kersa	Count	30	26	2	11	13	4	86
		% of Total	16.8%	14.5%	1.1%	6.1%	7.3%	2.2%	48.0%
	Haramaya	Count	2	10	1	1	3	3	20
		% of Total	1.1%	5.6%	.6%	.6%	1.7%	1.7%	11.2%
Total		Count	45	52	6	14	27	35	179
		% of Total	25.1%	29.1%	3.4%	7.8%	15.1%	19.6%	100.0%

Table 7. Reasons why the respondents failed to learn handcraft skills

			Reasons why the respondents fail to learn some skills					Total
			Lack of access	lack of personal interest	Social taboo	Lack of inputs	others	
District	Babile	Count	6	33	4	8	3	54
		% of Total	3.5%	19.3%	2.3%	4.7%	1.8%	31.6%
	Kersa	Count	38	36	8	7	2	91
		% of Total	22.2%	21.1%	4.7%	4.1%	1.2%	53.2%
	Haramaya	Count	4	5	4	9	4	26
		% of Total	2.3%	2.9%	2.3%	5.3%	2.3%	15.2%
Total		Count	48	74	16	24	9	171
		% of Total	28.1%	43.3%	9.4%	14.0%	5.3%	100.0%

Household's main source of income and major income generating activities

Rural households in the district had farming (63.4%) as their main source of income (Table 8 and 9).

Table 8. Household's Income source

			What is the main source of income for the family?						Total
			Farming	employment to other farmers	selling some handcrafts	mixed	Khat selling	any other	
District	Babile	Count	73	2	13	15	0	3	106
		% of Total	24.5%	.7%	4.4%	5.0%	.0%	1.0%	35.6%
	Kersa	Count	92	0	3	46	6	0	147
		% of Total	30.9%	.0%	1.0%	15.4%	2.0%	.0%	49.3%
	Haramaya	Count	24	0	3	14	3	1	45
		% of Total	8.1%	.0%	1.0%	4.7%	1.0%	.3%	15.1%
Total		Count	189	2	19	75	9	4	298
		% of Total	63.4%	.7%	6.4%	25.2%	3.0%	1.3%	100.0%

The rural community engages in various sector of rural non-farm micro and formal and informal household and village level activities. There could be many reasons to me mentioned as to why there exist disparities among different villages in terms of the practice of handcraft activities. The question remains with what factors constrain the continuity and advancement of rural household off-farm income activities.

Understandably, devoting time to off-farm activities, while complementing agricultural incomes, may be constrained by labor availability and financial capacity. The importance of off-farm activities for food security is unremarkable. It contributes to the availability of agricultural labor, and financial constraints on off-farm employment decisions.

Farm households are involved in two types of off-farm activities: wage employment and self-employment (own business activities). Wage employment includes paid community development work (often called food-for-work), farm work, and manual work in construction, masonry, and carpentry. Self-employment includes petty trading, transporting by pack animal, fuel wood selling, charcoal making, selling fruits, making pottery and handicrafts and stone-mining. The majority of farm households participate in some farming activities (63%). Most of the farm households work in their home some cash crops. Most of the off-farm works are temporary and do not require any professional qualification with the exception of masonry and carpentry. The proportion of households that do participate in mixed employment is 25% (Table 8).

Table 9. Major income generating activities in the Household

			Household's income generating activities			Total
			Farm income	Nonfarm income	Off-farm income	
District	Babile	Count	89	14	3	106
		% of Total	30.9%	4.9%	1.0%	36.8%
	Kersa	Count	135	2	1	138
		% of Total	46.9%	.7%	.3%	47.9%
	Haramaya	Count	37	4	3	44
		% of Total	12.8%	1.4%	1.0%	15.3%
Total		Count	261	20	7	288
		% of Total	90.6%	6.9%	2.4%	100.0%

In most farm households, more than one member participates in off-farm activities. For reasons of simplicity family members are categorized into six groups: household head, wife/spouse, children, relatives, servant, and hired laborer.

The dominant type of off-farm work is paid development work. The household heads work in farm activities in 80% of the households, in off-farm activities in 6.4% of the households, and in non-farm activities in 2.1% of the households. The household wives work only in farm activities (10.2%) and other manual work (2%). Other family participant members work little or no paid development work. This is due to the fact that almost all the respondents were either adults or family heads. Unless a person is unable to work, the provision of food aid (in case of drought) is linked to the participation of households in development activities such as terracing, reforestation, dam and road construction and maintenance, and the rehabilitation of social services like clinics and schools. Regardless of crop failure, terrace construction and maintenance is done every year until the whole area that needs terracing is covered. Farm households allocate their labour between farm and off-farm activities as well as homework (Table 10).

Table 10. Family relationships and Participation in income generating activities

		Relationship											
		Head		Spouse/wife		Children		Relatives		Servant		Hired labourer	
		N	N %	N	N %	N	N %	N	N %	N	N %	N	N %
Household income generating	Farm income	226	79.90%	29	10.20%	1	0.40%	0	0.00%	0	0.00%	0	0.00%
	Nonfarm income	18	6.40%	1	0.40%	1	0.40%	0	0.00%	0	0.00%	0	0.00%
	Off-farm income	6	2.10%	1	0.40%	0	0.00%	0	0.00%	0	0.00%	0	0.00%

Conclusion and Recommendations

Agriculture is the backbone of the economy and the performance of the sector directly or indirectly affects the lives of so many people in Ethiopia. More than 85 percent of the labor force is engaged in agriculture. Low productivity of the sector is the major cause of unemployment and underemployment in the rural areas. Hence rural off farm activities can play an important role to improve the well being of the rural population.

In a risk free and perfect capital market environment, diversification to other alternative economic activities can make farm households loose the gains that they could have achieved from specialization in framing activities alone.
However, in an environment where agriculture is risky and the credit market is nearly non-existent, diversification, especially income diversification increases the farm households' capacity to undertake risk at farm level and to use more variable inputs in production which will eventually lead to higher return in agriculture.

The foregoing analysis has made clear that income diversification by accommodating off-farm and nonfarm activities increases ensuring sustainability of households' food security and sustainability. It also reveals that off-farm income helps to finance farming activities such as purchase of farm labour and other inputs such as seeds, fertiliser, and pesticides. Since crop diversification is done to match the type of crop with the soil type, it does not result inefficiency in production. Therefore, there is a substantial potential for increasing farm income of farm households by diversifying their income sources in general and by promoting off-farm employment in particular.

Studies indicated that the supply of labour for off-farm work (and hence off-farm income) is largely determined by farm characteristics, market wage rate and household compositions. It increases with market wage rate, livestock wealth, and family size, and decreases with non-labour income, farm assets, variable farm inputs, and area of land cultivated.

While farming is the main economic activity of the Eastern Hararghe zone, there is a significant difference on the practice of handcraft activities. The distribution of such handcraft skills differ from household to household because of many reasons. Availability of inputs, access to markets, learning opportunities and gender differences could be a few among the many reasons to be mentioned.

The diversification of some handcraft activities in the zone could be attributed to existing skill practices and inputs. The results of the foregoing discussions indicated that in terms of their distribution households in Kersa district indicated the largest share (52.1%) of the total handcraft distributions followed by Babile which accounts for 39% of the total distributions. Pottery is the main handcraft category reported in the survey which needs further attention of rural income diversification programs in the study apart from leather processing and carpentry. Haramaya recorded the least in the distribution of hand crafts. Pottery is the mainly done by women and this skill should be an advantageous to them if practiced with proper training and tools for increasing their productivity and marketability of their products. Intervention programs should be designed to enhance existing skills such as in pottery products development and market enhancement at Kersa district with main focus on women. These and other skills should be promoted to Haramaya district as well.

Inter-generational handcraft skills learning is becoming an old fashioned and this caused gaps among the young and the elders. This definitely resulted in the termination of certain handcraft skills. The results of the focus group discussions made indicated that, parents do not want to pass their skills (such as smith) to their children because such jobs are not valued by the society. Consequently, such skills were not encouraged and grown up. Therefore, awareness creation programs should be developed in order for such skills to be enhanced for improvement of employment and proper use of labor and resources. Many animal produces known in the area but the skills of using skin and hide for income earning is quite minimal in the study area.

Therefore, apart from increasing agricultural output and raising agricultural productivity, complementary policies and programs must be developed to strengthen the link between farm and non-farm activities. The current agricultural extension program should encompass both farm and non-farm activities and encourage the growth of small-scale business and create non-farm employment opportunities in rural areas.

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Pastoralists' vulnerability to recurrent drought and the need for index-based livestock insurance (ibli) as a pro-poor risk management strategy in Ethiopia: a case study on borana pastoralists

By

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Funded by HrU Government Research Grant

Abstract: *Pastoralists in Sub-Sahara African region are the most vulnerable groups in the world. Their capacity to manage risk is especially low due to multiple stressors like drought coupled with their poor asset base. Particularly in Ethiopia, rampant livestock mortality due to climate change induced drought is the typical characteristic of the economic loss of pastoral/agro-pastoral households. The trend of global climate change has remained devastating and future climatic scenarios are also predicted to be pessimistic as changes in climate and weather patterns are inevitable. In spite of rapid advances in using geographical information systems (GIS) and simulation models, there is no clear picture of how climates will change. Hence, in the face of changing climate, the enhanced role of agriculture should be to contribute to mitigation without compromising its role for adaptation and food security. As adaptation to climate change is a priority for smallholders and a top agenda for development, demand-driven innovations in agricultural technologies and services are deemed for interventions. Consequently, the last several years have seen the development of innovative instruments for managing weather-related agricultural risks in which global efforts to reduce the impact of climate change on livelihood and food security of farm households has significantly increased. One of such innovations is the index-based livestock insurance (IBLI) which was, for the first time, designed to manage the risks of livestock mortality among pastoralist in Marsabit district of northern Kenya. The preference is that index-based insurance contracts avoid the twin asymmetric information problems of adverse selection (hidden information) and moral hazard (hidden behavior) because the indices are not individual-specific; they explicitly target – and transfer to insurers – covariate risk within the contract place and period. Due to these essential characteristics and its potential for adaptation, the IBLI was planned to be adopted for pastoralists in Borana zone in southern Ethiopia. However, the pilot experiment in Marsabit was left with a number of caveats in terms of assessing the potential dynamic pricing and behavioral learning of pastoralists, justification of demand and willingness to pay, test for commercial sustainability and varying product attributes for differential preference. The main objectives of the study, therefore, were to assess the impact of climate change on pastoralists' livelihood and measure the degree of pastoralists' future vulnerability to recurrent drought, design gender-centric index-based livestock insurance (GIBLVI) in the context of Ethiopian pastoralists, assess the effective demand and pastoralists' willingness to pay (WTP) for the GIBLVI services and study feasible ways of institutionalizing and implementing GIBLVI service in the context of Ethiopian pastoralists. Double bounded dichotomous elicitation format of contingent valuation method (CVM) was employed to value the WTP for IBLI. Apart from the descriptive analysis, both Probit* *and interval regression econometric models were employed to identify the determinants of farmers' willingness to pay and the intensity of payment for IBLI service. Results of the Probit model showed that age of the household head, agricultural land availability, livestock size, education level of the household head, family size, location, training and financial literacy were the main factors determining the WTP for IBLI decisions. Similarly, the interval regression model shows that the intensity of cash payment as the indicator of stated demand is found to be determined by ambiguity aversion, awareness, climate change perception, credit, the amount of expense households expend on ceremonial activities, distance from the market, family size, financial service use experience, land holding, loss expectation, risk aversion and number of livestock that the households have. Therefore, strategies that promote IBLI as an innovative and commercially sustainable insurance product should take the above factors into account for crafting policies and designing pro-poor intervention actvities.*

Key words: *climate change, drought vulnerability, livestock mortality, IBLI, WTP, probit model*

Introduction

Background and Rationale of the study

Ethiopian pastoralists face recurrent drought almost three times in a decade. The recent catastrophe, often called the '*East African Drought'*, is characterized as the worst climatic catastrophe of its nature in the history of the last sixty years. Its most horrible impacts are perceived among pastoralists in arid and semi-arid lands of Eastern Africa, where it caused 70-90%, 70-80% and 75% of the total livestock losses in Maasi district in Kenya, Borana zone in Ethiopia and Niger, respectively (Huho *et al*., 2011).

Empirical evidences reveal that the root cause of the drought is climate change which led to the disappearance of precipitation and rainfall. In Ethiopia, average rainfall intensity, which ranges from 2000 mm in south-west to 200 mm in north-east low lands of Afar during 1961-1990, has decreased from average precipitation of 2.04 mm per day to 1.97 mm per day. The decrease in rainfall amount is exacerbated by higher evaporation rate which is associated with the increasing temperatures (Cline, 2007). In the future, average annual temperature is predicted to increase from 23.08^{o}_{c} to 26.92^{o}_{c} for the next two decades with an average estimated rise in temperature between 0.5^{o}_{c} and 3.6^{o}_{c}. During the last two decades, drought manifested by acute shortage of rainfall has adversely affected crop and vegetation growth of the pastoralists' landmass, making it difficult for livestock feed and forage production and this shock is predicted to continue in future with its severe consequences.

Changes in climate and weather patterns are inevitable, and in spite of rapid advances in using geographical information systems (GIS) and simulation models, there is no clear picture of how climates will change. Instead, there is now a wide consensus that these changes have significant impact on the economies of agrarian communities. Due to Africa's heavy dependence on agriculture, its high proportion of low input, rain-fed farming (95%) and existing stresses such as land degradation and population pressure, the impact of climate change and its fatal consequences such as drought will remain very high in Africa. Hence, research-oriented innovative interventions are recommended as mandatory to cope up with the ever changing climate and to mitigate impact of its adverse consequences on the livelihoods of the poor.

In Ethiopia, there are more than fifteen million pastoralists who reside in 61% of the nation's landmass. Livestock production is an integral part of the Ethiopian agricultural system. In addition to the recent drought that caused about 80% of total livestock losses, the pastoral areas of Ethiopia have lost significant number of livestock population due to droughts that occurred in the years 1918-19, 1928-29, 1933-34, 1943-45, 1975-76, 1983-86, 1990-91, 1999-2000, and 2002-2003 (Sandford and Habtu, 2000).

FAO (2004) estimated about 1,378,165 livestock losses due to the 2002-2003 drought mainly in Oromia, Afar and Somali regions while Sandford and Habtu (2000) revealed that the total livestock loss in these regions from 1972-1997 were a 72% decrease in the number of cattle herds from the then existing stock. The occurrence of the drought at different periods that has decreased the per capita livestock population in different pastoral areas of Ethiopia has made the poverty situation in these areas complex and worse than it is in the other regions. Besides the decrease in livestock population, the provision of social services such as health, education and water supply is at the lowest level in pastoral areas contributing to the deterioration of life condition. For instance, the gross enrolment ratio in primary schools for the country is 62% in 2002 while it is 12.6% and 13.1% for Afar and Somali regions, respectively. It is not only that there are fewer schools and fewer teachers in the pastoral areas but also less pupils come to attend in the already existing schools (FDRE, 2002).

All these factors added together increased the number of vulnerable pastoral population. The proportion of pastoralists in need of food aid generally varied from 10% to 22% between 1991 and 1999 and peaked at 40% in 2007 and 2009 (Amsalu, 2010). In this condition, Ethiopian pastoralists face the world's gravest hunger and impoverishment which is gradually getting worse. Pastoralists' poverty status in the country has always been studied in a world of certainty. However, if the aim of studying poverty is not only improving the well-being of pastoralists who are currently poor, but also preventing the others from becoming poor in the future, vulnerability assessment as a new forward-looking, ex-ante risk management approach must be adopted. Vulnerability within the framework of poverty eradication is defined as the ex-ante risk that a household will, if currently non-poor, fall below poverty line, or if currently poor will remain in poverty. Vulnerability, therefore, is a forward-looking concept and is not directly observable. The observed poverty status of a pastoralist household can be seen as the ex-post realization of potential poverty states whose probabilities are predicted ex-ante as the household's level of vulnerability. Hence, vulnerability assessment is a pro-poor risk management strategy.

Developing reliable and easily applied measures of pastoralists' vulnerability to drought or food insecurity is a necessary but not sufficient condition for household well-being. Social protection which is inextricably interconnected with agriculture in low income nations like Ethiopia is required. Added to this, in Sub-Saharan Africa in general and in Ethiopia in particular, pastoralists' capacity to manage the risks of climate change and drought is especially low due to multiple stressors coupled with a poor asset base. Poor pastoralists are frequently confronted by severe uninsured idiosyncratic risks in addition to the covariate livestock mortality risk, which cause high variability in their income and asset endowments that in turn, makes them particularly vulnerable to poverty and food insecurity.

Pastoral economies in Ethiopia are evidenced with a poverty trap characterized by a herd threshold that leads to bifurcation in herd growth prospect (Lybbert *et al*. 2004; McPeak, 2004, Barrett *et al*., 2006 and Santos and Barrett 2006). As a result, the presence of catastrophic risk of livestock loss can place long-term impacts on households' welfare dynamics, especially if shocks knock their herd beneath the threshold onto the decumulating growth trajectory toward an irreversible poverty trap. Studies reveal that all factors that seem to impede the capacity of poor households to surmount the critical threshold (poverty line) revolve around some combination of market imperfections and institutional failures that generate exclusionary mechanisms, like credit and insurance rationing, resulting in the separation of subpopulations into distinct groups with different prospects.

In Ethiopia, like in many developing countries, given the importance of the livestock sector and poorly developed pastoralist areas, on the one hand, and the reluctance of the traditional formal credit and insurance institutions to penetrate into the rural pastoralist areas, on the other, practical and timely steps were not taken to provide policies and legal framework services to the rural poor pastoralists who faces acute shortage of access to credit and insurance services. Studies in developing countries reveal that while formal insurance markets routinely fail to provide adequate insurance for covariate risk in poor and infrastructure-deficit pastoral areas, informal mutual insurance networks are structurally ill-suited to insure against covariate risks, calling for the need to develop effective covariate risk management strategy for reducing persistent poverty among pastoralists.

However, despite its innovative nature and considerable commercial and development appeal for replication to Africa and Asian regions with similar poverty and livestock population profile, the IBLI designed for pastoralists in northern Kenya has a number of caveats that can limit the commercial viability, long-term sustainability and replicability of the product. Overall, we came to learn that most studies focus on study of poverty in a state of certainty than predicting the probability of shocks in the future, in a state of uncertainty. It is also evidenced that only few attempt are made to study, design and implement crop and livestock insurance in Africa. While livestock insurance is being designed and attempted in northern Kenya, and tried to be adapted in Ethiopia, a number of caveats are remained untouched to contextualize the model taking into account the socio-economic characteristics of the pastoralists in Ethiopia.

Statement of the problem

Review of existing but few studies on IBLI in Kenya and Mongolia and its adaptation in Ethiopia have shown us different gaps. First of all, like many other agricultural technologies, IBLI is a supply-driven technocratic product designed for pastoralists in northern Kenya. For effective and self-sustenance in the globally competitive insurance market, a thorough analysis of context-specific demand is yet required to be assessed to supplement supply of the innovation.

Our particular interest in this case is to assess the Ethiopian pastoralists' willingness to pay (WTP) for the IBLI product as well as identification of the determinants for demand and WTP. Secondly, as Carter *et al* 2011 pointed out the simulation model applied by Chatarat *et al* 2009 to design IBLI in the context of pastoralists in northern Kenya ignores pastoralists' behavioural choice for the product, focusing instead on herd size as a state variable which follows a stochastic path to determine each household's future welfare. This is a critical limitation of the existing IBLI model which has a significant bearing in providing a demand-driven insurance product development that matures over time in the insurance market.

Thirdly, insuring the livestock sector cannot be holistic by providing indemnity only for herders. The livestock sector is a critical source of livelihood not only for the herder but also for different economic units in a pastoral community including women milk traders, petty restaurants serving macchiato or milk, livestock marketing cooperatives and livestock trade associations. Hence, the existing innovation is not designed for group-based insurance marketing. The current study, thus, addresses this gap in designing and assessing demand for group-based livestock value chain insurance. The concept of value chain insurance was required to be championed differently from traditional insurance based on similar scientific development principles of value chain finance as a paradigm shift in microfinance.

Fourthly, the other important element in the design of IBLI product that might limit its long term commercial sustainability is the fact that its pricing system is conjugated with macro-scale disaster prevention mechanisms in which donors and humanitarian agencies working on provision of social protections or safety nets are expected to subsidize or cover the full cost of IBLI on behalf of the pastoralists. For instance, IBLI Marsabit was designed to complement a Hunger Safety Net Program (HSNP) that the government launched in the area using funds from different humanitarian agencies. Given the erratic nature of donor-driven funds and phase-out intervention approaches of humanitarian agencies, such pricing and valuation system significantly limits self-standing potential and viability of the product in the insurance industry. To fulfil this gap, the current study puts IBLI as a non-traded commodity in Ethiopia and assesses its demand, customers' willingness and ability to pay using appropriate tools. Finally, IBLI requires not only innovative design but also innovative institutionalization and implementation. This is never attempted in the previous studies.

In general, this study addresses the prevalence of uninsured risk of livestock mortality as a common driver behind the existence of poverty traps among Ethiopian pastoralists. Our particular focus in the study was on the need for innovative insurance mechanisms for covariate risks associated with extreme weather event, particularly drought that devastates poor pastoralists' productive assets with distressing frequency. Uninsured risk has long been recognized as a serious obstacle to poverty reduction in poor agrarian nations. In order to limit risk exposure, risk adverse poor households often select low-risk, low-return asset and activity portfolios that trade-off growth potential and expected current income for a lower likelihood of catastrophic outcomes (Dercon 2005; Carter and Barrett, 2006)

Objectives of the study

This study addresses how the Ethiopian pastoralist are vulnerable to the future faces of drought caused by inevitable climate change, but can be adapted innovatively using the index based livestock insurance (IBLI) as a social protection mechanism of financing the vulnerable herder thereby contributing to poverty reduction and food security. The true nature of the study is multi-disciplinary requiring integrative approach, idea, methods and tools.

The geneal objective of this study is to design group-based GIBLVI service as a pro-poor risk management strategy for vulnerable pastoralists to cope up with recurrent drought and climate change in Ethiopia. The central aim of the study is to design an innovative social protection mechanism to insure pastoralists in arid and semi-arid lands of Ethiopia taking the pastoralists in Borana and Guji zones of southern Ethiopia as cases. The study inquired into new foreward-looking perspectives of studying pastoralists' vulnerability and social protection mechanisms by exploring the effective ways of linking these to credit contracts within the livestock sector. Hence, the specific objectives of the study are to: i) assess the perceived impact of climate change on pastoralists livelihood and economics value losses ii) assess the need gender-centric index-based livestock insurance (GIBLVI) in the context of Ethiopian pastoralists iii) identify the determinants of demand and pastoralists' willingness to pay (WTP) for the GIBLVI services iv) study feasible ways of institutionalizing and implementing GIBLVI service in the context of Ethiopian pastoralists.

Scope and significance of the study

The first contribution of this study is a paradigm shift in studying pastoralists' vulnerability and risk caused by drought from measuring in a world of certainty to predicting future probability of shocks in a state of uncertainty. This is expected to be a new theoretical and empirical approach for pastoralist poverty and vulnerability assessment. Second, the study helps to design innovative and effective forward-looking pastoralist climate risk management strategies. In relation to this, the contribution of the study is to generate workable and innovative livestock mortality insurance in the context of Ethiopian pastoralists. This is the Index-based Livestock Insurance (IBLI). The fourth contribution of this study would be clear identification of the determinants of pastoralist' willingness to pay for the index-based livestock insurance service in the study area and this would have great implications for other pastoralist areas with similar socio-economic setup. Thus, the main pastoralist specific idiosyncratic risks and community level covariant risks that have considerable impact on pastoralist livelihood and welfare were identified. Fifthly, full understanding of how households exposed to severe idiosyncratic and covariate risks and climatic shocks do cope-up were made through a detail investigation of the households' degree of risk mitigation and/or, their ability to use their local institutional knowledge during times of stress.

Literatures on Index-based Livestock Insurance (IBLI)

The most innovative device to insure the risks of livestock mortality that recently attracted the attention of many stakeholders in livestock sector is the Index Based Livestock Insurance (IBLI). Index-Based Livestock Insurance (IBLI) provides indemnity for managing livestock asset mortality risk by compensating for location averaged livestock mortality estimated using remotely sensed measures of vegetative cover on range lands (Chantarat, 2009).

A parametric indicator used to estimate IBLI is the Normalized Differential Vegetation Index (NDVI). NDVI is a satellite product that measures the deviation or variation in vigor and greenness of vegetation on the earth's surface from its average greenness cover for the past reasonable years. The logic behind using this index in IBLI design is that by measuring greenness, NDVI provides a description of vegetation health, livestock feed and forage availability at any given time in different seasons. NDVI values are thought to reflect the many variables affecting crop and vegetation growth, production and yield as well as distress, leading to a more comprehensive expression of livestock health than an index based on one or two weather variables like rainfall (Chantarat, 2009).

Hence, NDVI is used as a proxy indicator to predict covariate herd mortality in a particular location. NDVI is tested checked for its strong relationship with livestock feed growth, production and yield. An objectively measured predicted herd mortality index constructed from such strong predictive relationship was then used to trigger IBLI's indemnity payments for the insured tropical livestock unit (TLU).

In this setting, the returns to an effective program that insures pastoral and agro-pastoral population against drought-induced livestock losses can be substantial. It was hypothesized that IBLI can have and be oriented towards the following impacts: i) stabilize asset accumulation and enhance economic growth through insuring assets against catastrophic loss addressing the high risk of investment in such environments. This should improve incentives for households to build their asset base and thereby climb out of poverty ii) stem the downward spiral of vulnerable households into poverty. Because it provides indemnity payments after a shock, livestock insurance should help stem the collapse of vulnerable-but-presently-non-poor households into the rank of the poor following a drought (or related crisis) due to irreversible losses from which they do not recover iii) Crowd-in finance for ancillary investment and growth: The negative effect of a risky environment in investment incentives is not limited to households. Private creditors are presently unwilling to lend for ventures such as lorries for livestock marketing cooperatives or equipment for abattoirs and slaughterhouses in the area-downstream value of livestock sold to urban areas iv) Reinforce extant social insurance mechanisms as rural Ethiopia has a rich tapestry of social insurance mechanisms in the form of mutual assistances and v) Enhance local adaptation to climate change: the most trusted impact of the IBLI that it enables pastoralists to adapt to climate change.

By construction, the IBLI index captures covariate risk since it reflects the average (e.g., yield, mortality) or shared (e.g., rainfall, temperature) experience of the insurable population. If this covariate risk can be reinsured or securitized, locally-covariate risk can be transferred into a broader (international) risk pool where it is weakly or uncorrelated with the returns to other financial assets (Hommel and Ritter 2005; Froot, 1999). Furthermore, index insurance contracts avoid the twin asymmetric information problems of adverse selection (hidden information) and moral hazard (hidden behavior) because the indices are not individual-specific; they explicitly target – and transfer to insurers – covariate risk within the contract place and period.

Finally, insurance companies and insured clients need only monitor the index to know when a claim is due and indemnity payments must be made. They do not need to verify claims of individual losses, which can substantially reduce the transactions costs of monitoring and verification of the insurance contracts. However, these gains come at the cost of basis risk, which refers to the imperfect correlation between an insured's potential loss experience and the behavior of the underlying index on which the index insurance payout is based. A contract holder may experience the type of losses insured against but fail to receive a payout if the overall index is not triggered.

Conversely, while the aggregate experience may result in a triggered contract, some insured individuals may not have experienced losses yet still receive payouts. The trade-off between basis risk and reductions in incentive problems and costs is thus a critical determinant of the effectiveness of index insurance products. In addition, while the concept of IBLI is noble, contextualization and innovation is its stylistic nature in modeling and implementing in different countries. In our case to serve this purpose, it is important to supplement the existing potential with the effective demand of the Ethiopian pastoralists and their willingness (WTP) to pay for the IBLI service.

Research Methodology

Borana and Guji Zones of Southern Ethiopia

Borana and Guji zone were located in southern part of Oromia region at about 687 Km from Addis Ababa. The Borana plateau of southern Ethiopia is a vast pastoralist territory occupying nearly 10% of Ethiopia. The region is comprised of arid and semi-arid ecological zone with bimodal rainfall. Pastoralist is a key livelihood, dominated by large cattle herds and increasing numbers of goats and camel. Livestock can range widely in search of forage and water during dry periods, but households in general are increasingly settled for most of the year. The sustainability of these pastoral communities has been significantly undermined due to recurrent drought, violent conflict, and loss of spatial refugia to bush encroachment, privatization of key rangelands and gazzeting of parks and protected areas.

Livestock comprise the overwhelming majority of households' non-human capital and account for more than two-third of their average income. Livestock, however, are subject to frequent, severe shocks, which often bring about catastrophic losses that strike many households at once. Among these drought is by far the greatest cause of livestock mortality in the areas explaining the key covariate losses in the region. There exist a range of social insurance arrangements that provide informal inter-household transfers. But these schemes cover less than ten percent of household losses, on average, do not include everyone, and are generally perceived as in decline. Food aid is used to (highly imperfectly) insure households against covariate risk of livestock loss among pastoral households in this region.

As the cost and frequency of emergency response in the region has grown, however, mounting dissatisfaction with food aid-based risk transfer has prompted exploration for more comprehensive and effective policies. These shocks have resulted in long-term, community-wide deprivation with a lasting effect of deterioration in the indigenous capacity to cushion those who slide into permanent destitution. The importance of developing effective livestock mortality risk management is amplified by the apparent presence of poverty traps in these semi-arid pastoral areas of southern Ethiopia. Previous research identifies multiple herd size equilibria such that losses beyond a critical threshold amount appear to be irreversible, or to at least have very severe, long-term consequences (Santos and Barrett (2008). Put differently, livestock losses that push households below this threshold amount appear to be irreversible, or to at least have very severe, long-term consequences. Thus, uninsured drought risk appears as the primary driver of such poverty traps among the Borana and Guji pastoralists.

Livestock rearing is the major economic activity in the area. People keep cattle, goat, sheep, camel and equines which are usually under risk of mortality due to drought caused by climatic change. In addition, opportunistic farming is practiced in few pocket areas. Thus based on the household income, it can be said that people in the district are pastoralists. Livestock is basic for the economic life of Borana and Guji people and they have strong affluence for cattle. People are considered as out of culture if they do not keep cattle as one source of income. Even those who reside in urban and semi urban areas have cattle that are kept by themselves or with their relatives in rural areas. The region is also known for its good breed of livestock, the Borana breed.

The Borana-Guji land is one of the known rangelands in east Africa and the people are known for their strong traditional institutions and mutual social protection or insurance mechanisms, which enabled them to survive in such fragile environment. These include *iddir* and *iquib* as social financial insurance, and the *Gada system* as a community based indigenous democratic governance system. As Legesse (1973) put it, the Borana Gada system is a complex traditional democratic system of self rule that governs the social, economic, political and spiritual life of the whole Oromo society.

Pastoralists in the study rear the four major livestock species found in the Horn of Africa – sheep, goats, cattle, and camels. Cattle and sheep are the most dominant species since pastoralist areas are mostly flat and the long dry season that covers from October to February is usually cold, which is a problem for goats and camels. Camels and goats are dominant and are common in the mountainous ranges where the bushy plants (used by browsers) are common. Pastoral area rangelands experience low rainfall with long spell of dry seasons and frequently recurring drought. The influence of drought on the quantity and quality of forage production has largely affected pastoralists' livelihoods. That is, the productivity of the rangelands is determined mostly by variation in the rainfall patterns. The amount of average rainfall in the study areas ranges from 500 to 700 mm per year. Still worse, the distribution and intensity of the rainfall is erratic and irregular. The existing rangelands are mainly woodlands without any grass and they appear to be infested badly with some undesirable plant species. Additionally, rangelands are also subject to the problem of soil compaction. Several factors cause degradation of rangelands though their impacts vary across time and space. In the study areas, the main reasons for rangeland degradation are climate change, repeated and prolonged drought, over grazing (over population of livestock and low mobility), soil erosion (gulley formation) and deforestation. The frequent drought, which the households experienced for the past two decades, reduced the quality (grass and tree composition) and coverage of rangelands.

Over grazing, especially in the grazing areas, reduced the rangelands species composition and sometimes made them rocky. Although soil erosion is not considered as a cause it is found important for the formation of gullies that dissect rangelands and make them inaccessible. Deforestation is mainly practiced during drought period when sales of fuel wood and charcoal serve as a mechanism to cope with food shortfalls. In pastoralist areas, ownership pattern of the grazing land is mainly communal type and they are using the grazing and pasture lands available for large number of animals and all stock graze in the same place. The livestock productivity is mainly affected by availability of feed. But for different species of livestock the availability of feed varies across seasons. In dry season feed is available more for camel and small ruminants and is scarce for cattle. The basic grazing management practices of Ethiopia pastoralists in the rangelands are moving animals each season and moving to distant places when the situation turns against them. They also move animals in dry season though it is preferred to keep them in settlement area in wet season. In some situations herds are divided into moving and village groups. Burning grazing land is practiced in order to initiate fresh grass growth and avoid incidences of some parasitic insects.

Data sources and methods of collection

In this study, both primary and secondary data were collected using formal data collection process. Primary data were collected from sample pastoralist households, who are actively involved in livestock production and whose livelihoods were adversely affected due to livestock deaths caused by severe drought, using structured questionnaire. The survey questionnaire was pre-tested before data collection and modified accordingly. Similarly, using Key Informant Interview and Focused Group Discussions (FGD), data were collected from community leaders, elders and local regional, national and international organizations working on livestock related activities.

Empirical analysis was implemented using primary data collected through a survey of 223 pastoral households in Borana and Guji Zones of southern Ethiopia, Oromia National Regional State. These households are engaged in livestock production as the main sources their income. A three-stage sampling technique was employed to select the final unit of observation. Firstly, the two Zones were purposively chosen due to the large population of livestock susceptible for drought risk in the area. Secondly, among the 10 Kebeles in Guji and 17 Kebeles in Borana Zone, 2 kebeles and 3 kebeles were randomly selected. Finally, proportionate random samples of 223 households were chosen. A structured questionnaire was designed to elicit information on a wide variety of topics including pastoral households' perception on climate change and its adverse consequences, livestock resource endowment, access to markets and financial services, saving behaviour, investment motive and demographic characteristics. In administering the questionnaire, enumerators who have experience in socioeconomic surveys were employed and introduced to the purpose of the study. The survey questionnaire was pre-tested and actual field survey was done in July 2012. In addition to the primary data, secondary data were collected from various published and unpublished documents and materials from secondary sources. There were continuous focus group discussions with the pastoral Gada System leaders, elders and personal observations.

Methods of Data Analysis

The methodological approaches involved in this study include framing the analysis using theoretical models and undertaking the analysis using empirical models. The analytical framework combines conceptualization of herd mortality from differentials of the vegetation cover which constitutes livestock forage, estimation of insurance indemnity and premium based on the expected estimated livestock losses. The framework conceptualizes the demand and willingness to pay for the insurance. The empirical models were fitted to the data based on the objectives of the study. Accordingly, both descriptive statistics and econometric tools were used to analyze the data. The main empirical methodologies are estimation of the predicted herd mortality from the NDVI, designing the IBLI contract (estimation of both premium and indemnity), estimation of the effective demand and measurement of the pastoralists' willingness to pay (WTP) for the service.

Analytical Framework

Two analytical frameworks were considered in the current study to conceptualize design and pricing of the insurance, on the one hand, and measure the prevailing demand and willingness to pay for IBLI on the other. In pastoral and agro-pastoral areas, it is common that drought causes rampant livestock mortality as it results in disappearance of the vegetation cover which in turn causes forage unavailability. Hence, climate risk management approach should enable us to predict the livestock mortality from prediction of vegetation and forage scarcity. In order to estimate average herd mortality rate, the study was based on the concept that pastoralists usually experience livestock losses due to severe drought induced by climate change. Changing climate through time results in shortage of rainfall and rise in temperature adversely affecting vegetation cover and forage availability for livestock which in turn leads to livestock mortality. Hence, livestock mortality is a function of availability/unavailability of forage, feed or feed stock, termed as vegetation cover. Thus, assuming that the rate of livestock mortality is, $\boldsymbol{m}$, and the intensity of vegetation index is, $\boldsymbol{v}$, then, literally it is plausible to represent that $\boldsymbol{m} = \boldsymbol{f}(\boldsymbol{v})$. The aggregate vegetation cover on the surface of the pastoralists' grazing land is usually measured by a proxy indicator known as normalized differential vegetation index (NDVI). This index is a satellite product computed from a longitudinal data set of metrological stations. Previous studies on crop insurance design have tested and verified the applicability of NDVI and revealed its strong correlation with livestock mortality (McLaurin and Turvey, 2011). Thus, the livestock mortality rate, $\boldsymbol{m}$, can be better represented as the function of NDVI as: $\boldsymbol{m} = \boldsymbol{f}(\boldsymbol{NDVI})$. In Chanatrat et al (2009), it is argued that the advantage of using NDVI to estimate area average livestock mortality rate than a single weather parameter like rainfall for two reasons. The first is conceptual. Catastrophic herd loss is a complex, unknown function of rainfall which affects water to grow vegetation and contribute to forage availability. It also affects disease and predator pressure – and rangeland stocking rates – which affect competition for forage and water as well as disease transmission. Rangeland conditions manifest in vegetative cover reflecting the joint state of these key drivers of herd dynamics. When forage is plentiful, disease and predator pressures are typically low and water and nutrients are adequate to prevent significant premature herd mortality. By contrast, when forage is scarce, whether due to overstocking, poor rainfall, excessive competition from wildlife, or other pressures, die-offs become frequent. Thus a vegetation index makes sense conceptually. The second reason is practical. In most developing countries where large significant numbers of pastoralists exist, longstanding seasonal or annual livestock surveys of the sort used for computing area average mortality is not available. Rainfall estimates based on satellite-based remote sensing remain controversial within climate science. For this purpose, NDVI, which is a satellite-derived indicator of the amount and vigor of vegetation, based on the observed level of photosynthetic activity (Tucker, 2005) is feasible. Images of NDVI are referred to as 'greenness maps.'

NDVI data are commonly used to compare the current state of vegetation with previous time periods in order to detect anomalous conditions and to anticipate drought (Bayarjargal *et al*., 2006) and have now been used by many studies that apply remote sensing data to drought management (Kogan, 1990, 1995; Rasmussen 1997). The index on which the insurance contract is written is the predicted area average mortality rate, defined as a function of the NDVI-based vegetation index. Because NDVI data are available in real time, the predicted mortality index can be updated continuously over the course of the contract period. By definition, area average livestock mortality rate is a measure of the pastoralists' covariate risk or livestock asset shocks within a given location. But as discussed before, pastoralist households face idiosyncratic risks. Hence, predicted area average mortality rates address only covariate risks, leaving household-specific livestock mortality risks (i.e risks which area caused by household characteristics other than drought like accident). The later constitutes idiosyncratic basis risk which remains uninsured.

Based on the frame adopted in Chantarat *et al*., 2007, the covariate and idiosyncratic risks of households in the study area can be simulated as follows. Let m_{ils} represents the realizable aggregate livestock mortality rate of household *i* in location *l* over season *s*. Then, $m_{ils} = \bar{m}_{il} + \alpha_i(m_{ls} - \bar{m}_l) + \varepsilon_{ils}$, where, $\bar{m}_{il}$ represents household *i*'s long-term average livestock mortality rate, m_{ls} is area average livestock mortality rate at location *l* over season *s*, $\bar{m}_l$ is the long-term mean mortality rate in location *l*, the parameter α_i determines how closely household *i*'s livestock mortality losses track the area average livestock mortality (i.e if $\alpha_i = 1$, household *i*'s livestock losses closely track the area average while $\alpha_i = 0$ means *i*'s mortality losses are statistically independent of the area average), the expected value of α_i overall the location being necessarily 1. And ε_{ils} is the idiosyncratic risk component of households *i*'s herd losses (for instance due to accident, conflict etc), experienced during seasons i.e the household's specific basis risk.

IBLI insures only the covariate component of m_{ils} that is associated with the observable vegetation index. Chantarat *et al*., 2007 argue that the area average livestock mortality rate, m_{ls}, can be orthogonally decomposed into the systematic risk covariate risk and the idiosyncratic risk component as: $m_{ls} = m(f(ndvi_{ls})) + \varepsilon_{ls}$, where $f(ndvi_{ls})$ represents a transformation of the average NDVI observed over season *s* in location *l*, $ndvi_{ls}$ – which we discuss below – $m(.)$ represents the statistically predicted relationship between $f(ndvi_{ls})$ and m_{ls}, and ε_{ls} is the idiosyncratic components of area average mortality that is not explained by $f(ndvi_{ls})$ i.e., location-specific basis risk. Following this, we will predict area average mortality from observations of $ndvi_{ls}$ specific to each location *l* and season *s*, as: $\hat{m}_{ls} = m(f(ndvi_{ls}))$, which serve as the underlying index for insurance contract. There are the two sources of basis risk: the household's idiosyncratic losses that are uncorrelated with area average losses and area average mortality losses that are not correlated with the vegetation index.

Next, it is possible to derive the basic insurance variables like the amount of indemnity and premium. The predicted mortality rate is used to calculate the value of total sum assured. Considering Y_{ls} and p_{ls} as the amount of pre-agreed indemnity and premium per unit of TLU, p_{ls}, sum assured over season *s* in location *l*, and the average mortality rate, $\widehat{\mathrm{m}}_{ls}$, then, it holds true that insurance companies engaged in this business, for instance the Oromia Insurance Share Company pays indemnities for the assured TLU units when the livestock loss is beyond a contractually specified strike level as sensed by the NDVI satellite indicator. Thus, derivation of the indemnity value, Y_{ls}, follows: $Y_{ls}(\widehat{m}^*{}_{ls}/m^*{}_l\,, q_{ls}, p_{ls}) = \max\,(\widehat{m}_{ls} - m^*{}_l, 0) X q_{ls}\, p_{ls}$. The product of $q_{ls}\, p_{ls}$ reflects the total insured value. The expected insurance payout and hence the actuarially fair premium for this contract insuring $Q_{ls}P_{ls}$ can be indicated as Prm_{ls} and estimated as: $prm_{ls}(\widehat{m}^*{}_{ls}/m^*{}_l\,, q_{ls}, p_{ls}) = E(max\,(\widehat{m}_{ls} - m^*{}_l, 0) X\, q_{ls}\, p_{ls})$,whereas $E(.)$ is the expectation operator taken over the distribution of the vegetation index and so we can write $prm_{ls}(\widehat{m}^*{}_{ls}/m^*{}_l) = E(max\,(\widehat{m}_{ls} - m^*{}_l, 0)$ as the actuarially fair premium rate quoted as percentage of total value of livestock insured. Similarly, total insurance payout at the end of year *t*, is given as follows: $prm_{ls}(\widehat{m}^*{}_{ls}/m^*{}_l\,, q_{ls}, p_{ls}) = \sum max\,(\widehat{m}_{ls} - m^*{}_l, 0) X\, q_{ls}\, p_{ls}$. Hence, this equation provides the combined results of the relationship between vegetation intensity, livestock mortality with indemnity and premium features of the IBLI.

The other core activity of our study in this exercise is to identify the determinants of pastoralists' decision to use the IBLI product. This is a participation decision which may be affected by a number of household specific socio-economic factors. In participation decision studies, responses to a question such as whether pastoralists are willing to participate in a given technology, for instance IBLI, could be 'yes' or 'no', a typical case of dichotomous variable. In this study, pastoral households are expected to reasonably show their decision to buy or not to buy IBLI with the objective of shielding their herds from climate change induced livestock mortality risk. This insurance market participation decision would depend on the expected level of satisfaction that pastoralists' derive from buying IBLI and expect indemnification. Pastoralists' willingness to pay or not to pay for IBLI products at any time is also influenced by various factors such as objectives and constraints as well as costs and benefits. In other words, pastoral households would be willing to pay for insurance if and only if the utility they derive from buying IBLI (new insurance technology) to mitigate their livestock mortality risk and maximize livestock benefits, livestock product yield or income, is higher not buying it. Thus, the pastoralists' decision behaviour can be represented by a utility function and the problem can, therefore, be shown as a utility maximization problem. In line with this, it can be assumed that pastoralist households derive utility from buying IBLI to secure their livestock which entitles them with economic benefits of using the livestock/livestock products and resource endowment, even under the changing climate regime.

Let the pastoral household's decision to participate in the livestock insurance market through buying IBLI is represented by a function f where $f = 1$ if the pastoral household decides to buy

IBLI and $f = 0$, otherwise. The resource endowment of the pastoral household is represented by r and vector v represents other observable attributes of the pastoral household that might potentially affect the participation in the insurance market and the willingness to pay decision for the IBLI. If a pastoralist household is willing to pay for the use of IBLI technology, the household's utility is given by $U_1 = U(1, r, v)$ and, if the household is not willing to pay, the utility is given as: $U_0 = U(0, r, v)$. Therefore, based on the existing farm household economic theory, households are expected to be rational decision makers who try to decide or prefer the best option from the stated alternatives, subject to their demographic, socio-economic, institutional and other constraints. Based on the utility specification function of Wegayehu (2000), the study assumed additively separable utility function in the deterministic and stochastic components where the deterministic component is assumed to be linear in the explanatory variable. That is, the two utility functions representing the probable two decisions of the household to buy or not to buy IBLI are: $U_1 = U(1, r; v) = D(1, r; v) + \varepsilon_1$or $U_0 = U(0, r; v) = D(0, r; v) + \varepsilon_0$, respectively, where $U_t(.)$ is the utility derived by the pastoralists household as a result of buying and using IBLI climate change induced risk mitigation, $D_t(.)$ is the deterministic part of the utility and ε_t is the stochastic component representing the component of utility known to the households but unobservable to the economic investigator. Without specifying the choices, it is expected that pastoralists households are assumed to know their resource endowment r and implicit cost of using IBLI in terms of commitment of their resources and making clear decisions whether to buy or not. Considering the farmer's implicit cost of deciding to buy and use IBLI to be represented by c, then, the farmer will decide to participate IBLI market if $U_1(.) \geq U_0(.)$ which means if $D(1, r - c; v) + \varepsilon_1 \geq D(0, r, v) + \varepsilon_0$ and then, the presence of a random component permits to make probabilistic statements about the behavior of pastoralist household's decision to participate in IBLI market. If the pastoralist household decides to participate in IBLI market, the probability distribution is given by $P = \Pr[D(1, r - c; v) + \varepsilon_1 \geq D(0, r, v) + \varepsilon_0]$ and if the pastoralist household did not participate IBLI market, the probability distribution is given by $P = \Pr[D(0, r, v) + \varepsilon_0 \geq D(1, r - c; v)]$, with the assumption that the deterministic component of the utility function is linear in the explanatory variables, the utility function in (1) and (2) can be given as: $U_1 = \beta_1' Y_i + \varepsilon_1$ and $U_0 = \beta_0' Y_i + \varepsilon_0$ where β_1' and β_0' are the vector of response coefficients while ε_1 and ε_0 are stochastic or random disturbance terms. For practical purpose, the probabilities in above can be represented by a probability cumulative distribution function (index) as follows:

$$P(WTP) = \Pr[U_1(.) \geq U_0(.)] \Leftrightarrow P(WTP) = \Pr[\beta_1' Y_i + \varepsilon_1 \geq \beta_0' Y_i + \varepsilon_0] \Leftrightarrow P(WTP) = \Pr[\beta_1' Y_i - \beta_0' Y_i \geq \varepsilon_1 - \varepsilon_0] \Leftrightarrow P(WTP) = \Pr[Y_i(\beta_1' - \beta_1') \geq \varepsilon_1 - \varepsilon_0] \Rightarrow P(WTP) = \Pr[Y_i \alpha > e_i],$$

where P is the probability function, $e_i = \varepsilon_1 - \varepsilon_0$ is a random disturbance term $\alpha = \beta_1 - \beta_0$ is K*1 vector of parameters to be estimated, Y_i is an n*K matrix of explanatory variables. P $(Y_i \alpha)$ is the cumulative probability distribution function for e_i evaluated at $Y_i\alpha$. The probability that a pastoralist household uses IBLI technology is, therefore, a function of the vector of the explanatory variables, of unknown parameters and the disturbance term**.**

Empirical Models

Two econometric models were fitted into the data set pertinent to the two basic issues that require empirical analysis in this study. First, the ordered Probit model was used to determine the decision of the pastoral households whether they are willing or not to pay for IBLI technology. Secondly, the censored interval regression model was applied to determine the number of TLU and then, amount of payment that a respondent pastoral household would be willing to pay. The following section explains these two models fitted in the data set.

Ordered Probit Model: Since the demand for insurance of the pastoral households indicated by their willingness to pay is a sequential decision, it is analyzed using the ordered Probit model which assumes that the decision of a pastoralist household to pay for IBLI ($\mathrm{Y_i} = 1$) or not to pay ($\mathrm{Y_i} = 0$) depends on an unobservable utility index $\mathrm{I_i}$ (which is also known as a latent variable), that is determined by one or more explanatory variables, $\mathrm{X_i}$ in such a way that the larger the value of the index, $\mathrm{I_i}$, the greater the probability of a household to pay for IBLI. The index can be expressed as: $I_i = \beta_1 + \beta_2 X_i$, where $\mathrm{X_i}$ represents the household's characteristics affecting the WTP for IBLI decision, β_1 and β_2 are the slope and coefficient parameters to be estimated. The unobservable index could be related to the actual decision as follows. As mentioned earlier $\mathrm{Y_i} = 1$ if a household is willing to pay and$\mathrm{Y_i} = 0$, otherwise.

Assuming that there is a critical or threshold level of the index, I_i^*, where a household is willing to pay if I_i exceeds I_i^*, otherwise will not. The threshold I_i^* is also not observable, but it is normally distributed with same mean and variance. Given the assumption of normality, it is possible to estimate the parameters and the probability of I_i^* to be less than or equal to I_i can be computed from the standardized normal cumulative density function as: $P_i = P(Y = 1/\mathrm{X}) = P(I_i \le I_i^*) = P(I_i \le \beta_1 + \beta_2 X_i) = F(\beta_1 + \beta_2 X_i)$, where $P(Y = 1/\mathrm{X})$ represents the probability that $(Y = 1)$ given some values of X, I_i is the standard normal variable and F is a standard normal cumulative distribution function (CDF). To obtain information on the utility index, I_i, and the coefficients (β_i), the inverse of (10 can be taken to obtain: $I_i = F^{-1}(P_i) = X_i\beta_i$, where F^{-1} the inverse of the normal cumulative density function. Therefore, the WTP decision behaviour can be modeled as: $Y = 1 = X_i\beta + e_i$ if $X_i\beta + e_i > I^*$, and $Y = 0 = X_i\beta + e_i$ if $X_i\beta + e_i < I^*$,where I^*represents the latent variable /unobserved index of household characteristics and $I = 1,2,3 \ldots N$. The index, I is a linear combination of explanatory variables and might take any value between $-\infty$ and∞, and its transformation ensures that all corresponding probability values lie between 0 and 1.

Interval Regression model: As we discussed above, the IBLI technology is a non-marketed product in Ethiopia. Thus, based the current study has employed double bounded dichotomous elicitation format of Contingent Valuation method (CVM) which has proved to be a valuable approach for assessing the value of non-marketed products or technologies. This elicitation format enables to create lower and upper bounds of payment for the intended product. The amount of payment that a respondent would be willing to pay for IBLI lies in a specified interval of payment for each category of product type which is assumed to be made available based on different degree of product preference and risk averse behavior of the households insuring their assets. The data required to be analyzed, is, therefore, with interval-censored, left-censored and right-censored values. Accordingly, the censored econometric model proposed by Cameron and James (1994) and Cameron (1991), which produces separate estimates for the standard deviation of the WTP and the parameters of the model was employed. Assuming a linear functional form, the Interval Regression econometric model measuring the magnitude of the pastoral household's willingness to pay (WTP_i) is specified as follows: $Y_{ij} = X_i\beta + \varepsilon_i$, where Y_{ij} is the true individual willingness to pay, X_i is the vector of pastoral household's socioeconomic and institutional characteristics determining the amount of payment for IBLI, ε_i is the error or disturbance term in estimating Y_{ij}, j represent the upper and lower bound values of the premium payment interval and i represents the i^{th} individual pastoral household included in the sample.

Variables and Hypothesis

Dependent Variables

Willingness to pay (WTP) Decision for IBLI (D_i): The willingness to pay decision of a pastoralist household to be determined using the probit model indicated above has a dichotomous nature measuring the willingness of a pastoral household o pay cash for acquiring IBLI contracts taking a value of 1 if the household is willing to pay and 0, otherwise.

Amount of premium to be paid (Y_i): the other hand, from the perspective operating an effective and sustainable insurance market by supplying adequate insurance contracts that can sufficiently handle the risk of livestock mortality caused by drought in the study area, not only the pastoralists' willingness to pay but also the amount of the payment that individual pastoral household is willing to pay is very important. Of course the sufficiency like breakdown level of operation for the insurer is determined by the overall predicted insurance sales of the reinsurer in the insurance industry overall the globe. Accordingly, once the farmer has made the choice to pay, the next decision is to determine the amount of payment (intensity) of cash premiums that the pastoral households are willing to pay. The intensity or amount of cash payment in Ethiopian Birr takes interval values that represent the amount of payment that a respondent could pay.

Explanatory Variables

In this study, explanatory variables are separately identified for each of the above dependent variables required to be measured. First, the willingness to pay decision of households (D_1), is hypothesized to be explained by risk aversion factors, wealth, perceived basis risk and expected livestock losses. Household characteristics (age, sex of household head, education, family size), farm characteristics (land size, types of crops grown, value of farm implements), household assets (physical, natural, financial, social and human), location characteristics (access to road, electricity, and distance from nearest market), institutional characteristics (access to credit, market information, membership in idir, iqup), risk factors (variability of climatic factors, market prices and diminishing returns).

The independent variables of the participation decision study are those, which are expected (hypothesized) to have association with the participation decision behavior pastoralists in IBLI service. Different researchers came up with different results as to what factors can influence pastoralists' decision to participate or to pay for IBLI service in Mongolia and Kenya. They identified a marked association between socio-economic characteristics of the household and the practice of using IBLI service. Based on theoretical background and empirical results of few studies on IBLI and other related credit and insurance service decision carried out elsewhere, the following variables are hypothesized to influence pastoralists' decision to participate in IBLI service. Demand and willingness to pay are elicited by considering household preferences, subjective beliefs, wealth and household-specific characteristics.

Firstly, considering household's preference, demand and WTP are hypothesized to increase in risk aversion behavior of the pastoralist and decrease with the discount rate of the premium in a setting without asymmetric information i.e when households fully understand the insurance contract. Secondly, with respect to their subjective expectation and beliefs, demand and WTP is expected to increase with pastoralist's perceived livestock mortality risk and in household's expected insurance payout taking into account the perceived basis risk associated with IBLI product (e.g., the correlations between individual mortality losses and the predicted mortality index that governs IBLI indemnity payout). Thirdly, by the standard wealth effect, household's income and assets represent the extent of financial resource to afford for IBLI, which have positive impact on insurance decision. As the welfare impact of a formal risk management instrument like IBLI depends largely on the effectiveness of the existing risk-coping mechanisms, household's wealth could also reflect availability of existing self insurance capacity and so could have negative impact on insurance decision. Theoretically, thus, wealth could have ambiguous impact on insurance decision.

By similar token, degree of credit constraint also plays key but ambiguous role in household's WTP for insurance. On one hand, credit constrained households may value reduction in asset risk provided by IBLI more highly because they have lesser ability to smooth consumption ex -post by other means. On the other hand, the shadow value of their needy liquid asset may be too high to make IBLI attractive. Many of these predictions will empirically verify especially in the insurance markets in developed countries. However, factors that deviate the economic setting away from full information – e.g., household's awareness, ability to understand the product and trust that condition their perceived cost and benefit of IBLI – are shown theoretically and empirically to influence demand for insurance and other financial instruments (Gine *et al*. 2008). These factors are expected to serve as important demand determinants for a new product like IBLI among the targeted pastoralist clients of the Borana with very limited knowledge and experience of insurance.

Table 1: Definition of hypothesized explanatory variables included in the two models

Variable	**Description o Variable**	**Type o Variable**	H_0 D_i	Y_i	**Unit of Measurement**
AGE/AGE^2	Age of the householc head	Continuous	+	-	Age of the household head in years
FAMSIZE	Family size	Continuous	-	-	Number of household members
MANEQ	Active age of family size	Continuous	+	+	Measured in man-equivalent
DEPRATIO	Dependency Ratio	Continuous	+	+	HH members of age <14 and > 65
GENDER	Sex of household head	Dummy	-	-	1 for male headed, 0 otherwise
EDUCA	Education of householc	Dummy	+	+	1 if literate, 0 otherwise
LNDHOLD	Land holding	Continuous	+	+	Land of the household in hectares
TLUHOLD	Livestock holding	Continuous	+	+	Number of live stock in TLU
OFF_FARM	Off-farm income	Continuous	+	+	Amount of income from farm activities
NON_FARM	Non-farm income	Dummy	+	+	Yearly income from non-farm activities
SOCICAPTL	Level of social capital	Dummy	+	+	Participation in idir,iquib
TOTLINCM	Household total income	Continuous	+	+	Amount of total annual income
TRAINING	Access to training	Dummy	+	+	1 if HH is trained, 0 otherwise
CRMEXPNS	Expenditure or festivals	Continuous	-	-	expenditure on social ceremonies ir ETB
CRDIT	Pastoralist's credi access	Dummy	+	+	1 if accessible, 0 otherwise
DISTMKT	Distance to marke place	Continuous	-	-	Distance from market measured ir kilometers
EXT_CTCT	Visits of developmen agents	Dummy	+	+	1 if farmer has contact, 0 otherwise
FINLITERAT	Financial literacy	Dummy	+	+	1 if literate, 0 otherwise

CLIPERC	Climate change perception	Dummy	+	+	1 if perceived, 0 otherwise
AMB_AVERS	Ambiguity Aversion	Dummy	+	+	1 if ambiguous future climate change 0 otherwise
RISK	Risk preference	Dummy	+	+	1 if the household is risk taker, 0 otherwise
TLU_COMPO	Herd Composition	Dummy	+	+	1 if cattle proportion>50%, 0 otherwise
LOCATION	Geographic Zone	Dummy	+	+	1 Boran, 0 if the Household is in Guji
INTERRATE	Discount rate	Continuous	+	+	expected/required rate of return in %
LOSS	Expected livestock loss	Dummy	-	-	1 if large livestock loss is expected, 0 otherwise
FINUSE	Financial services exprience	Dummy	+	+	1 if the household have bank account 0 otherwise
ASSET	Value of productive assets	Continuous	-	-	Estimated value of productive assets in ETB
NONASSET	Value of non-productive assets	Continuous	+	+	Estimated value of non-productive assets in ETB
AWARE	Level of awareness	Dummy	+	+	1 early warning oriented, 0 for the others

Result and Discussion

This part of the study presents the results of the analysis of the field data. As per the objectives of the study, the findings were presented in four subsections. Sections 4.1 and 4.2 present the findings of the analysis made on how the pastoral livelihood is threatened under the changing climate scenario and the indigenous adaptation strategies of the pastoral households in the study area, respectively. Section 4.3 which is the core of this section presents the result found in analyzing livestock insurance as an innovative climate risk management strategy. This section analyzes the feasibility, demand and willingness to pay for Index-based livestock Insurance (IBLI) technology meant to indemnity livestock mortality risk driven by climate change induced drought in pastoral areas. Section 4.4 provides feasible ways of institutionalizing the IBLI in the context of Borana and Guji pastoral households, taking into account mechanisms of insuring the livestock value chain and strategies for gender-centric livestock value chain insurance.

Climate Change and pastoral livelihood in the study area

Climate change is proved to be the main cause for the recurrent drought and rampant livestock mortality in pastoralist areas. As this is the main concern of this study, pastoralists were responded on the nature, pattern, perceived impact of the climate variability on their livelihood. From the analysis, the expected future climate phenomena and the households' associated uncertainties and risks were drawn. Household level understanding and the smallholders' perception about the pattern of climate change and the immediate cause, consequence and impact of the variability as well as the change is very important for the purpose of tackling the adverse consequences of these change on livelihoods of the households. Thus, this section provides the perceived patterns, consequences and impacts of climatic variability and change in the study to link their perception with pro-poor risk management innovations.

Households' perception on pattern of climate change: As indicated in table 2 below, among many factors, the respondent households have indicated long-period dry season without rain, irregularity in raining with decreased intensity of the amount of rain as the common pattern of climate change over a decade. In Borana Zone, the climate change pattern is characterized by a weather condition of severe drought and low intensity of precipitation, thus, acute shortage of rainfall and precipitation characterize the pattern of climate change in this zone as compared with the adjacent Guji pastoralist Zone in which long-period dry season and irregularity in raining were mainly perceived by the pastoralist households. In Guji zone 99.96% of the respondent households have reported long-period dry season as the most important adverse pattern of weather followed by irregularity in rainy season (84.61%) and decrease in rainfall intensity (90.65%). Similarly in Borana zone, 93.97% of respondent households have perceived severe drought as the first important pattern of climate change, followed by lack of precipitation (87.07%) and dry windy season (57.76%). In general, the Borana and Guji pastoralist of southern Ethiopia have perceived the impact of climate variability changing from long to short period rain, from regular and stable to irregular, pattern less, untimely raining and flooding, decreased intensity of rainfall, drought and minimized precipitation over periods in the past.

Table 2: Proportion of households perceived different patterns and impacts of climate change

Items	**Borana (n=116)**	**Guji (n=107)**	**Total (N=223)**
Perceived patterns of climate change			
Long-period dry season without rain	81.03	99.06	80.72
Irregularity in rainy season	88.79	84.61	86.54
Decreased in rainfall intensity	87.07	90.65	88.79
Untimely rain and flooding	52.59	61.68	56.95
Dry wind	57.76	30.84	44.84
Severe drought	93.97	95.33	94.61

Lack of precipitation	87.07	86.91	87.00
Perceived Adverse consequences of climate change			
Scarcity of water	97.41	96.26	96.86
Degradation in pasture land	93.97	87.85	91.03
Forage Unavailability	92.24	99.06	95.52
Emergency of unpalatable grass specifies	22.41	69.16	44.84
Perceived impacts of climate change			
Weakened carrying capacity of land biomass to feed livestock	54.31	50.46	52.47
Physical deterioration of livestock	83.62	80.05	84.30
Decrease in livestock breeding cycle	31.90	30.84	31.39
Pastoralists' migration to other areas	88.79	81.31	85.20
Children school leaving	87.93	83.18	82.06
Emergency of conflict and loss of life	81.03	71.96	76.68
Loss of family and dissolution of Social Capital	56.90	53.27	55.16
Asset Depletion	49.12	41.12	45.29

Source: Household Survey, 2012

Households' perception on adverse consequences of climate change: This study has aimed at assessing the perception of the pastoral households on the immediate consequences of the changing climate in the study area on their livelihood, mainly on livestock. As table 2 above indicates, pastoralists in Borana zone has indicated that degradation of the grazing land which was initially covered with shrubs (93.97%) and unavailability of forage (92.24%) as the two most important adverse consequences the changing climate overtime. On the other hand, the Guji pastoralist with better range land have indicated that due to the emerging climate change, water scarcity, disappearance of the traditional grass species and replacement by unpalatable species have taken place.

Households' perception on long-term adverse impacts of climate change: The most important issue required to be addressed in this section from the perspective of designing livestock insurance as an innovative pro-poor risk management is a thorough understanding of the long-term impact of climate change. As indicated in table 1 above, the long-term impact of climate change in Borana and Guji pastoralists include both environmental/ecological and socio-economic value losses. About 54.31% of Borana pastoralists and 50.46% of the Guji pastoralists have indicated overtime weakened carrying capacity of land biomass to feed livestock as the most important impact in the emerging climatic scenario. Physical deterioration of livestock 80.05% and decrease in livestock breeding cycle 30.84% were cited as significant adverse economic impacts of the climate change in Liben and adjacent woredas of the Guji zone. Similarly, pastoralists in Borana (81.03%) and in Guji (71.96%) have responded that emerging conflict on range resources, loss of life and deterioration in social capital were the impacts of the gradually changing climate and decrease in range resources in pastoralists' areas. Both pastoralist groups argue that the overall asset depletion and economic value losses were large over the past years which were attributable to the changing climatic scenario. Hence, these households opt for insurance and any other innovative intervention which makes them overcome the problem livestock and asset losses in their area.

Livestock as a main sources of livelihood in the study area

Understanding the pastoralists' main sources of livelihood and assessing the possibilities of income generation from diversified alternative sources of livelihood are important steps in enhancing vulnerable households to come of their poverty trap and economically cope up with climate change scenarios.

Table 3: Components of shares of household income in the study area

Items	**Borana (n=116)**	**Guji (n=107)**	**Total (N=223)**
Sales of livestock	84.37	75.40	81.70
Sales of livestock products	11.00	9.00	10.20
Sales of charcoal	0.02	0.01	0.015
Entrepreneurial sources	0.03	0.06	0.04
Causal work	0.04	0.07	0.06
Salary	0.04	0.06	0.05
Food aid	1.50	2.34	2.47
Crop sales	2.00	7.00	5.40
Other Miscellaneous sources	0.02	0.13	0.08

Source: Household Survey, 2012

As indicated in table 3 above, the contribution of livestock and livestock products to the total household income is largely significant, 84.37% and 75.40%, in the Borana and Guji zones, respectively. Probably due to orientation by local administrative units and governments' firm stand against charcoal making together with their personal secrete for security reasons, there is no respondent who engaged in charcoal making. This might be important for environmental and ecological maintenance of the pastoralist area. On the other hand, the contribution of the entrepreneurial sources like on/off-farm activities (0.04%), paid salary (0.05%), causal work (0.06%) and other miscellaneous sources in very small is total share of the pastoral households' income while crop sales (5.4%) and external support (food and cash) supply (2.47%) constitute the total households' income sources. Even though the role that the livestock sector plays in pastoral or pastoral/agro-pastoral system is obviously significant, it is important to determine the component of pastoralists' income by sources in order to understand the associated economic losses with livestock mortality. In other way, this helps us to value insuring the livestock based on the economic value of the livestock to be potentially lost.

Climate Change as a threat of livelihood in the study area

Still, the current study addresses how climate change threatens the livelihood of the pastoralists in the study area, which is pastoral dominated in Borana and both PA (pastoral/agro-pastoral) system in Guji.

Table 4: Main livelihood threats in the study area

Items	Borana (n=116)	Guji (n=107)	Total (N=223)
Irritating drought due to lack of rainfall	88.79	87.85	88.34
Declining crop production	6.03	80.37	41.70
Livestock mortality due to animal diseases	85.85	83.18	80.72
Tribe/caste based conflict on range resources	49.14	45.79	47.53
Rampant herd mortality due to climate change	93.97	97.20	95.52
Governments' banning of contraband	55.14	0	28.7

Source: Household Survey, 2012

Pastoralists in both zones have experienced severe drought as the most important factor threatening their livelihood. However, 80.37% of the Guji pastoralists have indicated decrease in crop production and 55.14% of the Borana pastoralists' particularly living Dire district which is adjacent to the Moyale land of Ethiopia and Kenya have indicated the banning of contraband as the most important factors threatening their livelihood. But, most importantly livestock mortality due to animal diseases (80.72%) and rampant herd mortality due to climate change (95.52%) have significantly threatened the lives of pastoralists in both zones, followed by tribe/caste based conflict on range resources as perceived by 49.14% and 45.79% of the respondents in Borana and Guji zones, respectively.

Livestock Mortality in the study area

As indicated in the above discussions, livestock is highly threatened by adverse weather conditions as a result of changing climate in the study area. Pastoral households have experienced livestock and livestock product losses due to rampant herd die-offs. Respondent households have indicated a large number of livestock that they lost in the face changing climate over decades. Based on their recall and substantiating it with the secondary data sources, the study has identified 80–90% deaths and decline of livestock from the existing stock per year. This is critical analysis provides an important input for the design of insurance in the study area From the perspective of livestock insurance as a risk management tool for pastoral households, it is important to focus on the degree at which drought as an adverse consequences of climate change contributes to the rampant herd mortality that pastoralists rank as the most important factor threatening their livelihood.

Table 5: Most important causes of livestock mortality in the study area

Items	Borana (n=116)	Guji (n=107)	Total (N=223)
Starvation due to drought	68.00	64.00	62.00
Diseases	18.00	20.00	17.00
predation	9.00	11.00	10.00
Raiding/rusting/conflict	3.00	7.00	5.00
Accident/poisoned	2.00	5.00	4.00
Just Lost and others	1.00	3.00	2.00

Source: Household Survey, 2012

As indicated in the analysis of the aforementioned sections, livestock are the most important assets in terms of income generation and consumption for pastoral households in both zones. However, table 3 above has indicated that herd mortality due to climate change is significantly large. Hence, it is important to identify the most important cause for such mortality so that innovative ways of handling this mortality causes would keep in pace a sustainable morbidity of the livestock sector in the pastoralists' economy. As table 5 above indicates, starvation due to drought which is caused by lack of pasture resources and water (62%) is by far the largest cause of livestock mortality, followed by diseases 17% and predation 10%. On top of this, disease and predation as indicated by the respondents were aggravated during seasons of drought and immediately after drought which indicates these are also the most likely consequences of the climate change. However, pastoralist responded that natural accident 4%, social conflicts resulting raiding livestock 5% and disappearance of herds 2% were some the causes of the livestock mortality. Hence, as the above analysis indicates the potential for weather index-based livestock insurance is large and adopting this technology is very important as it indemnifies herd losses due to climate change which is the main driver of the mortality.

Adaptation strategies of pastoralists to climate change in the study area

As the above sections indicate, climate change has caused immediate consequences and long-term impacts on livelihood of the pastoralists. Livestock which are the main sources of livelihood in terms of consumption, food security and income generation were being threatened by these adverse consequences of the changing climate resulting high mortality rates. However, before we discuss about technological innovations for adaptations, it is logical to understand the pastoralists' indigenous adaptation techniques. Generally, the study identified two main categories of adaptation strategies that pastoralists have underwent. The first strategy is adaptation to climate change risks which include weather-related risk prediction and adaptation, adaptation to risks associated with livestock, mitigation of risks related to range and water resources. Secondly, pastoralists have undertaken livelihood diversification as a strategy for risk mitigation under changing climate conditions.

Managing weather induced risks: In making economic decisions, pastoral households' understanding and interpretation of evidences about weather conditions plays a significant role. In line with this, pastoralist households in this study indicated three methods, by which climate information is gathered including i) using indigenous climate forecasting techniques, probabilistic forecasts and awareness and access to external information. In the section follow, these items will be elucidated. Table 6 explains the proportion of households' having understanding of the traditional techniques.

Table 6: percentage of respondent households using different climate forecasting techniques

Items	**Borana (n=116)**	**Guji (n=107)**	**Total (N=223)**
Reading the stars/astrological signs	79.31	75.70	77.58
Reading livestock intestines	57.76	39.25	48.89
Flowering/ leaf of specific plant species	50.00	72.41	63.68
The *Gada cycle*	94.83	94.39	94.62
Cattle body language	29.31	21.50	25.56
Cattle appetite	25.00	28.97	26.91

Source: Household Survey, 2012

As indicated in table 6 above, respondent households have different indigenous methods of forecasting the patterns and characteristics of climate change. This implies that households value these patterns and characters of climate in order to plan in advance in response to forecasts as a means of mitigating the impacts of drought. As indicated above, the method of probabilistic forecasts did not appear to be universally understood for the respondents. For instance, events that contradicted forecasts were brought up as evidence against modern methods. The overall understanding of the households about the changing climate using the traditional system of weather prediction is reading livestock intestines (74.2%), environmental variation through locating and identifying specific species of plants that are in leaf or flower (26.4%), interpreting astrological signs/reading from moving stars (34.3%), cattle body language and appetite (67.28%). Furthermore, the majority of the households (93.55%) have reported that the results of these traditional practices were cross-referenced against the *gada* calendar's predictions of drought cycles. Traditional practices and the *gada* cycle were used jointly to predict the likelihood and the severity of drought, allowing the Boran to plan ahead. The elders in FGDs noted that traditional methods recently (as in the past 20 years) seemed to be less predictable. In an interview with some Boran leaders, they noted that the younger generations of Boran were more adept in interpreting external information and that government and NGOs have been attempting to implement more and better warning systems. Interviewees expressed that the information on these warning systems was valuable but sometimes difficult to understand.

Mitigating Livestock-related risks: Livestock constitute the main source of livelihood for Borana and Guji pastoralists. Maintaining a sufficiently large herd size will be vital to ensuring sufficient caloric intake if animal sources continue to constitute the vast majority of their calories. Although a shift to non-traditional forms of pastoralist livelihoods is occurring, livestock still constitute the most crucial component of pastoralist livelihoods in Ethiopia. Although large herds may represent economic and food security, livestock herd size is also correlated with animal well-being and herd mortality. Larger herd sizes can increase herd mortality especially during conditions of drought and stress. Respondent households reported that due to reduced quality and quantity of rangeland, milk production has decreased. In current drought conditions, the number of lactating animals needed to sustain a household could be as high as 10-20 animals, as compared to forty years ago when one or two lactating animals was sufficient. According to Lybbert *et al*., 2004, in pastoralists systems, when herd size falls below a certain threshold, transhumant livelihoods cannot be maintained. In line with this, the Borana and Guji pastoralists adopted various strategies to cope with recurrent drought induced by climate change. Table 6 below explains the proportion of respondent households adopting these strategies.

Table 7: Proportion of respondent households adopting various livestock-related risk mitigations

Livestock-related risk mitigation techniques	**Borana (n=116)**	**Guji (n=107)**	**Total (N=223)**
Herd mobility	87.07	91.59	89.24
Rotational and selective grazing	93.97	94.39	94.17
Breeding drought-tolerant livestock variety	75.00	72.90	73.99
Preferential animal health treatments	87.93	91.59	89.67
Destocking	50.00	58.88	54.26
Indigenous social insurances	81.03	90.65	85.65

Source: Household Survey, 2012

As indicated in table 7 above, pastoralist households have used a number of strategies to cope with livestock-related climate induced risks. These include herd mobility which is maintained to ensure that herds can find pasturelands not decimated by drought, rotational and selective grazing in which certain traditional communal grazing areas were restricted not to be utilized for a season to provide extra nourishment for sick, young, and lactating animals in times of scarcity, preferential animal health treatments through which sick animals are isolated from healthy animals to prevent the spread of disease and animal injuries and diseases were treated using local knowledge. In addition to these practices, as indicated above a strong social welfare system has developed to ensure that all pastoral households can continue to herd livestock. For example, Boran pastoralists reported that households with more than five cattle can be called on to redistribute cattle to those who have sustained severe losses, as part of the social welfare system called *busa gonafa*. In sections below detail explanations of the households' strategies for livestock-related risk mitigation mechanisms were explained.

Herd Mobility: As an adaptation and risk mitigation strategy in times of drought, the Borana and Guji pastoralists travel with their livestock in search of water and pasture. The direction and route of movement is dictated by season and the availability of forage, as well as personal relationships, family structure, and immediate demands. In addition, herd mobility is aided by a network of watering points and wells maintained throughout Borana and Guji pastoral areas. Operation and maintenance of these points is controlled through the *gada* system. Prior to the emergence of recent climate-related changes, migration was limited to mainly wet and dry grazing areas, meaning that different pastures were used during the wet and dry seasons, and that traditional laws governed the use of these resources. As climate change has accelerated, the Borana and Guji pastoralists have altered how they migrate, when, where, and for how long. The Borana and Guji pastoralists now travel significantly greater distances to reach pasture and water, which takes more time and requires men to be away from home for longer periods. Increasing the time demands on herders places financial stress on families who must essentially support two households, and impacts the education of children as some may be removed from school to help at home or to help herd. Traveling greater distances also places extreme caloric demands on cattle and exposes them to disease. Livestock walk farther for food and water, and may expend more energy than they consume. They may also travel from areas that are disease-free to areas where disease is endemic.

*Traditional social insurance***:** In the event of massive die-offs of cattle, the Borana and Guji pastoralists rely on a traditional three-tiered social insurance system. The first tier is *busa gonafa*, a community-based re-stocking program in which several Borana and Guji pastoralists' families, whose cattle have survived, give a cow to other families that has lost their entire herd. The cow is a permanent gift and is intended to help the family begin tore build their herd. The second is *ames*, a short-term loan extended from one Borana and Guji pastoralists family to another in the form of a lactating cow. The Borana and Guji families that receive the lactating cow may keep the cow and use her milk for one lactation cycle (typically less than six months in Borana and Guji pastoralists) and then must return the cow. The third tier is *rebaray*, a charitable donation in which a single Borana and Guji families gives a cow to another families following the complete loss of their herd. The cow is a gift, and the family that receives the cow has full rights to the cow, her milk, and her offspring. In order for this system to work and be perpetuated, the families that are donating and lending cattle must have a minimum of five cows. Families that do not meet this minimum requirement are not asked to make donations. In the face of climate change, this traditional system is failing primarily because families cannot meet the minimum required livestock holdings in order to participate in the system. In the past, the provision of feed to cattle by women (cut and carry) within the Borana and Guji pastoralist systems was only extended to the young and the debilitated. Women would cut and collect grass and bring the feed to the animals housed at the homestead. This served two important animal health functions: (1) it minimized the spread of infectious disease by limiting the movement of sick cattle, and (2) it facilitated growth and healing by reducing the caloric expenditure associated with grazing activity. This system has now become a coping mechanism. In anticipation of drought, farmers collect and store hay in open protected structures, an activity never previously undertaken among the Borana and Guji pastoralists. Farmers who can afford to do so purchase feed for one to two individual animals in hopes that if they can supplement the diet of a few individuals, they can avoid complete herd loss. These activities require more inputs from the women in the household to collect the hay, and place more financial strain on households as they must re-direct income for the household to maintenance of the herd. This coping mechanism requires extensive planning and knowledge of impending climate conditions so that hay may be cut when it is abundant, which occurs less often now that drought conditions are becoming more frequent and severe. The purchasing of feed is not a feasible coping mechanism for the vast majority of the Borana and Guji pastoralists, who simply do not have the disposable income to support this practice.

*Drought-Tolerant Livestock***:** As the landscape in southern Ethiopia has become drier, the presence of drought-tolerant livestock has increased. Currently, proportions of different types of herds are being reduced relative to goats and camels, which are more droughts tolerant and disease resistant. Livestock diversification has become one of the most universally adopted coping mechanisms among Borana and Guji pastoralists. Nearly all Borana and Guji pastoralists have multispecies herds that include goats, with increasing numbers of herds adding camels. While this strategy has been widely successful, constraints exist. First, Borana and Guji pastoralists interviewees expressed concern over their lack of knowledge about the husbandry and management of camels. They are unfamiliar with camelid diseases, and lack knowledge of both traditional and non-traditional treatments. In focus group discussions conducted with Borana and Guji pastoralists pastoralists, interviewees stated that the care and housing of these animals was novel to them, and that they were unsure of how to manage animals in order to prevent (not simply to treat) disease. Secondly, camels are expensive relative to cattle. They can cost nearly six times more than a healthy cow. Furthermore, most camels cannot be sold before three years, but preferably six years, of age. It is therefore a relatively large financial investment and the return on the investment cannot be realized rapidly. While the Borana and Guji pastoralists will drink camel milk, the amount of milk produced by a camel is significantly less than that produced by a cow.

Therefore, ownership of camels does not contribute as greatly to the direct subsistence of the farmers. Lastly, ownership of camels in place of cattle is in direct conflict with Borana and Guji astoralists culture. Many Borana and Guji pastoralists in focus group discussions spoke passionately about their relationship and history with cattle. To paraphrase one group of pastoralists in Dhas (August, 2011), Borana and Guji pastoralists culture is defined by cattle ownership and husbandry, and without cattle the Borana and Guji pastoralists feel they can no longer call themselves “Borana and Guji pastoralists”. Among the Borana and Guji pastoralists, livestock diversification is even sometimes perceived as a threat to Borana and Guji pastoralists identity.

Direct subsistence on cattle and their products is waning in Borana and Guji pastoralists as a result of climate change. Fertility of cows may be compromised due to a poor plane of nutrition, and those who do become pregnant and give birth to live offspring have shortened lactation cycles which produce lower volumes of milk. Consequently, there is simply not enough milk available to sustain the calf and the people. As drought conditions worsen, lack of calories and lack of water results in a continued decrease in milk production. Animals approaching starvation are being sold in the market. Previously, selling animals was a rare event, as a large herd is a sign of prestige and is culturally valuable among the Borana and Guji pastoralists.

For example, evidences reveal that cattle traveling from the south where there are no tse tse flies to the north where the flies are abundant would contract trypanosomiasis, which could result in massive cattle die-offs (Yabello, July 2011). Additionally, there is concern that as the Borana and Guji pastoralists cattle migrate to novel geographic regions there will be increased opportunity for the Borana and Guji pastoralists cattle breed to cross-breed. Depending on which breeds the Borana and Guji pastoralists cattle breed is crossed with, the impacts could include improved or diminished hybrid vigor, disease tolerance, and drought tolerance. Unfortunately, simply changing traditional migration patterns as a means of coping with climate change will not mitigate all of the climate change-related risks. Migration over extremely large distances exacerbates the negative energy balance of the cattle in the region, an imbalance that can be compounded by exposure of naïve populations to novel disease. In the short-term more cattle will survive, but in the long-term more cattle will perish.

*Destocking***:** The Borana and Guji pastoralists appear to be reducing their herd size as a coping mechanism for several reasons. First, it minimizes risk and allows the Borana and Guji pastoralists greater financial gain than would be possible if the animal were to die. Secondly, income from the sale of livestock can be used to buy household goods or other urgent needs. While this offers immediate relief, it is problematic with respect to the market. The Borana and Guji pastoralists are selling their livestock when the market is flooded and prices are low. When asked about this practice, the focus group participants at all interview sites anticipated having to sell some cattle during the dry season, but indicated a preference for trying to maintain large herds as long as possible through the dry season. Reasons for this are unclear, but might be attributable to cultural prestige associated with having a large herd and risk-reducing behaviors. The perception seemed to be that a larger, less healthy herd had better odds of having some members survive, whereas a smaller, healthier herd risked losing all members. The alternative would be to sell cattle after the rains when the market price was high, and voluntarily reduce herd size, but this behavior was not reported. Therefore, the selling of livestock appears to be an emergent coping mechanism designed to buffer against extreme shocks within an already unstable system.

*Maintaining Animal Health***:** Animal health is one of the Borana and Guji pastoralists system's greatest strengths. Local knowledge of cattle husbandry and health is substantial, and appears to be very accurate and well applied. The government vaccination program is well organized and executed, especially in light of resource constraints in the region. When asked about the health of their cattle and death due to disease, all of the focus groups consistently reported that deaths due to disease had been significantly reduced in the last 40 years, and all expressed satisfaction with the government vaccination program. When asked about strategies to improve the health of their herds and increase drought tolerance, no mechanisms were volunteered. However, when asked about the impact of castration on animal health, all focus groups reported that they believed castration improved animal health, weight gain, and drought tolerance. Nevertheless, castration has not been adopted as a coping mechanism. When asked why so few animals were castrated, the explanation provided by several focus groups was that there was no longer a market for the meat of castrated animals, and that they did not fetch the same price as an intact animal at market. Some Borana and Guji pastoralists reported that 10 to 15 years ago, a very strong market for castrated animals existed in northern Kenya, but that it no longer existed. No one was able to speak to what caused the change but speculated that the change was driven by a large and increasing demand in the Middle East for reproductively intact animals, which provided a desirable marbling of fat and muscle.

All Borana and Guji pastoralists interviewees stated that they would be willing to castrate their animals if they believed they could sell them in the market, and some elaborated on traditional methods used in the past for castration, and identified castration services available through the local government veterinary office. Coping mechanisms being adopted by the Borana and Guji pastoralists to maintain their livestock herds are generally not perceived to be sufficient or sustainable by the Borana and Guji pastoralists, in part because frustration abounds over how these mechanisms are impacting Borana and Guji pastoralists culture, (e.g., through altered migration patterns, consumption of camel milk instead of cow milk, and reduced herd size), and because fear over the financial hardships associated with these practices exists. In order to keep cattle alive, men are away from home for longer, which is an added expense for little return. The market cannot support the large influx of cattle during drought periods, and the amount of income generated by the sale of a cow does not match the investment made to keep the cow alive. While the animal health system is generally very strong, and the animals that come to market are relatively healthy from a disease perspective, this could potentially change as animals migrate to new regions and become exposed to new diseases, or carry in new disease to naïve regions. The Borana and Guji pastoralists consistently express an interest in and desire for having better climate information, but how this information would be utilized for the management of livestock is unclear, especially with respect to the decision to de-stock and sell animals in the market.

*Rangeland-Related Risk Mitigation***:** The primary means by which pastoralists, like communities everywhere, will feel the impacts of climate change is in changes in land and water resources. The Borana and Guji pastoralists have been living with scarce pastureland and water for generations. A number of rangeland-related risk-mitigation measures have been undertaken by Borana and Guji pastoralists communities, as well as initiated by the government and NGOs. Many of these measures have been in use for at least decades, and were developed in response to local climatic fluctuations without specifically being in response to recent climate change. However, these measures may still be relevant in conjunction with other, more "modern", methods as responses to climate change, and are mentioned here.

Traditional Systems of Wet/Dry Grazing Areas: The Borana and Guji pastoralists have sophisticated traditional systems of managing land and water resources. Regions are designated as wet season grazing areas and dry season grazing areas. The dry season grazing areas tend to be areas of relatively lower elevation where water accumulates, thereby allowing pasture growth even in the absence of significant rainfall. The pressure is possibly due to growth of cultivation (see below) and population (human and livestock) increase, among other factors such as conflict, political boundaries, and private enclosures. Rangeland degradation may be both cause and effect of the disruption in the traditional systems. Focus group discussion participants mentioned attempts to revitalize this system, with some initiative on the part of the local government. This system may be especially useful if droughts become more frequent and/or severe since it allows Borana and Guji pastoralists communities to together reserve a part of pasture for drier times of the year. While this system alone is not adequate, having some pasture reserved for the dry season might allow the communities some additional time to plan responses in a bad year.

Bush Clearing Programs: Bush encroachment will likely interfere with the ability of the Borana and Guji pastoralists to adapt to increased climatic pressures as it effectively reduces the pastureland available. Moreover, areas which have been encroached by bush have little grass seed left in the soil, making reestablishment of grass very difficult. Thus, although bush clearing programs such as controlled burning do not occur strictly in response to climate change, they are relevant to climate change adaptation. Some FGD participants mentioned bush burning as having other beneficial effects such as promoting growth of preferred grass species. Though the government ban on bush-burning was brought up as an issue in many discussions, many interviewees asserted that rather than an absolute ban on bush-burning, a regulation passed against burning forests during the Derg regime was widely interpreted by local authorities to mean that burning for bush clearing was also banned.

Bush encroachment has increased steadily, though not necessarily related solely to the stoppage of burning. Solomon et al. (2007) report that the species of bush (*Acacia brevispica* and *Euclea shrimperi*) identified by community elders to be problematic are different from the species reported in previous studies. Bush clearing is very difficult due to the tendency of these species to grow back, as well as their long thorny branches. Government agencies and NGOs promote communities to undertake bush clearing through cutting. There have been some studies on burning as a method for controlling the bush, but burning is currently not as prevalent as cutting. A lack of grass to spread the fire between bushes was also raised as a reason for burning not being practiced. However in some areas the bush appeared dense. As bush encroachment reduces useful pasture, which is a scarce resource in times of drought, bush clearing can be an effective strategy to bolster other adaptation measures. Improvements in efficiency and effectiveness of bush clearing methods are however needed urgently for this approach to be feasible.

Livestock Insurance as an innovative risk management strategy in the study area

Households' Knowledge base about agricultural insurance

As indicated in the above discussions, pastoral households have been using different adaptation mechanisms to protect their livelihood against hostile environmental conditions. However, none of these techniques provide a guarantee to safe the pastoral resources from drought induced risks.

Table 8: Households' knowledge about agricultural Insurance as risk management tools

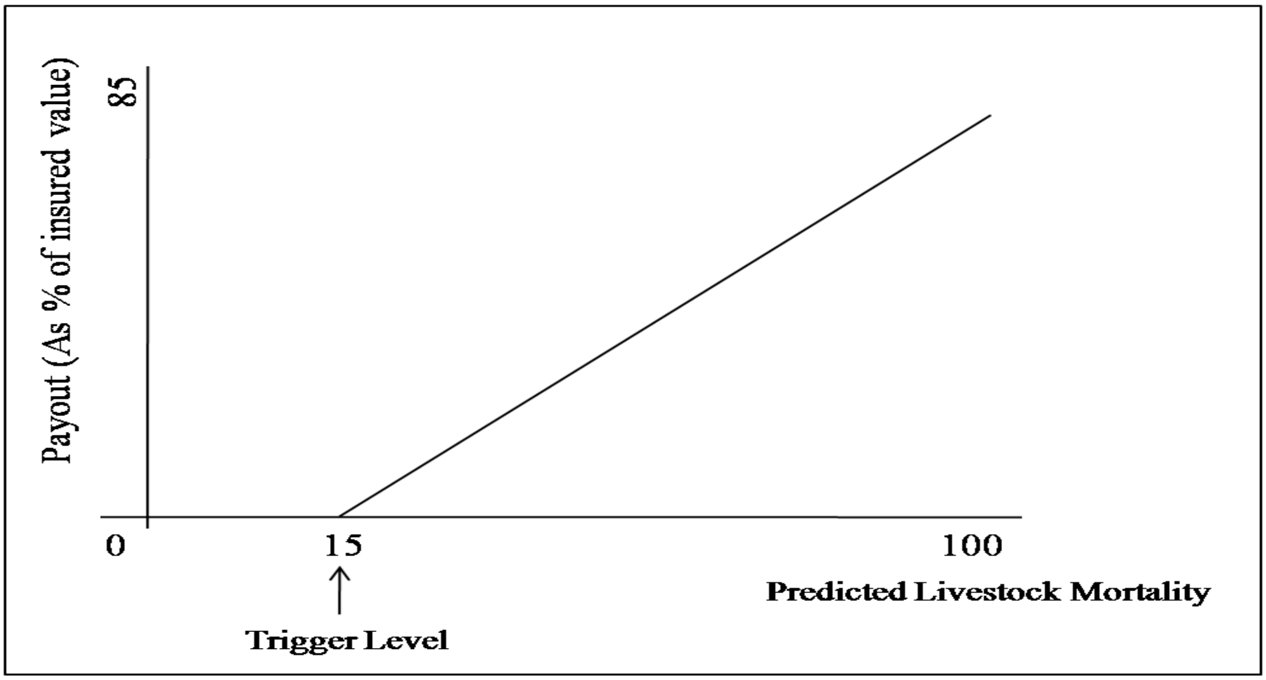
Items	Borana (n=116)	Guji (n=107)	Total (N=223)
Have little knowledge about insurance	32.76	29.91	31.39
Have ever heard about crop insurance	10.34	8.41	9.41
Have ever used crop insurance	0.00	0.00	0.00
Have ever heard about livestock insurance	2.59	0.09	1.79
Have ever used livestock insurance	0.00	0.00	0.00
Indigenous Social Insurances	81.03	90.65	85.65

Source: Household Survey, 2012

Therefore, innovative ways of insuring the pastoral households were designed in different parts of the world. For instance, the Index based livestock insurance is designed for the first time in northern Kenya and this technology is required to be replicated in southern Ethiopia. As the aim of this study was to test the applicability of insurance as a risk transfer approach, analysis of the understanding and perception of households was made.

Therefore, since the majority of the households have minimum understanding about IBLI, fully informing the pastoralists about the costs and benefits of IBLI is very important. As our study reveals the respondents have bare understanding even about agricultural insurance in general let alone IBLI. This remains part of the capacity building process of all stakeholders involved in IBLI including the Oromia Insurance Share Company, local, national or international NGOs/organizations promoting IBLI like ILRI should focus on awareness creation, training and informing the pastoralists to make use of the service.

In order to obtain pastoralists' opinion on insurance terms and conditions, during the experimental study in Guji and Borana zones of southern Ethiopia, the concept of IBLI was contextualized for pastoralists in the study area. Three main factors that determine the terms and conditions of the IBLI service including i) insurance trigger level (the insurance activation level of NDVI figure) which correlates with livestock mortality rate in the study area, the amount of indemnity (pre-agreed amount to be paid for each livestock loss due to drought per TLU)which trades-off with insurance triggering rate and the amount of insurance price or premium (which is determined by the insurer's /reinsurer's breakeven point of operation) were explained to the pastoralists in terms of how much livestock they can sacrifice to insure one TLU. Accordingly, they were convinced that the sell of one TLU can help the pastoralists to insure about nine to ten TLU units. As per the current pricing system of IBLI set at the Oromia Insurance Share Company, it is explained to the pastoralists that ETB 499 is the premium for insuring one TLU and this is the insurance contractual value of Oromia Insurance Share Company which was reached on consensus after taking many factors into account. This means a pastoral household who have ten TLU can sell one TLU unit for say, ETB 5000 , and buy 5000/499 = 10 insurance contracts for ten TLU units). This price can vary based on the severity of drought and level of insurance coverage as per the demand of the pastoralists through time. The diagram indicated below presents how pastoralists in our study have become convinced on their different opinions about IBLI.



As indicated in the figure above, Chantarat et al 2009 proved with their study that 15% is a reasonable level for triggering livestock insurance in Eastern Africa. Thus, as the NDVI reading goes beyond 15%, two factors (predicted livestock mortality rate and the consequent premium as well as insurance payment (indemnity) by the insurer) increases.

This concept can also help us to understand how large enough insurance contracts to make a breakeven point of operation for the insurer. This requires full understanding on the philosophy of IBLI. Basically it transfer risks from local to international reinsures like SWISS RE and BASIS, thus an insurance company in Ethiopia will not bankrupt unless and other wise livestock mortality in the range of indemnification is severe in all Asia like Mongolia and India and in Africa as well. Risk sharing is stretched overall the globe in IBLI approach.

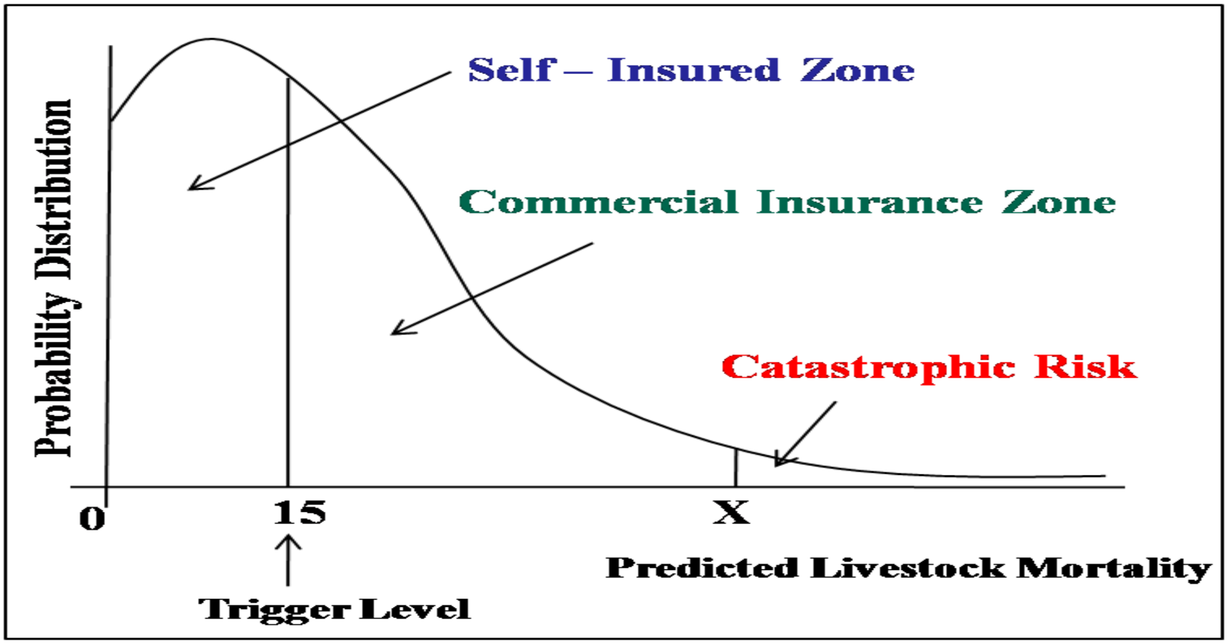
Pastoralists impression about the price of IBLI

As indicated in the above discussions, the IBLI is a non-marketed product in the study area. In such cases when a product is not marketed, getting the customers impression on price requires to distinguish between ‘observed’ and ‘hypothetical’ methods of pricing, which are more preferably common to be referred as revealed preference methods and stated preference methods. In IBLI study, we understood that revealed preference approach which uses information about a marketed commodity to infer the value of a related non-marketed commodity was not applicable.

Hence, the impression of the pastoralists about the price was assessed using the stated preference method which uses a direct approach to elicit willingness to pay. Our techniques for estimating values using stated preference methods involved asking the pastoralists directly about the values they place on IBLI services by creating, in effect, a hypothetical market. Respondents expressed their willingness to pay if the IBLI market can be existed for them. Specifically, among the frequently used methods of stated preferences, the study used the Contingent Valuation Method (CVM). The decision to pay for IBLI which reflects the pastoralists impression about the price was measured using their willingness to pay (WTP) or willingness to accept (WTA). As willingness and ability determines demand which is also determined by the price, pastoralists were willing to pay and able to pay, thus, their impression for the fair price was normal.

Demand for the product was also independently determined because IBLI expected to be self-standing and commercially sustainable product rather than a subsidized risk mitigation tool which may be conjugated with macro-scale disaster prevention schemes in an economy. Thus, the possibility of linking the payment for IBLI service with productive safety net programs (PSNP) was kept aside in this study. This is an important element in the design of IBLI product that might limit its long term commercial substantiality. However, practically the IBLI pricing system is conjugated with macro-scale disaster prevention mechanisms in which donors and humanitarian agencies working on provision of social protections or safety nets are expected to subsidize or cover the full cost of IBLI on behalf of the pastoralists. For instance, IBLI Marsabit was designed to complement a Hunger Safety Net Program (HSNP) that the government of Kenya has launched in the area using funds from different humanitarian agencies. The question of commercial sustainability arises from the fact that given the erratic nature of donor-driven funds and phase-out intervention approaches of humanitarian agencies, such pricing and valuation system significantly limits self-standing potential and viability of the product in the insurance industry. Thus, the current study puts IBLI as a non-traded commodity in Ethiopia and assesses its demand, customers’ willingness and ability to pay using appropriate tools.

However, it is important to understand that based on the level insurance activation (triggering level), there are three scenarios below the trigger level in which self-insurance is made, between the triggering level and the pre-agreed rate which can be detrained from the severity of drought (commercial insurance zone) and catastrophic zone.



Therefore, as indicated in the above diagram, the catastrophic zone is the scenario in which the efforts of humanitarian agencies like safety net provision can be made. In one way or another we are making the insurance service to be self-standing and the pastoralists to be rational decision makers.

Probit Model results of insurance market participation decisions of households

Households' market participation decisions reflect their demand for and willingness to pay for the insurance service. The result of the maximum likelihood estimation of determinants of the households' willingness to pay (WTP) for IBLI using Probit model is presented in table 9. As can be seen from the table, five of the eleven socioeconomic variables in the model including, age of the household head (AGE/AGE^2), agricultural land availability (LNDHOLD), livestock size (TLU), education level of the household head (EDUCA) and family size (FAMSIZE) were significantly related to the probability of the willingness to pay for IBLI of the households. Location of the household being in Borana or Guji is also statistically significant. Most of the climate risk related factors including climate perception (CLIPERC), ambiguity aversion (AMB_AVERS), households' expectation of future losses (LOSSEXPECT), the composition of herd (TLU_COMPO) and risk aversion behavior were significant in affecting the households' WTP for the IBLI service. From the institutional factors distance from the market (DISTMKT), households' experience in using financial services (FINUSE) and access to credit services (CRDIT) were significant in affecting households' participation decision in the insurance market as revealed by their WTP for the service. These variables are explained as follows.

Age of the household head (AGE/AGE^2): As indicated in table 9 above, the result of the probit model showed that age or age square of the household head has a negative and significant influence on the probability of the willingness of the households to pay for IBLI service. The result implies that as a person becomes aged, his/her interest to pay for the IBLI will decline. This might be because aged people or farmers at later age lack labour and money and restrict their expenditures especially of those which have long-run impact. The marginal effect result shows that holding other variables in the model constant, for each additional increase in age of the household head, the probability of his/her willingness to pay for the IBLI service will decrease by 0.22%.

Table 9: Probit estimates of determinants of pastoral households' WTP for IBLI

Variables	**Coefficients**	**Z**	**Marginal Effect**
AGE/AGE^2	-0.0487	-1.9468**	-0.0022
GENDER	-0.5947	-0.1742	-0.0740
LNDHOLD	0.4238	2.65**	0.1684
SOCICAPTL	0.5102	0.4074	0.0186
TLU	0.7614	3.2445***	0.2342
MANEQ	0.0744	0.864	0.0248
NON_FARM	0.0002	1.6248	0.0006
TOTLINCM	0.5323	4.0284	0.0438
CRMEXPNS	-0.0210	-3.11	-0.0040
DEPRATIO	-0.8231	1.0418	0.0329
EDUCA	0.0467	1.34**	0.0168
FAMSIZE	-0.5473	-2.87**	-0.0231
AMB_AVERS	-0.5687	-2.1014**	-0.0963
CLIMTTPRCV	0.1568	0.3602	0.6118
LOSSEXPECT	0.5432	0.1850	0.0743
TLU_COMPO	-0.4328	-4.3112	-0.4542
RISK_AVERS	-0.7852	-1.3792**	-0.0483
LOCATION	-0.2451	-1.3412	-0.3512
DISTMKT	0.3528	3.98***.	0.0043
EXT_CTCT	0.0437	2.1404	0.3727
CRDIT	8.7463	4.2384***	0.0943
AWARENESS	0.4002	0.1307	0.0408
FINUSE	2.6289	2.1308**	0.0865
INTERRATE	-0.2674	-3.3112	-0.1425
TRAINING	0.7689	0.8174	0.0644
_cons	4.8634	2.41**	

Number of observations = 223
Log likelihood = -18.6428
LR chi^2(25)= 74.2871
Prob > chi^2= 0.0000
Pseudo R^2= 0.6728

***, ** and * represent significance at 1%, 5% and 10% probability levels, respectively
Source: Survey results, 2012

Family size (FAMSIZE): The number of household members living under the same roof has been found to be negatively and significantly related to the probability of the willingness of households to pay for the IBLI supplied by the scheme. Obviously, with increase in household size, consumption and other household expenditures will increase. This might be true in the area as most of the family members are staying home, no alternative employment opportunities while few of them were moving with livestock. The results of the marginal effect shows that when the family size of a households increase by one, it will decrease the probability of willingness of the household to pay for the IBLI provided to them by 2.31%, *ceteris paribus*.

Credit service (CRDIT): The result of the model showed that access to credit is positively and significantly related to the probability of willingness to pay decision of a household head for IBLI service. The probable reason for this might be that farmers who have got access to credit used to solve their liquidity problems and continue to produce without much trouble. As this would enhance their economic benefits, households would be interested to pay for insurance to secure their livestock. This would make them more willing than the non-credit users. The marginal effect result shows that the probability of a credit user household to be willing to pay for IBLI is about 9.43% more than non-credit user, keeping other factors constant.

Households' Climate Perception (CLIMTTPRCV): The model result has also revealed that perception of the respondent households about the changing climate scenarios in the future is positively and significantly related to the probability of their willingness to pay. The reason is straight forward as farmers perceive the existence of severe climate scenarios in the future; there would be a threat of livestock production loss due to the problem. This pushes farmers to seek a sustainable solution in which self financing capacity of the scheme could appear the better option. The marginal effect of the result shows that the probability of willingness to pay for IBLI service for household who perceived future climatic conditions to be severe is higher by 61.18% than those who did not foresee and perceive the problem, *ceteris paribus*.

Land holding (LNDHOLD): The availability of agricultural land for respondents was positively and significantly related to the probability of the willingness to pay. This indicates that respondents who have higher total landholding are less willing to pay for IBLI. The marginal effect results show that as the size of land ratio increases by one hectare, the probability of the household head to be willing to pay for IBLI will decrease by 16. 84%, *ceteris paribus*.

Interval Regression results of determinants of intensity of cash payment for IBLI Service

As indicated above, the econometric model results of the interval regression model on the magnitude of cash that a household is willing to pay showed that the intensity of cash payment as the indicator of stated demand is found to be determined by ambiguity aversion, awareness, climate change perception, credit, the amount of expense they expend on ceremonial activities, distance from the market, family size, their financial service use experience, land holding, loss expectation, risk aversion and number of livestock that the households have. These results were indicated in table below.

Table 10: Interval regression model estimates of the magnitude (intensity) of premium payment

Variables	**Coefficients**	**Z**	**Marginal Effect**
AMB_AVERS	-86.8743	-1.9814**	-86.8743
AWARENESS	152.345	4.2384***	152.345
CLIPERC	67.1568	0.3602**	67.1568
CRDIT	88.7463	2.0384**	88.7463
CRMEXPNS	-56.4532	-2.11**	-56.4532
DEPRATIO	-42.8231	-1.3418	-42.8231
DISTMKT	36.3528	4.918***.	36.3528
EDUCA	64.5938	2.0261**	64.5938
EXT_CTCT	33.4295	1.9400	33.4295
FAMSIZE	132.4869	-2.6419**	132.4869
FINUSE	67.6530	1.8689**	67.6530
GENDER	41.3462	-0.2659	41.3462
INTERRATE	48.7641	-2.7340	48.7641
LNDHOLD	78.2965	2.7842**	78.2965
LOCATION	-60.8411	-1.7502	-60.8411
LOSSEXPECT	231.5672	0.1850**	231.5672
MANEQ	17.7654	0.56444	17.7654
NON_FARM	178.1456	1.5983	178.1456
RISK_AVERS	-48.9876	-1.8651**	-48.9876
SOCICAPTL	151.6084	0.7689	151.6084
TLU_COMPO	-179.6589	-3.4320	-179.6589
TLUHOLD	245.1359	3.9821**	245.1359
TOTLINCM	0.1789	1.0543	0.1789
TRAINING	108.8941	0.5730	108.8941
_cons	4.8634	2.41**	4.8634

Log likelihood = -321.4758

LR $chi^2(17)=27.3104$

Prob > $chi^2=0.04184$

Observation summary:	32	uncensored observations
	17	left-censored observations
	11	right-censored observations
	163	interval observations

***, ** and * represent significance at 1%, 5% and 10% probability levels, respectively
Source: Survey results, 2012

Institutionalization of IBLI in the study area

The common problem of innovative anti-poverty interventions is designing a one-fit-all design for institutionalization and implementation when the socio-economic setups and contexts vary. This study gives a greater emphasis on institutionalization and implementation aspects of IBLI in Ethiopia. To ensure this, the study will design an innovative insurance for pastoralists with livelihood-focused and demand-driven service, which offers optimal contractual structure that minimizes potential basis risk, sustainable demand and effective WTP, most effective risk transfer mechanism and which complements the currently prevailing social protection and risk management strategies in pastoral areas like productive safety net programs. Effective institutionalization requires demand development and feasibility analysis based on the available institutions, infrastructure and livelihood options taking into account the cross-cutting issues including gender. In the following section, analysis of facilitating institutions, infrastructure and livelihood option which makes the conditions for implementation of IBLI both effective and sustainable will be presented.

Institutions: Institutions are the "rules of the game", consisting of both the formal legal rules and the informal social norms that govern individual behavior and structure social interactions (institutional frameworks). As far as effective implementation of IBLI is concerned, both formal and informal social institutions were considered. In both Borana and Guji pastoralist areas included in this study, households have different degree of involvement in different institutions as shown in table 11 below.

Table 11: Sample households by proportion of their participation in social institutions

Items	**Borana (n=116)**	**Guji (n=107)**	**Total (N=223)**
Membership in *iddir*	84.37	75.40	81.70
Membership in *iqquib*	11.00	9.00	10.20
Membership in *busaa gonofaa*	0.02	0.01	0.015
Membership in funeral	1.50	2.34	2.47
Membership in MFI	2.00	7.00	5.40
Membership in Coops	0.02	0.13	0.08

Source: Household Survey, 2012

Similarly, as indicated in table 12below, respondents have shortage of access to different infrastructure in the study area.

Table 12: Proportion of households by their access to infrastructure

Items	Boran (n=116)	Guji (n=107)	Total (N=223)
Infrastructure			
Roads within 8 km (3 hours walk)	11.03	19.06	10.72
Credit Centers within 8 km (3 hours walk)	18.79	14.61	16.54
Tele center within 8 km (3 hours walk)	17.07	10.65	18.79
Market center within 8 km (3 hours walk)	12.59	11.68	16.95
Veterinary within 8 km (3 hours walk)	17.76	10.84	14.84
Public health center within 8 km (3 hours walk)	13.97	15.33	14.61
Electrified towns within 8 km (3 hours walk)	17.07	16.91	17.00
Water Points			
Natural river within 8 km (3 hours walk)	17.93	13.18	12.06
Bore well within 8 km (3 hours walk)	11.03	11.96	16.68
Water points within 8 km (3 hours walk)	16.90	13.27	15.16
Overhead tanks within 8 km (3 hours walk)	19.12	11.12	15.29

Source: Household Survey, 2012

As indicated above, the study area has acute problem in terms of infrastructural development. The majority of the households were unable to access basic infrastructure including roads, credit facility, market center, public health center, veterinary and extension services as well as water points within 8 Kms or about three hours walk on foot. These factors were expected to potentially affect the effectiveness of the IBLI service in the area.

GIBLVI: Innovative Institutionalization of IBLI

In this study, attempt were made for integration of gender and value chain approaches in livestock insurance system as this is evidenced to be the most effective way of implementing the index-based livestock (IBLI) which the study has indicated to have an adequate demand in the study area. The analytical framework followed in this model is a sort of designing livestock value chain enterprises (LIVE), imbedding IBLI in the major elements of the chain and integrating gender in the chain system. This approach is demanded in response to the recent research agenda of the smallholder in which the importance of gender integration for agricultural development is addressed on the one hand and the value chain approach for development and transformation is proved to be effective on the other.

Livestock Enterprise (LIVE) Analysis

In Borana and Guji pastoral communities, women play multiple and distinct roles throughout in the livestock sector including sourcing inputs, production, marketing, processing, storing and consumption. Recognizing and enhancing these roles is critical for meeting the food needs of current and future populations, and ensuring productivity increases emanating from shared roles. In this regard, the current study has undertaken analysis of integration of IBLI in traditional livestock value chain enterprises (T-LIVE), cooperative livestock value chain enterprises (C-LIVE) and gender sensitive livestock value chain enterprises (G-LIVE) which is collectively known as traditional, cooperative and gender sensitive livestock value chain enterprises – TCG LIVE – development. In the following paragraph, the results of the integration of these analyses will be presented.

TCG-LIVE Analysis: TCG-LIVE analysis is the analytical model considered in the current study. The model is centrally based on the development of livestock value chain enterprises which are linked with IBLI services. The model serves the primary purpose of innovations in livestock sector as a systematic way of shifting nomadic nature of the pastoral community's livelihood into diversified livelihood style based on alternative income generating activities. Both the traditional and cooperative livestock systems were considered as enterprises in which household level livestock sector is considered as household livestock enterprise. The integration of IBLI service, thus, follows the dual mode approach in which both the traditional and cooperative livestock enterprises can be insured. The TCG-LIVE analysis has three components including T-LIVE, C-LIVE and G-LIVE as explained below.

T-LIVE Insurance: This component of the model imbeds IBLI in the traditional livestock value chain. In this system those pastoral households which may not be registered as members of the livestock enterprise can acquire and use the insurance service. The presence of this component helps pastoralists to practice their traditional livestock management systems thereby combining their indigenous knowledge with insurance innovations. For instance, about 78% of the sample households were not registered in livestock enterprises yet.

But, more than 84% of them were interested in using the index based livestock insurance. With regard to their participation in cooperatives for higher and sustainable market for IBLI, these households have shown their consent that they can be actors in TCG-LIVE through both purchasing IBLI and selling their livestock and livestock products to the cooperatives.

C-LIVE Insurance: Under-developed markets, poor understanding of the benefits of value adds/chains, poor organization and the absence of collective action and bargaining capacity were identified as the basic problems of African pastoralists. Thus, the other important component of the TCG-LIVE is the cooperative enterprises. Effective implementation of the IBLI requires organization of cooperative enterprises in the livestock sector. As the above conceptual model of analysis indicates, this study has developed three cooperative actor units.
Livestock Feed Producing Cooperatives: to supply livestock feed for the cooperative farm. Input producer produce livestock forage from locally available and environmentally friend green.

Cooperative farm Enterprises: this farm keeps livestock meant for meat and milk production. The farm will be engaged in dairy and fattening. To be member of the enterprise pastoralist contribute in kind. The contribution can be cattle, goat, camel and poultry whose TLU determined at the point of entry.

*Livestock processing cooperative***:** these can be pastoralist who can be better organized for processing and marketing services due to their capacity (labor and technically fit for marketing) but have no adequate livestock asset due to drought; new graduate, newly married couples with no adequate livestock and will be gender balanced**.** These are members that accept livestock products and avert them value adding activities. These activities include accept milk, meat, eggs from other farmers which are members and non- members, process, packs or export livestock products for higher values, Selling raw milk, meet ,eggs and chicken for customer contracted in advance(for instance, Alefora and other livestock exporting) and non-contracted customer(e.g. Private users or traders)

Food processing cooperative: to meet the nutritional and food security needs of member. These are petty restaurant or small hotel composed of women self help groups producing food items using animal products and sell milk, tea, makiato etc.

Gender-centrism (G-LIVE)

By integrating gender, the study aims at analysis of how to introduce fair and equitable livestock value chain insurance system that takes into account the interest of all actors in the livestock sector. Thus, insurance is the part of the sustainable livestock production and marketing technologies which makes the chain an efficient, effective and sustainable.

Summary of the findings, conclusion and recommendation

Summary and conclusion

The risk of climate change induced drought causing rampant livestock mortality requires innovative risk management strategies to protect the economic loss of the smallholders whose adaptive capacity is very low. This study was aimed at analysis of how climate change systematically affects the pastoral economy, the degree of households' understanding about climate change, their perceived consequences and impacts together with the households' indigenous coping strategies to climate risk in order to design and test the commercial feasibility and institutional effectiveness of index-based livestock insurance as a pro-poor risk management strategy.

It is evident from the results of the study that climate change largely causes recurrent drought and rampant livestock mortality in pastoralist areas. A large number of the respondent households have perceived the pattern of climate change in terms of long-period dry season without rain, irregularity in rainy season, decrease in rainfall intensity, untimely rain and/flooding, dry wind, severe drought and lack of precipitation. Such patterns were revealed to cause adverse consequences on the livelihoods of the households causing, among many others, scarcity of water, degradation in pasture land and forage unavailability. In the agro-pastoral Guji Zone which has a relatively better rainfall and precipitation intensity, the adverse consequence of the climate change was manifested in terms of the emergency of unpalatable grass species in the study area.

It was also evidenced that the changing climate was a long-term phenomena leading to various socio-economic impacts as perceived by the respondent households. The majority of the respondent households have perceived weakened carrying capacity of land biomass to feed livestock, physical deterioration of livestock and overall asset depletion while some of them additionally indicated decrease in breeding cycle of their livestock as an impact of the climate change on their economy. The adverse economic impacts were indicated to cause social impacts like pastoralists' migration to other areas, children school leaving, loss of family and dissolution of social capital and emergency of conflict on range resources.

In general the analyses have indicated that livestock is highly threatened by adverse weather conditions as a result of changing climate in the study area. Pastoral households have experienced livestock and livestock product losses due to rampant herd die-offs. The large number of livestock that the households often lost due to drought induced livestock mortality in the face changing climate over decades were indicated. Based on their recall and substantiating it with the secondary data sources, the study has identified 80–90% deaths and decline of livestock from the existing stock per year.

This is critical analysis that provides an important input for the design of insurance in the study area. From the perspective of livestock insurance as a risk management tool for pastoral households, it is important to focus on the degree at which drought as an adverse consequences of climate change contributes to the rampant herd mortality that pastoralists rank as the most important factor threatening their livelihood. However, before the design, demand and commercial sustainability of the innovative insurance, index-based livestock insurance (IBLI), was undertaken, the study exhaustively explained the indigenous climate risk adaptation techniques of the households. Accordingly, climate change has caused immediate consequences and long-term impacts on livelihood of the pastoralists. Livestock is the main sources of livelihood in terms of consumption, food security and income generation were being threatened by these adverse consequences of the changing climate resulting in high mortality rates.

However, before we discuss about technological innovations for adaptations, it is logical to understand the pastoralists' indigenous adaptation techniques. Generally, the study identified two main categories of adaptation strategies that pastoralists have underwent. The first strategy is adaptation to climate change risks which include weather-related risk prediction and adaptation, adaptation to risks associated with livestock, mitigation of risks related to range and water resources. Secondly, pastoralists have undertaken livelihood diversification as a strategy for risk mitigation under changing climate conditions. Households mainly use indigenous climate forecasting techniques like the *gada cycle*, probabilistic forecasts and awareness through access to external information to manage weather related risks. Similarly, households use herd mobility which is maintained to ensure that herds can find pasturelands not decimated by drought, rotational and selective grazing in which certain traditional communal grazing areas were restricted not to be utilized for a season to provide extra nourishment for sick, young and lactating animals in times of scarcity, preferential animal health treatments through which sick animals are isolated from healthy animals to prevent the spread of disease and animal injuries and diseases were treated using local knowledge.

In addition to these practices, as indicated above a strong social welfare system has developed to ensure that all pastoral households can continue to herd livestock. For example, Boran pastoralists reported that households with more than five cattle can be called on to redistribute cattle to those who have sustained severe losses, as part of the social welfare system called *busa gonafa.* The primary means by which pastoralists, like communities everywhere, will feel the impacts of climate change is in changes in land and water resources. The Borana and Guji pastoralists have been living with scarce pastureland and water for generations. A number of rangeland-related risk-mitigation measures including traditional systems of wet/dry grazing areas and bush clearing programs have been undertaken by Borana and Guji pastoralists communities, as well as initiated by the government and NGOs. Many of these measures have been in use for at least decades, and were developed in response to local climatic fluctuations without specifically being in response to recent climate change. However, these measures may still be relevant in conjunction with other, more “modern”, methods as responses to climate change, and are mentioned here. The most innovative device to insure the risks of livestock mortality that recently attracted the attention of many stakeholders in livestock sector is the Index Based Livestock Insurance (IBLI). Index-Based Livestock Insurance (IBLI) provides indemnity for managing livestock asset mortality risk by compensating for location averaged livestock mortality estimated using remotely sensed measures of vegetative cover on range lands. And our analysis has indicated that livestock are the most important assets in terms of income generation and consumption for pastoral households in both zones. Herd mortality due to climate change is also indicated to be significantly large. As it is logically important to identify the parameter and empirics of most important cause for such mortality so that innovative ways of handling this mortality causes would keep in pace a sustainable morbidity of the livestock sector in the pastoralists’ economy, starvation due to drought which is caused by lack of pasture resources and water was found to be the largest cause of livestock mortality, followed by diseases and predation. On top of this, disease and predation as indicated by the respondents were aggravated during seasons of drought and immediately after drought which indicates these are also the most likely consequences of the climate change. Hence, the potential for weather index-based livestock insurance is large and adopting this technology is very important as it indemnifies herd losses due to climate change which is the main driver of the mortality.

As indicated in the above discussions, pastoral households have been using different adaptation mechanisms to protect their livelihood against hostile environmental conditions. However, none of these techniques provide a guarantee to safe the pastoral resources from drought induced risks. Therefore, innovative ways of insuring the pastoral households were designed in different parts of the world. For instance, the Index based livestock insurance is designed for the first time in northern Kenya and this technology is required to be replicated in southern Ethiopia. As the aim of this study was to test the applicability of insurance as a risk transfer approach, analysis of the understanding and perception of households was made. The summary of these responses were given below. The methodological approaches involved in this study include framing the analysis using theoretical models and undertaking the analysis using empirical models. The analytical framework combines conceptualization of herd mortality from herd mortality from differentials of the vegetation cover which constitutes livestock forage, estimation of insurance indemnity and premium based on the expected estimated livestock losses. The framework conceptualizes the demand and willingness to pay for the insurance. The empirical models were fitted to the data based on the objectives of the study. Accordingly, both descriptive statistics and econometric tools were used to analyze the data.

Households' market participation decisions reflect their demand for and willingness to pay for the insurance service. The result of the maximum likelihood estimation of determinants of the households' willingness to pay (WTP) for IBLI using probit model indicated that five of the eleven socioeconomic variables in the model including, age of the household head, agricultural land availability, livestock size, education level of the household head and family size were significantly related to the probability of the willingness to pay for IBLI of the households. Location of the household being in Borana or Guji is also statistically significant. Most of the climate risk related factors including climate perception, ambiguity aversion, households' expectation of future losses, the composition of herd and risk aversion behavior were significant in affecting the households' WTP for the IBLI service. From the institutional factors distance from the market, households' experience in using financial services and access to credit services were significant in affecting households' participation decision in the insurance market as revealed by their WTP for the service. Similarly, the intensity of cash payment as the indicator of stated demand is found to be determined by ambiguity aversion, awareness, climate change perception, credit, the amount of expense they expend on ceremonial activities, distance from the market, family size, their financial service use experience, land holding, loss expectation, risk aversion and number of livestock that the households have.

Institutionalization and operation of the IBLI was found to be the most important step. To this effect, membership in *iddir, iqquib, busaa gonofaa,* funeral associations, MFI and cooperatives were found to be effective. However, the infrastructure base is found to be very poor. In this study, attempt were made for integration of gender and value chain approaches in livestock insurance system as this is evidenced to be the most effective way of implementing the index-based livestock (IBLI) which the study has indicated to have an adequate demand in the study area.

The analytical framework followed in this model is a sort of designing livestock value chain enterprises (LIVE), imbedding IBLI in the major elements of the chain and integrating gender in the chain system. This approach is demanded in response the recent research agenda of the smallholder in which the importance of gender integration for agricultural development is addressed on the one hand and the value chain approach for development and transformation is proved to be effective on the other.

In Borana and Guji pastoral communities, women play multiple and distinct roles throughout in the livestock sector including sourcing inputs, production, marketing, processing, storing and consumption. Recognizing and enhancing these roles is critical for meeting the food needs of current and future populations, and ensuring productivity increases emanating from shared roles. In this regard, the current study has undertaken analysis of integration of IBLI in traditional livestock value chain enterprises (T-LIVE), cooperative livestock value chain enterprises (C-LIVE) and gender sensitive livestock value chain enterprises (G-LIVE) which is collectively known as traditional, cooperative and gender sensitive livestock value chain enterprises – TCG LIVE – development. In the following paragraph, the results of the integration of these analyses will be presented. By integrating gender, the study aims at analysis of how to introduce fair and equitable livestock value chain insurance system that takes into account the interest of all actors in the livestock sector. Thus, insurance is the part of the sustainable livestock production and marketing technologies which makes the chain an efficient, effective and sustainable. In general the following strategies were identified to be important to integrate gender in the integrated TCG-LIVE analysis.

Gender analysis is undertaken before implementation of the project. These include gender issues with respect to social relations (how 'male' and 'female' are defined in that context; their normative roles, duties, responsibilities); activities (who do what?); access and control over resources, services, institutions of decision-making and networks of power and authority; and needs, the distinct needs of men and women(both practical and strategic). Most importantly, gender issues relate to livestock production, processing, marketing and impact of gender specific need in livestock activities on nutrition and availability of dietary animal protein will be identified and gender integration strategy of the project will be designed accordingly.

In general, the Borana and Guji pastoralist of southern Ethiopia have perceived the impact of climate variability changing from long to short period rain, from regular and stable to irregular, pattern less, untimely raining and flooding, decreased intensity of rainfall, drought and minimized precipitation over periods in the past. Both pastoralist groups argue that the overall asset depletion and economic value losses were large over the past years which were attributable to the changing climatic scenario. Hence, these households opt for insurance and any other innovative intervention which makes them overcome the problem livestock and asset losses in their area. Even though the role that the livestock sector plays in pastoral or pastoral/agro-pastoral system is obviously significant, it is important to determine the component of pastoralists' income by sources in order to understand the associated economic losses with livestock mortality. In other way, this helps us to value insuring the livestock based on the economic value of the livestock.

Policy Recommendations

Based on the results of the study the possible policy recommendations that emanate from this study are presented as follows.

i. Climate change induced drought is proved to be the main cause for rampant livestock mortality in Borana and Guji pastoral and agro-pastoral areas of southern Ethiopia. Households have experienced both short-term consequences and long-term impacts of the problem reflected on their economic loss. Hence, policy makers in livestock sector should promote climate risk management strategies in pastoral areas to sustain the livestock sector. All stakeholders including government and non-government organizations (NGOs) working with pastoralists groups should value climate risk management and innovative adaptation techniques in planning their pro-poor interventions.

ii. Indigenous techniques of predicting the fate and effect of climate change were evidenced to be prevalent for long among the pastoralist in the study area. pastoralists' value for the *gada system* in which factors aggravating the adverse impacts of the climate change like overgrazing and deforestation are banned as well as social insurance mechanisms like *buusa gonofaa* were found to be the most local adaptation techniques to the climate change. Hence, policy makers should build on the traditional and adaptation techniques to the climate change in order to design innovative climate risk management strategies.

iii. The feasibility of index-based livestock insurance (IBLI) to manage livestock asset risk by compensating for location average livestock mortality estimated using remotely sensed measures of vegetative cover on the pastoralists' grazing land is tested by the existing ample demand and willingness to pay (WTP). Hence, policy making in the area of developing sustainable livestock insurance should be based on the tested and verified demand for the product. IBLI should also be adopted as a pro-poor risk management strategy which is innovative and persuasive as it easily overcomes the twin problems of information asymmetry including adverse selection and moral hazard.

iv. In developing the demand for IBLI, policy makers should take into account, the age of the household head, agricultural land availability, livestock size, education level of the household head and family size. IBLI policy should be set for location specific purposes. For instance, the Borana and Guji insurance package should be different in terms of product attribute. Training and financial literacy should be provided for pastoral and agro-pastoral households to enhance their indigenous knowledge about their climate risk perception and minimize their ambiguity and risk aversion behaviors, and encourage them to undertake calculated risks future losses within a given domain of expectation. Similarly, the intensity of cash payment as the indicator of stated demand is found to be determined by Ambiguity Aversion, awareness, Climate change perception, credit, the amount of expense they expend on ceremonial activities, distance from the market, family size, their financial service use experience, land holding, loss expectation, risk aversion and number of livestock that the households have.

v. Basically the pastoral development policy should be geared towards enhancing pastoral household enterprise and livestock cooperative enterprises to easily cope with both man-made like market price volatility and natural like drought induced livestock mortality risks. Policy should promote diversification of herd composition towards drought resistant stocks like shoats, camel and Guji cattle variety in the household enterprise but the Boran variety in cooperative livestock enterprises.

vi. Institutionalization and implementation of effective and sustainable insurance industry should be promoted based on the existing social institutions including *iddir*, *iquib* and *buusaa gonofa*. Institutional factors including, households' experience in using financial services and access to credit services households' and development of the infrastructure base in pastoral areas should be promoted to increase the households' market participation in the insurance industry.

vii. Livestock value chain development and gender sensitivity in pastoral development requires a great policy attention. As farming land is scarce or non-existent in pastoral areas and undue reliance on a single livestock sector is risky in the face of increasing families, diversification towards alternative income generating activities should be promoted. Agencies working with pastoral communities should give due attention to the diversification of income by expanding non-farm activities. The expansions of non-farm activities with diversified business plan will hedge smallholders' against natural calamities.

viii. It is important that more attention be given to the livestock sector through improved feeding and management, breeding and animal health care. Consequently, strengthening and establishing sustainable value chain for animal and animal products marketing should be given due attention by policy makers and rural development practitioners to improve the production and productivity of the livestock sector.

ix. Income from crop production is paramount for the farming community in Guji Zone since the sector contributes significant percentage of revenue for smallholder households besides being source of food for consumption. Hence, crop production especially high value crops through irrigation should be given due attention by development practitioners and policy makers by strengthening and establishing sustainable supply chain for inputs and value chain for agricultural products marketing.

x. Finally, agencies working to improve the living standard of the pastoral community and policy makers should give due attention to female borrowers, family planning and reduction of spending on social ceremonies and a need to determine an appropriate risk management strategy like insurance that just suffices the insurance cost or purpose of the hedging, through a thorough investigation of the demand for insurance and reinsurance in which the insurance industry operates optimally both in the local, national and international reinsurers' market.

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3. College of Education and Behavioral Sciences

Adjustment Problems and Coping Strategies: Their Impact on Academic Achievement and Self-Esteem of First Year Students in Dire Dawa, Haramaya, and Jijiga Universities

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Abstract: *This study was aimed to investigate adjustment problems and coping efforts among first year undergraduate students in Haramaya, Dire Dawa and Jijiga Universities and the impact of these variables on academic achievement and self-esteem of selected students. 509 first year students selected by stratified random sampling techniques from the three universities were participated in the study. The study employed a survey and correlation design and data was analyzed using descriptive and inferential statistics to address the research objectives. Findings from this study showed that the students experienced stress at a moderate level with academic adjustment problem being the highest followed by social and personal adjustment in the Universities. Moreover, the correlation result indicated that there is positive relationship between coping strategies of Acceptance of responsibility and planful problem solving and self-esteem. The coping strategies regressed together significantly predicted the academic achievement of students. The correlation coefficient result of the study assured that there was a negative relationship between self-esteem and coping techniques. Moreover, male students experienced more academic adjustment problems than female students.In addition, the study indicated that students prefer to use emotional focused followed by problem focused coping strategies. The finding also assured that there was no significant mean difference between male and female students in escaping, acceptance and distancing coping strategies. But planful problem solving and social support was used more by male students than female students. The result of Regression Analysis also confirmed that academic, social, and personal emotional adjustments and coping strategies were significantly predicted the academic achievement of students. Lastly recommendations were forwarded to the university administration body, faculties and ministry of Education for further action in alleviating the challenges.*

Background of the Study

Attending university is supposed to be a very appealing experience that could give satisfaction to students. For many students, however, transition from secondary school to university is a stressful experience as they struggle to cope with an array of changing situations including: movement away from home, modifying existing relationship with parents and family members, changing peer group and establishing new friends, developing learning habits for new academic environment, struggling with exams and assignments, and coping with demandsand challenging professors (Hogan & Majeski, 2004). Failing to meet these demands and challenges appears to be the most common reason for first yearstudents withdrawing from university (Gerdes&Mllinckrodt, 2004). This requires the adoption of strategies specifically aimed towards coping with the changing situation.

Previous studies reveled that *adjustment difficulties* are found to be the most common problems among first year university students. A study conducted by Tinto (2006) showed that 40% of all students in America who started out in a four year college failed to earn a degree; and nearly 57% of all dropouts left before the start of their second year. Another study conducted by Wintre and Bowers (2007) on the persistence to graduate among 944 undergraduate students in a Canadian university reported that within six years, 57.9% of the students had graduated, 9% remained enrolled, and 33.1% were neither enrolled nor graduated.

According to Tinto (2006) seven major causes of first year students' withdrawal from university were academic difficulties, *adjustment difficulties*, uncertain, narrow, or new goals, weak and external commitments, financial inadequacies, incongruence between the students and the institution, and isolation.Moreover, based on the research conducted in a local public university in Malaysia, the *adjustment difficulties* faced by first year students were found to be academic problems, health problems, financial crisis as well as social and personal problems (Ahmad & Zailani, 2002).

The earliest definition of adjustment was given by Arkoff (2003) as a person's interaction with his or her environment. Arkoff (2003) further define university adjustment in termsof achievement which covered students' academic achievement and personal growth. In his approach, the adjusted student is the one who obtains adequate grades, passes in his or her courses and eventually graduates. Conversely, the maladjusted student is the one who demonstrates unsatisfactory grades, marginal level of performance in course work, or failing, and shows tendency in dropping out of university before graduation. Besides academic achievement, university adjustment also involves the idea of personal growth. An adjusted student is the one who will show good personal growth in terms of non-academic potential with reference to accomplishments outside of the classroom such as in co-curricular activities, creativity, and leadership.

Baker and Siryk (2006) suggested that there are four aspects of adjustment to university namely academic adjustment, social adjustment, personal-emotional adjustment, and institutional attachment. Studies have shown that adjustment among first year undergraduates has a strong impact on their academic achievement (Wintre& Bowers, 2007). Studies also have indicated that gender is a significant predictor of students' adjustment in university and male students are found to be better adjusted compared to the female students . Female students are found to demonstrate more adjustment problems such as establishing social relationships in campus compared to the male students. They are less involved in campus activities and have less opportunities to be appointed as leaders in clubs and societies in campus (Enochs& Roland, 2006).

Coping represents an individual's cognitive, affective and behavioral efforts to manage specific external and internal demands. Specifically, it can be defined as the conscious, rational way of dealing with the anxieties of life and is reflected in the self-protection strategies adopted by the individual (Kashden et al., 2006). Effective application of such strategies allows the individual to resolve problems, relieve emotional distress, and stay on track towards achieving their goals, and ineffective application may result in subtle avoidance or suppressed behavior (Brown et al., 2005).

Models of coping identify two distinct categories based on the intention and function of coping efforts: problem focused and emotion focused. Problem focused coping refers to cognitive and behavioral efforts used to change the problem, and includes such strategies as problem solving, planning and effort (Holt et al., 2005).Therefore, the focus is towards the successful completion of the given task.

Emotion focused coping involves strategies that help control emotional arousal and distress that are caused by the stressor without addressing the problem, and includes avoidance, detachment and suppression (Kashden et al., 2006). The ability of the individual to adopt appropriate coping strategies impacts upon their overall performance and consequently their level ofattainment. More explicitly where coping is ineffective, performance is adversely affected and coping strategies can either buffer or aggravate these adverse effects, depending upon the tactics used (Brown et al., 2005).

Gender differences in the selection of coping strategies have been identified, with males adopting more problem focused strategies and females adopting a more emotion focused approach. Genderdifferences in terms of attainment have also been established (Smith and Naylor, 2001). In addition, it has been shown that girls value academic success and that being too successful at school could disadvantage some boys among their peers (Tinklin et al., 2001). Further, females take education more seriously and tend to be better prepared, more careful, cooperative, organized and respectful. Males in contrast, are seen as ill prepared, competitive, disruptive, and overconfident and less attentive (Warrington et al., 2000).

Links have also been established between coping strategies and self- esteem, both of which have the potential to impact upon the wellbeing of the individual (Lane et al., 2002). Further, it has been suggested that low self-esteem may lead to performance deficits, negative mood states and motivational deficits, which in turn lead to a reduction in the exercise of adaptive problem-orientated coping and the relative infrequent opportunity to gain successes and bolster self-esteem (Ader et al., 2001). Self-esteem may also influence coping responses that seek to deal with or avoid stressors. Avoidance generates negative self-evaluations owing to the inherently undesirable qualities of this behavior, which create bad feelings and failure to obtain personal growth (Bednar et al., 2009). The preoccupation with emotional upset may inhibit individuals with low self-esteem from engaging in assertive and adaptive coping behaviors to combat stress.

To this end, *firstly*, adjustment difficulties among first year university students should be given serious attention as a serious adjustment problem could lead to students' failure to complete their studies. Hence, this research is intended to explore adjustment problems among first year university students. *Secondly*, within the current higher education environment there is a drive towards the development of greater independence and personal reflection requiring students to take ownership of their learning. In order to do so, it is important that they are able to adopt appropriate coping strategies for adjustment difficulties they encountered. Therefore, a need arises to understand and identify the coping strategies adopted by students and the extent to which these impact upon their self-esteem and level of academic attainment. This will allow the identification and implementation of support mechanisms where appropriate.

To sum up, given the importance of the first year (students are more likely to drop out at this level), this study focused on the adjustment problems and coping strategies adopted by a cohort of first year students and the extent to which these impacted on self-esteem and academic attainment three Universities of Eastern Ethiopia.

Statement of the problem

Since the introduction of a new Educational and Training Policy in 1994, expansion of higher education has been a main agenda in Ethiopia. Within the past few years, beside regional and private colleges, the number of public universities in the country has increased from 9 to 31. Following this, the yearly public universities' acceptance rate has dramatically increased from approximately less than ten thousand (ten years ago) towards nearly hundred thousand students (MOE, 2010).

However, irrespective of the increment in enrollment rate, dropout and attrition rate have been frequently reported to be high in almost all public universities. The problem has been pronounced since 2004, the year in which universities have started admitting students passing through the newly introduced curriculum. Evidently, the consequences of premature departure from university become more severe in such countries where almost 44% of the population is living below the poverty line (World Bank, 2000), and where education is a main vehicle to escape from it.

On the top of this, the first year in university is a critical transition period. This is because it is a time when students lay the foundation on which their subsequent academic success and persistence rest.Further,it marks a new stage in their education, one where they have been given control of the decision of what and where to study. It is a chance for universities to prepare them for their degree, and in turn the world of work and to help them to become motivated, independent lifelonglearners. This being the case, however, the pressures on students are numerous and many do not succeed due to adjustment problems that lead to drop outs (HESA, 2006).

Ultimately early leaving from a university is often associated with negative consequences for students, their families, and university administration. It can cause heavy unrealized costs to universities and families. A student leaving university without having completed her/his study may also be exposed to various psycho-social problems.Dissatisfaction with college experience, disruption of life plans, and being jobless or being engaged in minor jobs to earn much less over a life time are some among others. *Therefore, it is important that educators take time to consider why this happens and how this situation could be improved*.

The purpose of this study was, therefore, to investigate the potential adjustment problems encountered by first year studentsand the effectiveness of coping strategies they employed to handle the problems in three Eastern Ethiopian Universities namely Dire Dawa, Haramaya and Jijiga Universities. If such factors can be well understood, it will inform policy derivatives, further research and intervention programs that can be designed to enhance success and retention rates in Universities.

Accordingly, the following research questions were answered at the end of the study:

1. What are the potential adjustment problems encountered by first year studentsin three selected Universities of Eastern Ethiopian?
2. Is there a difference between male and female students regarding adjustmentproblems they encountered in three selected Universities of Eastern Ethiopian?
3. To what extent do adjustment problems predict the academic achievement and self-esteem of first year studentsin three selected Universities of Eastern Ethiopian?
4. Whatare the nature and type of coping strategies adopted by first year studentsin three selected Universities of Eastern Ethiopian?
5. Is there a difference between male and female students regarding coping strategies they employedin three selected Universities of Eastern Ethiopian?
6. Do the coping strategies used related to self-esteem and academic achievement of the studentsin three selected Universities of Eastern Ethiopian?

Objectives of the study

Given the many implications of transition to university life for new students, this study was warranted to examine students' adjustment experiences upon entry to a university and the effectiveness of coping strategies adopted by them.

More specifically, the objectives of this study were to:

1. Find out the potential adjustment problems encountered by first year studentsin three selected Universities of Eastern Ethiopian,
2. Assess the differences between male and female students regarding adjustment problems they encountered in three selected Universities of Eastern Ethiopian.
3. Determine the relationship among students' adjustment, self-esteem and academic achievementin three selected Universities of Eastern Ethiopian.
4. Identify the nature and type of coping strategies adopted by first year studentsin three selected Universities of Eastern Ethiopian,
5. Find out the differences exist between male and femalestudents regarding coping strategies employed in three selected Universities of Eastern Ethiopian.
6. Describe the extent to which coping strategies linked to self-esteem and academic achievementin three selected Universities of Eastern Ethiopian.

Significance of the Study

Findings of this study is supposed to increase understanding on students' adjustment upon entry to a university. This study yielded several implications and suggestions in helping students to adjust to campus life. Firstly, there was a need to identify adjustment problems experienced by students . Secondly, appropriate intervention programs was recommended to be planned to assist new students who had problems in coping with the demands and challenges that could create stress and tension to their life in campus. If such factors can be well understood, it will inform policy derivatives, further research and intervention programs that can be designed to enhance success and retention rates in universities.

Although university life is the most exciting, intellectually rewarding, and emotionally loaded experience of a student's life, entering university is a stressful period. In this period first-year students are faced with several difficulties such as, lack of social support, feeling lonely, anxious and depressed, as well as vagueness about academic purposes. If the first year students cannot deal with these difficulties they are faced with the problems of dropping out, low self-esteem, and depression. Therefore, greater attention should be given to university adjustment and the students' ways of coping. However, in Ethiopia, lack of research on investigating the effects of different coping strategies on different dimensions of university adjustment is expected to make the present study significant because it believed to fill the gap .

In terms of counseling implications, the present study is expected to be helpful for the counselors to understand the variables involved in the counseling process while they deal with problems of university adjustment. In developing university adjustment programs, this study may provide a theoretical foundation for the counselors both for improving students' adjustment and helping them to learn to use effective coping strategies, particularly during stressful times.

The results of this study were significant for several constituencies with respect to future practice, research, and policy.

Future Practice

One group that could take advantage of the findings includes those individuals who work in campus students services programs. The results of this study provided program coordinators with information regarding areas of adjustment problems that have an influence on first-year student’s academic achievement. This information could be used to examine the content of training and support systems programs that are offered to first-year students.

Second groups that may be interested in the findings include high school administrators. The results of this study provided information regarding areas of adjustments that may affect the ability of high school students to be academically successful in universities. This information could be used to assist students as they prepare to transition from the secondary school environment to the higher education environment.

Theories on Student Development

Transition to university is a challenging period and has some developmental tasks that first-year students are expected to accomplish. Therefore, university life plays an important role in student development. Much of the early works on student development models are the basis for university adjustment studies. Historically, three major theories have been proposed to explain student development in university, namely, Vectors of Student Development (Chickering, 2009), Theory of Student Involvement (Astin, 2009) and Theory of Student Departure (Tinto, 2008). These three major theories also provide bases for further studies on university adjustment.

Chickering (2009) identified seven “vectors of development” which university students typically go through during their university years. They were called “vectors” of development because each seems to have direction and magnitude-even though the direction may be expressed more appropriately by a spiral or by steps than by a straight line. In other words, all the vectors support each other and develop, thus creating an intertwined process. These vectors help the university student development to be comprehended. These vectors were named as achieving competence, managing emotions, becoming autonomous, establishing identity, freeing interpersonal relationships, clarifying purpose, and developing integrity (Chickering, 2009).

The theory of vectors of student development was supported by the research findings to explain the psychosocial development of the university student. For example, Winston (2010) developed Student Developmental Task and Life-Style Inventory, based on Chickering's theory and found that seven theoretical dimensions explained the psychosocial development of university students. Shultheiss, Palladino, and Blustein (2011) also supported Chickering's theory and found that the students who progressed in their development were likely to be better adjusted to university.

Astin (2009) proposed a student development theory to explain student involvement. Student involvement refers to the level of physical and psychological energy, which the student enthusiastically dedicates to academic experience. Thus, it is naturally expected that a student who dedicates his/her energy to studying spends considerable time on campus, participates actively in student organizations, and interacts frequently with faculty members and other students. According to the theory, when the involvement of the student in the university increases, the level of student learning and personal development will increase too.

According to Astin (2009), student involvement occurs in various forms, such as incorporation in academic work, participation in extracurricular activities, and interaction with faculty and other institutional personnel. The theory of student involvement provides a useful frame of reference for faculty, administrators, counselors, and student personnel workers to understand how university life affects students.

Tinto (2008) explained why students depart from the university. In other words, his theory examines the process of student persistence in university and tries to understand reasons of student departure from university. According to Tinto, students bring some personal, familial, academic characteristics, and skills and abilities as well as intentions with respect to personal goal and institutional commitments with them while entering a university. All these pre-entry characteristics are reshaped by academic (e.g., academic performance, faculty/staff interactions) and social (extracurricular activities and peer group interactions) system of the university. The theory postulates that institutional experience combined with academic and social integration are critical in the long-term success. Negative institutional experiences, on the other hand, led to a decrease in academic and social integration of the students and ultimately promoted the student's withdrawal.

The theory of student departure stated that the characteristics of the new students are in an interaction with the academic and social life of the university with results that are either positive or negative. Student persistence is related to the three stages, namely, stage of separation, transition to university, and incorporation in university, through which the new students pass.

Through these stages, the student first, is to detach from the past community, then, to experience a passage between the past and the new university life, and finally, to try to completely integrate to the university to establish a competent membership in the absence of the past community.

As proposed by these three models, adjustment to university is a complex and multifaceted phenomenon. Besides, as suggested by the researchers the first-year of the university is a particularly critical period for student change in terms of educational growth and persistence (Terenzini, et al., 2011).

University Adjustment

Baker and Siryk (2009) proposed a comprehensive, multidimensional scale measuring university adjustment as a multifaceted concept. They defined successful university adjustment as responding to academic demands, being socially integrated with other students, faculty, and personnel in the university, being involved in campus activities, maintenance of one's own psychological and physical well-being, and being attached and committed to the university. This complex nature of adjustment indicated that university adjustment was not a one-dimensional, but a multidimensional phenomenon. Consequently, some attempts that were made to identify the different dimensions of adjustment to university and they identified four dimensions of university adjustment, namely, academic, social, personal/emotional, and goal commitment/institutional attachment.

Academic Adjustment-Academic adjustment refers to the students' success in dealing with the various educational demands of the university experience. It is displayed by positive attitudes toward academic goals and academic work, by motivation to learn, and by a sense of satisfaction with the academic environment (Baker &Siryk, 2009). They defined some contributing elements of academic adjustment, including academic performance and success, academic ability, academic motivation, academic purposes, and satisfaction with the academic environment. Some of the behavioral correlates of lower scores in academic adjustment subscale were found to be lower GPA in the first-year; being on academic probation; low GPA in high school and low scores on Scholastic Aptitude Test; unstable and age-inappropriate goals; and less realistic self-appraisal (Baker &Siryk, 2009).

Social Adjustment- During the first year of university, students typically face with new challenging situations in the social world of the university. Some of the students are away from their families for the first time; enter a social environment, which is quite different from the one in which he/she was raised. First-year students have an opportunity to create new friendships and to gain new experiences. On the other hand, they are separated from their past social ties. This is very stressful and painful for the students. Although the first-year students maintain their relationships with their family members, they are also expected to develop close ties with their peers and faculty. A healthy social adjustment to university requires interacting and forming relationships with peers, faculty, and staff. Taken all together, social adjustment can be defined as the student's success in social activities, relationships with other persons on campus; ability to cope with social relocation and being away from home and significant others; and satisfaction with the social aspects of the university environment (Baker &Siryk, 2009). Baker and Siryk (2009) defined the behavioral correlates of this subscale as less participation in social activities in university, lack of social skills, difficulties in separating from home and establishing social autonomy; greater sense of loneliness, greater social avoidance, less social self-confidence and less self-concept; less success in coping with life challenges; and less perceived social support.

Personal/Emotional Adjustment-Personal/emotional adjustment focuses on a student's level of psychological distress and somatic problems during his/her adjustment to university. Personal/emotional adjustment requires the students to have a positive sense of psychological and physiological well-being, such as feeling calm, stable, and secure, controlling intense emotions, dealing with daily stresses, and having less somatic complaints (Baker &Siryk, 2009). Behavioral correlates of this dimension are determined as being known to university counseling services, less coping resources, a lesser degree of psychological well-being, and a high level of psychological distress such as anxiety and depression, and greater experience of negative life events that are negatively associated with personal/emotional adjustment (Baker &Siryk, 2009).

Goal Commitment/Institutional Attachment- As universities have expanded in size, they have become impersonal environments in which students have difficulty in feeling attachment to the institution and this may contribute to university adjustment problems. Students' commitment to educational-institutional goals and attachment to the particular university have been found to play an important role in adjusting to university (Baker &Siryk, 2009). Feelings about the institution, satisfaction with the institution and the established bond between the student and the institution are some of the indicators of goal commitment/institutional attachment. Behavioral correlates of this dimension were indicated as student attrition and less overall satisfaction with the university experience (Baker &Siryk, 2009).

Baker and Siryk (2009) found a significant relationship between attrition rate and goal commitment/institutional attachment. In other words, if the student got a high score from the goal commitment/institutional attachment scale, the student was less likely to discontinue his/her education at the university of original enrollment as a first-year student. Having a career goal, a value of university education, earning a degree at a particular institution are the signs of attachment and goal commitment. Smith and Baker (2009) compared the first-year university students who had made a major decision and who had not. The researchers indicated that decidedness regarding academic major was positively related to goal commitment/institutional attachment like academic adjustment.

Coping

The roots of cognitive theory of stress and coping are based on the transactional perspective, which considers the person and the environment in a dynamic, mutually reciprocal, bidirectional relationship. Stress is conceptualized as a relationship between the person and the environment that is appraised by the person as taxing or exceeding his/her resources and as engendering well-being. The theory proposed two processes, namely, cognitive appraisal and coping, which are considered as the critical mediators of stressful person-environment relationships and of their immediate and long-term outcomes (Folkman, Lazarus, Gruen, &DeLongis, 2006).

Cognitive Appraisal Process- During the cognitive appraisal process, the person determines if a particular encounter with the environment is relevant to his/her well-being and how he/she will be affected by it (Folkman, Lazarus, Gruen, &DeLongis, 2006). There are two processes in cognitive appraisal: primary and secondary appraisal. The primary appraisal process helps the person to evaluate the importance of the event and to understand if it is irrelevant, positive, or stressful. An irrelevant event is not significant for one’s well-being thus; the person is not a part of its outcome. In a positive event, only a good outcome is considered. Finally, if the event is appraised as stressful, it is considered as harm-loss, threat, or challenge. Harm-loss refers to a damage already done, such as injury or illness, damage to a friendship, loss of self-esteem or a significant one; threat concerns the possible potential for harm or loss that did not happened yet; and challenge focuses on a potential for gain or growth. Therefore, it demands exceptional efforts from the person (Folkman, 2004; Folkman& Lazarus, 2005).

McCrae (2004) examined the relationship between categories of stressors and the selection of coping strategies. He found that in challenging situations, positive thinking, rational action, escapist fantasy, self-blame, restraints, self-adaptation, and humor are frequently used as coping strategies. In harm-loss situations, subjects are more likely to use expression of feelings, faith, and fatalism as coping strategies. In threat situations, wishful thinking, faith, fatalism, active forgetting, and controlling the feelings are commonly used as coping strategies.

In the secondary appraisal process, the person evaluates the coping resources and options trying to find a response to harm-loss, threat, and challenge (Folkman& Lazarus, 2005). The person evaluates resources, such as, social, physical, and personal ones in order to meet environmental demands. Social networks, support systems, and emotional support are examples of social resources. Physical resources are comprised of special training programs, social agencies, and money. Finally, self-esteem, skills for problem solving, sense of control make up personal resources. Having a sense of control is an important part of secondary appraisal. Depending on whether or not the stressful event is under control, the type of coping chosen varies accordingly (Folkman, 2004).

Two appraisal processes operate interdependently. If there is already an appropriate coping resource, the threatening event may become less threatening. In contrast, a nonthreatening situation may become threatening if the coping resources are not enough to meet environmental demands (Folkman& Lazarus, 2005). When faced with a stressful situation, the person at first evaluates the significance of the situation then tries to find appropriate resources to deal with the situation in order to meet the environmental demand.

The Coping Process- As stated above, the second process of the Stress and Coping Theory is the coping process. Coping has been defined as "constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" (Lazarus &Folkman, 2004). Coping has two major functions: regulating the emotional responses to the stressor called emotion-focused coping and having direct action to change or control the sources of stress referred to as problem-focused coping (Folkman& Lazarus, 2005). Problem-focused coping is an attempt to take direct action in order to find a solution to change the stressful situation into a better situation. Emotion-focused coping is an attempt to change the interpretation of the stressful situation reappraising the threatening event into a nonthreatening one (Lazarus, 2003).

Some studies (e.g., Folkman& Lazarus, 2005) indicated that problem-focused and emotion-focused coping strategies were both used in the same stressful encounter. Folkman and Lazarus (2005) confirmed that both types of coping, problem- and emotion-focused, were used in three stressful situations, namely, before the exam, after the exam, and when the grades were announced. The findings demonstrated that people coped with a single situation in complex ways. It has been reported that subjects have appraised the examination as both threat and challenge at any given phase of the exam. This finding showed that both types of appraisal could occur at the same time. In addition, both types of coping were used simultaneously. Researchers suggested that emotion-focused coping could facilitate problem-focused coping as long as it was used to manage emotions.

However, in certain situations, depending on whether the situation is perceived as changeable or not, one type of coping is preferred. For example, Folkman and Lazarus (2005) found that the person used frequently problem-focused coping when he/she appraised the situation as changeable. On the other hand, emotion-focused coping was more frequently used for the situation that was appraised as unchangeable.

Lazarus (1993) summarized features of the coping process utilizing the result of his and his colleagues' research findings as follows: coping is complex and people use most of the coping strategies for widely varying stressful situations; appraisal has an important role in choosing the coping strategy. For example, if a person appraises the situation as changeable, problem-focused coping is used; unexpectedly, men and women use very similar coping strategies for constantly stressful situations, such as work, health, or family related stress; coping is a dynamic process, which can change throughout a stressful situation; people choose the coping strategies highly depending on the type of stressful situation, the type of personality under stress, and the outcome modality studied (e.g., subjective well-being, social functioning, or somatic health).

Classifying Coping Strategies- The most well-known categorization made by Lazarus and Folkman (2004), was problem-focused coping and emotion-focused coping. Both included a variety of cognitive and behavioral strategies. Problem-focused coping includes the behaviors or thoughts regarding actively dealing with the situation. Emotion-focused coping involves wishful thinking (wishing the situation to go away), distancing (trying to forget the stressful situation), emphasizing the positive (trying to see the situation in a positive way), self-blame (criticizing oneself for the problem), tension-reduction (decreasing the tension by eating, drinking, smoking, using drug, or exercising), self-isolation (avoiding being with people), and seeking social support (getting sympathy and understanding from someone).

Moos and Billings (2002) categorize coping skills in three domains according to their primary focus: appraisal-, problem-, and emotion-focused coping. Appraisal-focused coping involves efforts to understand and to find a pattern of meaning in a crisis. The process of appraisal and reappraisal works to modify the meaning and to comprehend the threat resulting from a situation. Problem-focused coping searches for confronting the reality of a crisis by dealing with the consequences and trying to construct a more satisfying situation. Emotion-focused coping is trying to manage the feelings after a crisis and to maintain affective balance. Accordingly, coping skills can focus on the meaning, the practical aspects, or the emotions associated with a crisis.

Holahan, Moos, and Schaefer (2006) identified two categories: approach and avoidance coping strategies. Approach coping strategies included logical analysis, positive reappraisal, seeking guidance and support, taking problem-solving action. In contrast, avoidance coping generally was associated with psychological distress. Avoidance coping strategies were cognitive avoidance, resigned acceptance, seeking alternative rewards, emotional discharge. Roth and Cohen (2006) argued that approach coping seemed to resemble problem-focused coping in terms of direct efforts to alter the stressful event whereas avoidance coping was like emotion-focused coping which involved indirect efforts to adjust to stressors by distancing oneself either by focusing on one’s feelings or otherwise avoiding solving the problem.

Another categorization of coping was made in terms of using more salutary (e.g., making decisions, seeking social support, and talking about problems with family) and less salutary (e.g., verbal aggression, alcohol use, and minimizing the importance of the problem) coping strategies (Jorgensen &Dusek, 2000).

Olah (2005) made a different categorization based on the empirically derived coping dimensions in the literature. He proposed three dimensions: assimilation, accommodation, and avoidance. Assimilative coping referred to the person’s cognitive or behavioral attempts to change the environment to his/her benefit. Similar kinds of coping mentioned in the literature were problem-focused, task-oriented, information-seeking, problem solving, and instrumental support. Accommodative coping involved the person's cognitive or behavioral attempts to change him/herself to adapt to the environment. Similar categories in the literature are emotion-focused, emotion-regulation, acceptance, emotional support, passivity. Avoidance coping referred to behaviors and cognitive acts that help to escape from the stressful environment, either physically or psychologically. Similar kinds of coping identified in the literature are escape, behavioral and mental disengagement, escapist fantasy, alcohol and drug use, active forgetting (Olah, 2005).

In reviewing the diversity of coping, Compas and his colleagues (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001, as cited in Miller & Kaiser, 2001) recently proposed a theory of coping and stress responses that organized most of these classifications or dimensions in this empirically supported model. Responses to stress were divided into voluntary coping responses and involuntary responses. According to them not every response of an individual to stress constituted coping. People might have had involuntary emotional, behavioral, physiological, and cognitive responses to stress that did not serve to regulate or modify stressful experiences. Coping was volitional efforts to regulate emotion, thought, behavior, physiology, and the environment reaction to stressful events.

Both voluntary coping responses and involuntary responses to stress can involve engagement (approach) or disengagement (avoidance) with the stressful event or problem. Voluntary efforts can be distinguished as primary- and secondary-control. Primary-control coping tries to influence objective events or conditions to enhance a sense of personal control over the environment and one's reactions. These included problem solving and efforts to directly regulate one's emotions or the expression of emotion. In contrast, secondary–control coping responses involved trying to change the individual's feelings about the bad situation, which had occurred. Distraction, acceptance, positive thinking, and cognitive restructuring fell into this coping domain (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001, as cited in Miller & Kaiser, 2001).

All these research findings demonstrated that coping strategies were categorized in different ways, such as problem- and emotion-focused coping; appraisal-focused, problem-focused, and emotion-focused coping; approach and avoidance coping; more salutary and less salutary coping; assimilative, accommodative, and avoidance coping; and voluntary coping responses and involuntary s responses.

Coping Effectiveness- In spite of the recent advances in theory, research and assessment, the coping effectiveness issue is still open to debate (Zeidner&Saklofske, 2006). It is very difficult to state that one strategy is naturally better than any other. The effectiveness of a coping strategy is determined according to its outcome in the stressful situation in the long term (Lazarus &Folkman, 2006).

The positive effects of problem-focused coping and negative effects of emotion-focused coping on psychological outcomes have been emphasized frequently (e.g., Collins, Mowbray, &Bybee,

2009). On the other hand, Compas (2007) stated that both problem- and emotion-focused coping are important in successful adaptation to stress in children and adolescents. Therefore, effective coping is considered as flexible and changeable. Since new demands require new ways of coping, one type of coping strategy cannot be effective for all types of stress (Compas, 2007). However, Zeidner and Saklofske (2006) asserted that some coping strategies appear to be inherently maladaptive in managing stress. For example, alcohol and drugs may provide brief relief, but ultimately the person gets worse.

Zeidner and Saklofske (2006), in their review, concluded that the same coping strategy might reveal different outcomes and all coping strategies are not effective in managing stressful situations. If a strategy removes the stressor or its cause, then it can be thought of as effective. For example, in order to cope with a difficult university course, an individual might exhibit behaviors such as, increasing study time, getting peer assistance, or dropping the course. In the process of coping, effective strategies must be implemented that help to reduce the concurrent anxiety, worry, and depressed mood (Zeidner&Saklofske, 2006). Therefore, it is difficult to reach a conclusion about which coping strategy is appropriate in a given stressful encounter. The appropriateness of a coping strategy varies from one encounter to another.

Coping and University Adjustment

Entering a university is one of the major experiences in the transition from adolescent to adulthood. In this period, students meet with certain developmental tasks in a particular culture. The main tasks are the following: 1) separation from significant others, such as, parents, siblings, and close friends; 2) greater autonomy to make important decisions, to take responsibility for oneself, and to regulate one's own behavior; 3) establishing new friendships; 4) internal and external pressures toward greater intimacy and adult sexuality; and 5) dealing with new intellectual challenges (Silber, Hamburg, Coelho, Murphey, Rosenberg, &Pearlin, 2006).

During the first-year of the university, emotional, social, and intellectual skills of students are tested. Coelho, Hamburg, and Murphey (2006) determined socioeconomic tasks of this transition period, which the students should overcome. These challenges are: (1) unfamiliar subject matters; (2) more difficult and demanding course contents; (3) demands on generating new ideas, techniques within a limited examination schedule; (4) assignments requiring time management strategies; (5) new fields of knowledge that have no immediate vocational application; (6) various demands of university requiring good time and activity management; (7) curricular and extracurricular demands of campus life, requiring the ability to make long-term and binding decisions.

In order to get through these tasks or challenges, students are in need of many different patterns of coping behavior. Moos (2006) emphasized that the accomplishment of each task, and how it is accomplished, may affect the adult life of the individual and those close to him. Although university adjustment and coping have been separately studied and well documented in the literature as explained in this chapter, there are limited numbers of studies, which examine the effects of coping strategies on university adjustment.

In an attempt to understand how competent adolescents cope with anticipated university tasks, Silber, Hamburg, Coelho, Murphey, Rosenberg, and Pearlin (2006) conducted a study over a 6-month period, from the spring of the last year of high school through September (prior to student's departure for university). Fifteen competent adolescents who were good at academic work at school, maintaining interpersonal closeness with a peer and participating in social groups were selected for the study. Researchers made interviews with the students 6 or 7 times. They found that the students' general characteristics were the positive attitude toward new experiences, a tendency to be active in dealing with the tasks of the transition, and an enjoyment of problem solving and pleasure derived from mastering of the challenges. This pleasure derived from the feeling of efficacy and serving to facilitate an active involvement and pleasure in coping with the new situation.

Research Design and Methodology

Research Participants

This study employed a quantitative approach with a descriptive and correlation design. A total of 509 first year students were selected by using stratified random sampling techniques from Dire Dawa, Haramaya, and Jijiga Universities to participate in the study. The following indicates the distribution of the students who were participated in the research study and total population across the universities.

Table1: Total population of the three universities students and sample size for the study

	Universities	**Total**	**Samples**	**Percent**
1.	Dire Dawa	3130	164	32.2
2.	Haramaya	4530	182	35.8
3.	Jigjiga	2104	163	32.0
	Total	9764	509	100

Instrumentation

Three instruments were administered to collect the necessary data from the students. The first **instrumentwas the Student Adaptation to College Questionnaire** (SACQ) developed by Baker and Siryk (1999), the second instrument was the **Way of Coping Questionnaire** (WCQ) developed by Folkmanand Lazarus (1988), and third was **York Self-Esteem Inventory** (YSEI: Rector and Roger, 1996). Finally, Students' academic achievement in this study was assessed based on their grade point average (CGPA) obtained at the end of first semester in 2012 academic year.

Student Adaptation to College Questionnaire (SACQ)

The SACQ was made up of three sub scales that measure three different types of university adjustment dimensions (Baker & Siryk, 1999). The *Academic Adjustment* subscale assesses students' ability to cope with the various educational demands and college experiences (e.g., students' motivation, academic performance, and satisfaction towards the academic environment offered in college). The *Social Adjustment* subscale assesses students' ability to cope with the interpersonal-societal demands inherent in university experiences (e.g., students' involvement in social activities and relationships with other persons on campus, and satisfaction with the social aspects of the college environment). *Personal-Emotional Adjustment* indicates students' intra-psychic state or the degree of general psychological distress and somatic symptoms of distress experienced by them. In addition, the *Institutional Attachment* subscale assesses student's degree of commitment to educational-institutional goals and the degree of attachment to the particular university he or she is attending.

SACQ consists of 36 self-rating statements regarding subjects' perception of their adjustment to university. Subjects are required to select one response that best describe them for all the statements using a 4-point Likert-scale ranging from "highly applies to me" (4) on the left to "doesn't apply to me at all" (1) on the right. The SACQ yields a full-scale score as an indicator of the overall adjustment to university and a meanscore for the four subscales indicating the level of each adjustment dimension. The higher the score, the better the self-assessed adjustment to university, and conversely, the lower the score the greater the difficulty being reported (Baker &Siryk, 1999). Theprior reliability of the SACQ was found to be high (a = 0.91). The same goes for the four subscales which ranges from 0.78 to 0.86 for the alpha values as pilot tested with some sample students from Haramaya University.

Way of Coping Questionnaire (WCQ)

WCQ was used to assess subjects' effort in coping with adjustment problems encountered in university. The WCQ used in this study which was modified from the original version of WCQ comprised of 50 items assessing 6different types of coping scales/strategies used by students when confronted with stressful situations in campus. The coping strategies are: Distancing, Self-Controlling, Seeking Social Support, Accepting Responsibility, Escape-Avoidance, PlanfulProblem Solving. However the instrument was adapted to the context of our culture by pilot testing and computing factor analysis. Accordingly, some inconsistent items were adjusted as well as a few items were removed which made the total items measuring coping strategies to be 32.Respondents were asked to respond to each statement by circling only one response that best described the action taken by them such as, 1 (never apply to me), 2 (somewhat apply to me), 3 (Moderately apply to me) and 4 Highly apply to me). Raw scores describe the coping effort of the six types of coping and high raw scores indicate that the respondent often used the coping behaviorsdescribed by the scale in coping with the stressful event.Theadapted version WCQ used in this study was found to be reliable (ex = 0.87). The alpha values for the six subscales were found to range from 0.54 to 0.79 which was tested through pilot testing in Haramaya University. Moreover, Factorial analysis was carried out and items with low validity were reduced and some items were modified.

York Self-Esteem Inventory (YSEI)

The scale comprises 13 items measuring global self-esteem. Items reflect various evaluative self domains including personal, interpersonal, familial, achievement, and the degree of evaluative uncertainty across these domains. Preliminary psychometric examination of the scale has revealed strong internal reliability (t = 0.86) and test-retest reliability (0.83). The self-esteem has also been shown to correlate highly significantly with established indices of self-esteem including the Rosen-berg Self-Esteem Scale (1965).

Data Collection Procedure

Participants' were asked to complete a questionnaire package containing consent and demographic form, and the SACQ, WCQ and YSEI, at the end of first semester in academic year of 2012. During the administration of the questionnaires one of the investigatorswas there together with data collectors and answeredquestions that were raised. Finally, at the end of the first semester academic year attainment grades for each participant wereobtained from a registrarof each University to counter check the GPA recorded by the students on the survey questioners. Accordingly, some inconsistencies were screened from the main data during the encoding processes. Gradeswere averaged and grouped according to degree classification criteria for the further analysis purposes.

Methods of Data Analysis

To analyze and interpret the datagrand Mean Scores, T-test**,** Pearson Product Moment Correlations, ANOVA, andLinear and Multiple Regressions were used. In addition, the open ended data was analyzed qualitatively using phrasal expression. Data analyses process was employed the latest SPSS version 16. Finally, conclusions were drawn from the findings and recommendations were given accordingly

Analysis and Interpretation of data

Demographic Characteristics of Respondents

Sex distribution of students

The participants were from three Universities namely Haramaya, Jigjiga and Dire Dawa which comprised of 509 across different department and fields of studies. With regards to sex distribution 52% of the respondents were Female and 48% were male. This indicates that the sex distributions were represented equally in the study.

Table2: Gender distribution of research participants

	Sex	**Frequency**	**Percent**
1.	Female	265	52
2.	Male	244	48
3.	Total	509	100

Stress level of the University students

Table 3: The responses of students regarding the utilized potential for academic work

	Respondents	
Alternatives	Frequency	**Percent**
Yes	264	52.0
No	244	48.0
Total	508	100.0

Do you think that you have fully utilized your potential in the first semester on academic work? In response to this question, the majority (52%) confirmed that they have fully utilized their potential in the first semester on academic work. But about 48% stated that they haven't fully utilized their potential for academic work. In response to the item what are the factors that hinder you not to use your maximum potential in your academic work? The majority of participants stated the following reasons as the main factors that hamper their full utilization of potential on academic work.

These were:

- Misinformation from the senior students
- Difficulty of examination
- Fear of university exam approaches and teaching methodology of teachers
- Lack of systematic study skills and failure to manage time
- Inability to read for long period of time
- Shortage of adequate reference books
- Being new for all things and inability to adjust self with the circumstances
- Homesickness of family and friends
- Hotness of the weather condition & sleeping too much
- Inability to adapt to new learning styles in the university, lack of cooperation in assignment work and language difficulty.

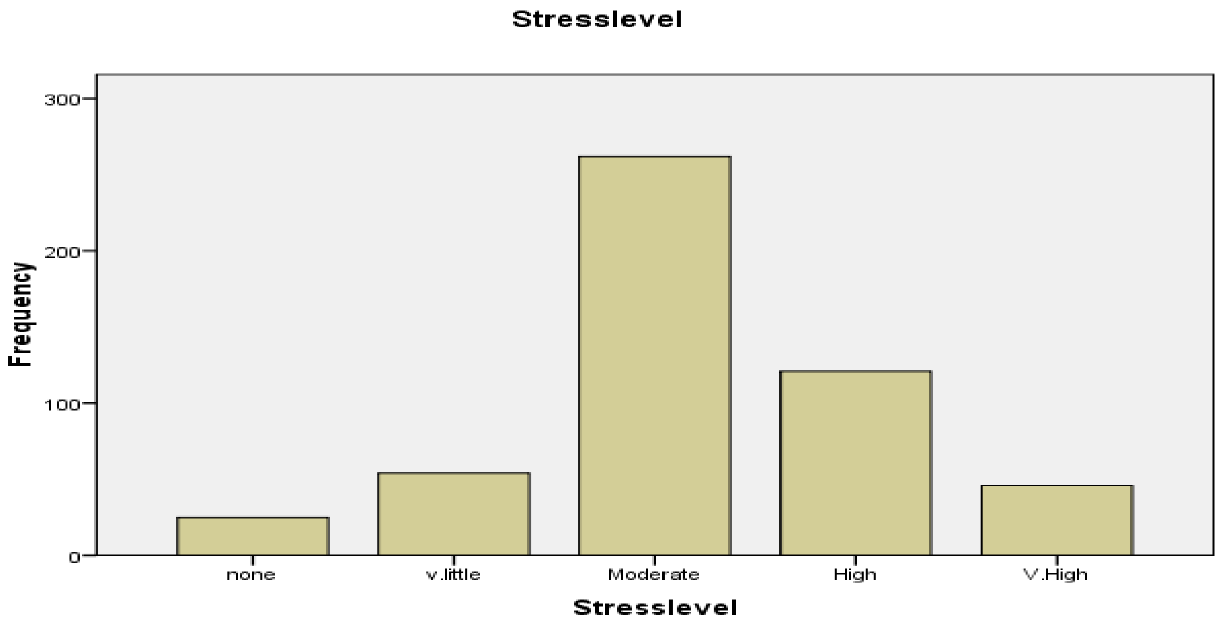
Generally the main challenges that the students encountered during the first year first semester of their university experiences were related to the changes in the teaching learning situation of the university which was more of academic adjustment problems. In addition, the students listed social adjustment problems such as difficulty to adapt to social life in dormitory, homesickness, lack of cooperative learning among students and discrepancy between expectation and reality in the university as other important factors in affecting university adjustment. The descriptive statistical analysis also supported that the academic adjustment challenges in the transition from high school to university is an influential factor in affecting students learning.

Table 4: Percentage of respondents to the levels of stress

	Respondents	
Level of stress	**Frequency**	**Percent**
None	25	4.9
Very little	54	10.6
Moderate	262	51.6
High	121	23.8
Very High	47	9.2
Total	509	100.00

In response to the item level of stress experienced in the first semester by the first year university student of Haramaya, Dire Dawa and Jigjiga as described by the participants were 51.6% of the respondents affirmed that the level of stress they have experienced in the first semester was moderate while 23. 8% reported that they experienced high level of stress. But only 10.6% and 4.9% responded they have experienced very little and no stress at all respectively. However, the students who responded that they have experienced at high and very high were found to be 33% which indicated that the level of stress was significantly experienced in the universities.

Bar graph below demonstrates the Stress levels of students across the three universities in the first semester of 2013 academic calendar in their fresh year.



The finding of this research indicated that first year students in the university reported that they were experienced moderately level of stress which implies their susceptibility to academic and social stress problems which might inhibit the effort and capacity to use one's potential in academic affairs. It was also followed by some of the students who declared that the level of stress they experienced was so high. Thus, the finding of this study indicated that the freshman year is a transition period were students experienced institutional, social and personal adjustment challenges in the three universities.

Adjustment problems of students

Table 5: ANOVA result of difference **in Adjustment across Universities**

	Adjustment Problems		Sum of Squares	df	Mean Square	F	Sig.
1.	**Social Adjustment**	Between Groups	584.864	2	292.432	12.626	.000*****
		Within Groups	11696.514	505	23.161		
2.	**Academic Adjustment**	*Between Groups*	639.227	2	319.614	15.893	.000*****
		Within	10155.881	505	20.111		

		Groups					
3.	**Personal & Emotional Adjustment**	*Between Groups*	240.461	2	120.230	8.089	.000*****
		Within Groups	7506.396	505	14.864		

Significant at P< 0.01

There is a statistically significant mean difference among the first year students of Haramaya, Dire Dawa and Jijiga in social adjustments, academic and personal emotional adjustment problems. However, the mean difference of social adjustment experienced by students was significant between Haramaya (Mean=30.4) and Jijiga (32.67) as well as between Dire Dawa (30.34) and Jijiga but there was no significant mean difference between Haramaya and Dire Dawa university students. The Tukey post hoc test indicated that the adjustments problems was higher for the Jijiga university first year students than Haramaya and Dire Dawa which had lower mean in the adjustment problems. Furthermore, the mean difference between the three university students was significant on academic and personal emotional adjustment problems.

More importantly the qualitative analysis of data assured that the institutional challenges with regard to Jijiga University was highly related to the hotness of the area, lack of the reference materials Homesickness of friends and family as well as in ability to adjust with the university teaching learning methodology as crucial in impacting the students' adjustment.

Table 6: ANOVA result of difference in adjustment problems between Sexes

	Adjustment Problems		**Sum Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1.	**Social**	Between Groups	81.248	1	81.248	3.369	.067
		Within Groups	12226.233	507	24.115		
2.	**Academic**	**Between Groups**	**479.236**	**1**	**479.236**	**23.473**	**.000 ***
		Within Groups	**10351.074**	**507**	**20.416**		
3.	**Personal Emotional**	Between Groups	.145	1	.145	.010	.922
		Within Groups	7747.583	507	15.281		

* Significant at P< 0.01

There were statistically significant mean differences between male and females in academic adjustment problemswhereas there were no significant mean differences between male and females in social and personal and emotional adjustment. Male students experienced more academic adjustment problems with mean (35.93) than that of females with mean (33.99).Thus, the ANOVA result confirmed that the female students were experiencing lesser university academic adjustment problems than their male counterparts. This might be because of the coping techniques used by female in well adapting self to the life styles in the university.

Sex difference in coping Strategies

Table 7: ANOVA Result of coping strategies between sexes

	Coping Strategies		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1.	*Planful problem solving*	**Between Groups**	**229.903**	**1**	**229.903**	**29.422**	**.000****
		Within Groups	**3961.657**	**507**	**7.814**		
2.	*Escaping*	Between Groups	25.678	1	25.678	2.174	.141
		Within Groups	5988.593	507	11.812		
3.	Self-controlling	Between Groups	76.642	1	76.642	**7.305**	**.007****
		Within Groups	5319.110	507	10.491		
4.	Social Support	Between Groups	114.226	1	114.226	10.130	**.002****
		Within Groups	5717.043	507	11.276		
5.	Acceptance	Between Groups	.688	1	.688	.117	.732
		Within Groups	2970.089	506	5.870		
6.	Distancing	Between Groups	.237	1	.237	.035	.851
		Within Groups	3398.414	506	6.716		

** Significant at P< 0.05

ANOVA test result in table 6 above demonstrated that there is significant mean difference between Male and Female first year students in Planful problem solving, Self-controlling and Social Support coping techniques. Female used self-controlling coping technique more often than that of male with mean of (Female=16.02, Male=15.24). But male students were using Planful Problem Solving and social support coping techniques more often than that of Female students. The mean for Social Support across sex was Male=13.68, Female=12.73; whereas the mean for Planful problem solving was found to be 13.15 for Female and 14.50 for males. On the contrary, there were no significant mean differences between male and female students in using escaping, acceptance and distancing techniques of coping.

Relationship between Coping and Self-esteem

Table 8: Correlation coefficient between coping strategies and self esteem

Ser.No	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1.	Planful	--						
2.	Escaping	-.032	--					
3.	Self-controlling	**.202****	**.264****	--				
4.	Social support	**.527****	**.237****	**.339****	--			
5.	Acceptance	**.238****	**.158****	**.302****	**.370****	--		
6.	Distancing	-.041	**.265****	**.137****	-.003	**.137****	--	
7.	Self Esteem	**.133****	**-.256****	-.056	.031	**.134****	-.072	--
8.	GPA	**-.092***	-.029	**-.142****	-.063	.015	.033	**.117****

** Correlation is significant at the 0.05 level (2-tailed); * Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficient r indicated that there was negligent positive relationship between self-esteem and planful problem solving coping as well as self-esteem and acceptance coping techniques. But there was a low negative relationship between self-esteem and escaping coping technique. Moreover, there was no any relationship between self-esteem and coping techniques of: self-controlling, social support and distancing. Thus the correlation implied that those university students who highly used Acceptance and planful problem solving coping techniques would have higher self-esteem.

On the other hand, there was a negative relationship between self-esteem and Escaping coping technique. This implies that those students who highly used escaping coping strategy tends to have lower self-esteem and vice versa. In addition, there was a positive relationship between GPA of the students and self-esteem.

Adjustment Problems and Coping Strategies

Table 9: Demonstrates the Grand mean of student's responses to adjustment problems

	Adjustment Problems	N	Mean	Std. Deviation
1.	Social adjustment	509	2.59	.41
2.	Academic adjustment	509	2.69	.35
3.	Personal Emotional	509	2.39	.35

In table 8 above the research participants response to the experiencing of adjustment problems in the first year university period indicated that the Academic adjustment problem was found to be mean of 2.69 which implied that the respondents agreed that the academic achievement adjustment problems moderately applies to them in the past few months in the first semester of 2013. It also indicated that the higher of the adjustment challenges students experienced in their transition time in the university. While the Social adjustment and personal & Emotional adjustment was found to be 2.59 and 2.39, respectively. This implies that the students' had experienced moderate level of adjustment problems with academic adjustment being the highest followed by social and emotional -personal adjustment problems.

Table 10: Shows Grand mean of coping strategies experienced by students

No	**Coping techniques**	**Grand Mean**	**Mean**
1.	Planful problem solving	2.75	13.79
2.	Escaping	2.12	14.89
3.	Social support	2.63	13.18
4.	Acceptance	2.79	11.16
5.	Self-controlling	2.60	15.65
6.	Distancing	2.38	11.90

To address the second research question of the study, students' experience of coping strategies we performed descriptive statistics of Grand mean comparison. Finding in table indicated that the coping strategy most preferred by the students was Acceptance (Grand mean of 2.79), followed by planful problem solving (M=2.75), Social support (2.63) and self-controlling (M=2.6), distancing (M=2.38) and escaping (M=2.12). This result indicate that the majority of the students prefers to use emotional focused coping strategies followed by problem focused coping strategies to adjust to adjustment problems in the universities. In response to open ended item regarding the techniques of coping strategies that respondent students have used in the first semester the majority of them stated following :

- Advice from senior students, department heads and adapting self to the university regulation
- Cooperative Study with classmate; Sharing with friends
- Getting much sleep
- Patience, studying hard, confronting the challenges
- Plan in life & patience and Time Management
- Studying & attending class, doing assignment
- Get experience and education from challenges
- Looking bright side of life and convince oneself
- Asking for counseling services
- Accept the challenges ,effective use of time ,doing group /assignment
- Selecting good friends, follow religion ethics
- Taking stimulants , enjoy at entertainment

4.7. Regression Adjustment Problems on the self-esteem

Regression was used to test the significant prediction power of Sex, Stress level and adjustment problems (Social, Academic & Personal emotional adjustments) on the self-esteem of students. The result in table 10 indicates the percentages of variability accounted for by the aggregate adjustment problems.

Table 11: **ANOVA and R Square result of Adjustment problems and self esteem**

Model		Sum of Squares	df	Mean Square	F	Sig.	R Square
1	Regression	166.638	1	166.638	3.091	.079[a]	***.067***
	Residual	27282.402	506	53.918			
2	Regression	1842.159	5	368.432	7.223	.000[b]	
	Residual	25606.880	502	51.010			

a. Predictors: (Constant), Sex

b. Predictors: (Constant) Sex, Personal Emotional, Stress level, Social Adjustment ***Academic***

c. Dependent Variable: Self esteem

The table of ANOVA also confirms that the first constant variable (sex) alone did not predict the self-esteem of the students. On the contrary the sex together with the predictor variables (Stress level, and Adjustment problems) predicted the self-esteem of the students to a statistically significant level with p-value of < 0.05. Thus to specifically determine the impact levels of predictor variables (Adjustment problems) on self-esteem; each of the social, Academic and personal-emotional adjustment problems were regressed to self-stem. Accordingly, the table 11 below indicates the predictive power of Academic adjustment on the self-esteem.

Table 12: Regression result of Academic Achievement on self esteem

	Model	R	R Square	Adjusted R Square
1.	Sex	.078[a]	.006	.004
2.	Sex and Academic Adjustment	.237[b]	**.056**	.052

Academic adjustment problems statistically predict the self-esteem levels of students. The prediction power of the academic adjustment problems on the self-esteem accounted for 5.6%.In this case the percentage of variability accounted for change in the self-esteem due to academic adjustments went up from 0.6% to 5.6% which is statistically significant. However, the social and personal emotional adjustment problems did not significantly predicts the self-esteem level of first year university students. Sex was also not predictive of the self-esteem.

Levels of perceived stress and Academic Achievement

The regression coefficient computed for the prediction of academic Achievement from Higher Institution Entrance Exam Result, Personal emotional adjustment, socialadjustment, Academic adjustment problems and level of stress perceived together was statistically significant (F test 8.70 at $p < 0.05$). While the combined prediction of the Higher Institution Entrance Exam Result and adjustment problems and level of stress together was found to be 9.1%. This implies that variability in the academic achievement of students accounted for by the pulled impact of the independent variables of adjustments, level of stress and Higher Institution Entrance Exam was found to be 9.1%. Moreover, when each variable was regressed with academic achievement only the Higher Institution Entrance Exam Result found to be statistically significant which predicted 8% of the academic performance of the students.

Table 13: *Regression result of Adjustment problems on Academic Achievement*

Model	R	R^2	Adjusted R Square
1. Predictors Variables	0.302	.091	0.081
2. Higher Institution Entrance Exam	0.283	0.08	0.78

Predictors: Social, Personal Emotional Academic Adjustments, Higher Institution Entrance Exam, level of stress, Dependent: Academic Achievement

Do the coping techniques determine the Academic Achievement of Students?

Table 14: *Regression result of coping strategies on Academic Achievement*

Model		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*R Square*
1	Regression	21.673	7	3.096	**3.437**	.001[a]	.047
	Residual	442.351	491	.901			
	Total	464.024	498				

a. **Predictors:-**Social Support, Distancing, Self-controlling, Escaping, Acceptance, Plainful
b. **Dependent Variable**: Academic Achievement

In order to determine if coping strategies was positively associated with academic achievement, as measured by grade point average, the researchers performed a multiple linear regression using the six subsets of coping strategies (Social Support, Distancing, Self-controlling, Escaping, Acceptance, Planful problem solving) as independent Variables. The result in table 4.7.1($F=3.437$, $P<0.05$) demonstrated that the coping strategies together significantly predicts the Academic achievement of students. However, when further regression was computed to investigate each variables predictive power only self-controlling coping technique was significantly ($F=11.764$, $P< 0.05$) determine the academic achievement. Thus the variability of self-controlling coping strategies accounted for about 2.3% of change in academic achievement.

Result, discussion, and Recommendation

Results and Discussion

This research was designed to investigate the levels and nature of stress experienced as well as coping strategies used by undergraduate freshman students of Jigjiga, Haramaya and Dire dawa Universities. In addition, it aims to examine the relationship between self-esteem and academic achievement of the students as well as the extent to which adjustment problems predict the academic achievement and self-esteem of first year students. To explore the findings, samples of 509 first year students were selected randomly from respective Universities across different faculties. As a result the following research findings were investigated.

In order to determine the potential adjustment problems encountered by first year Eastern Ethiopian public university students the simple statistics of grand mean analysis was done. Accordingly, the Academic adjustment, social adjustment and personal emotional adjustment were the main challenges encountered by the students. Furthermore; the qualitative analysis of the students' responses to open ended item assured that Academic adjustment like: Inability to adapt to new learning styles in the university, lack of cooperation in assignment work, Fear of University exam approaches and teaching methodology of teachers, Lack of time management skills and study skills found to dominant in stressing the students. With regards to the level of stress experienced; the research also assured that half of students experienced stress at the moderate level. Still some of the students have had encountered very high level of stress. The students' had experienced moderate level of adjustment problems with academic adjustment being the highest followed by social and emotional -personal adjustment problems.

To determine the difference in adjustment problems between sexes ANOVA was computed and the result indicated that Male students experienced more academic adjustment problems than that of females. Thus the finding confirmed that the female students were experiencing lesser university academic adjustment problems than their male counterparts. But there was no significant difference between male and female students in social and personal emotional adjustment problems. The qualitative data result also supports that the major factors which were a barrier to the first year students to fully apply their potential and efforts were:

- Time management and study skill challenges
- Misconceptions about the difficulty levels of university Exam
- Teaching methodology of instructors
- lack of cooperation in assignment work among students
- Inability to quickly adjust with the life styles in the university

To put it in a nut shell most of the challenges were academic in their nature which tends to be supplemented by the social and personal emotional adjustment difficulties.

In order to investigate the nature and type of coping strategies adopted by first year students the finding indicated that the majority of the students prefers to use emotional focused coping strategies (Accepting responsibility) followed by problem focused coping strategies (planful problem solving) to adjust to adjustment problems in the universities.

Moreover the qualitative data supplements that the majority of the students were inclined towards using emotional focused coping like being optimistic, confronting the challenges, studying strategies to cope up with the academic and social adjustment problems of the universities. Still a few of the respondents assured that they have used negative coping styles of sleeping too much, taking stimulant substances and escaping away from the challenges. Moreover, with regards to coping strategies used the result of the research affirmed that male students were using Planful Problem Solving and social support coping techniques more often than that of Female students whereas self-controlling was used more often by female students than males. But, there were no significant mean differences between male and female students in using escaping, acceptance and distancing techniques of coping strategies.

The result of correlation coefficient indicated that those students who highly used escaping coping strategy tends to have lower self-esteem and vice versa. In addition, there was a positive relationship between GPA of the students and self-esteem. Moreover, the correlation implied that those university students who highly used Acceptance and Planful problem solving coping techniques would have higher self-esteem. But there was a low negative relationship between self-esteem and escaping coping technique. On the contrary, there was no any relationship between self-esteem and coping techniques of: self-controlling, social support, and distancing. In addition, there was a positive relationship between GPA of the students and self-esteem.

Academic adjustment problems statistically predict the self-esteem levels of students**.** However, the social and personal emotional adjustment problems did not significantly predicts the self-esteem level of first year university students.

The coping strategies together significantly predicts the Academic achievement of students. However, when further regression was computed to investigate each variables predictive power only self-controlling coping technique was significantly ($F=11.764$, $P< 0.05$) determine the academic achievement. The present study also corresponds with the findings of Brown & Cross (1997) which confirmed coping as a significant predictor of achievement, but differs from Ryland et al. (1994), who found no relationship between coping and academic achievement. However, the result was inconsistent across different situation which signify further investigations of the problem with large samples.

Lastly the finding indicated that variability in the academic achievement of students accounted for by the pulled impact of the social, Academic and personal emotional adjustments and total stress level was significant. But, the independent regression of each variable alone did not predict the academic achievement levels of students.

Conclusion and Recommendation

This study has provided evidence that first year students experienced academic, social, and personal emotional adjustment which in turn affects the academic achievement and self-esteem of students in the university. Hence, it is important to help students' especially first year undergraduates to identify various coping strategies to overcome stressful encounters during the transition period to higher institutions.

It would be beneficial for students if relevant authorities and personals institutions of higher learning such as policy makers, university administrators, lecturers, counselors, academic advisors are aware of the importance of coping skills to be acquired by students upon entrance to the university, thus, providing the knowledge of coping to these students before they proceed with their studies is important.

Counselors and academic advisors should equip themselves with the knowledge of coping in order to help students who have difficulties in adjusting themselves to life in campus. They should be able to provide appropriate advices on the effective use of coping strategies to reduce distress in coping with adjustment problems. Perhaps, one way to do that is to include coping effectiveness intervention or training in the orientation program organized for university freshmen which is usually conducted during the first two weeks of the first semester. As suggested by Folkman et al. (1991), coping training can begin by familiarizing participants with the distinction between problem-focused and emotion-focused coping using hypothetical and real life situations. Trainings should also include teaching participants on the fit between appraisal and the coping strategies used for effective coping. The exercises used in the training sessions should include examples of stressful situation or events that might be encountered by students during the college/university transition which focus on the four adjustment dimensions (academic adjustment, personal-emotional adjustment, social adjustment, and attachment and commitment to higher education and institution). Maintaining and enhancing support and communication systems from friends, peers, and senior students should be promoted for students in coping with problems in learning and life skills.

Students should be made aware of the various coping strategies available when confronted with stressful encounters, the accurate appraisal of the changeability of the person-environment relationship and the fit between appraisal and the coping strategies used for effective coping that could reduce stress. Since findings in this study indicated that 'Escape-Avoidance' and negative coping techniques like sleeping too much, using substances had a negatively correlated with students' self-esteem and academic achievement, students should be cautioned against the use of this coping strategy in dealing with adjustment problems during college/university transition.

We would like to urge the relevant ministry of Education in-charge of Higher Education and the student affairs division of respective universities to consistently plan suitable activities or programs for the students such as organizing training on self-management, motivation, time management, study skills and stress management. These programs should be organized continuously, not only during orientation week. Such programs and activities would help the students to identify, understand and manage their stress levels.

More importantly, the research finding indicated that academic adjustment was found to be the main challenge to institutional adjustment. Thus each faculty and department together with the directorates of assessment in higher education should give consistent awareness creation training on examination and test as well as teaching learning process to correct the misconception and illusion of freshman students.

With regards to social and personal emotional adjustments the respective universities should establish an organized student support system whereby the students get guidance and counseling and assistance though student dean services. Moreover, the administrative body of the university should also develop a formal peer group of students whereby the students guide and update the new students on teaching learning, assessment and social life in the universities.

The present study employed a correlational and survey approach where the data were collected from the respondents in a semester. Accordingly, a future study is suggested to be carried out using the cross sectional and longitudinal method to examine the development/progress of students' coping abilities throughout their learning period in the university. For future research, a qualitative and quantitative approach can be used to investigate the various specific coping strategies that might contribute to university adjustment and academic achievement among undergraduates as well as factors (e.g., demographical and psychological factors) that are related to students' coping efforts and choice of coping strategies in dealing with college/university transition.

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4. Institute of Technology

Evaluation of the efficiency and sustainability of small-scale dams and river diversion weirs and their Design: The case of wertebi basin, Harar, Eastern Ethiopia

By

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Introduction

The project area, Mawir-I and Mawir-II are located in Hareri National Reginal State. It is found at a distance of 8 KMs to the eastern direction of Harar town. This small scale irrigation project is based on Mawir River as source of water. The project area is characterized by three types of local geologic formations. These are the Precambrian basement complex which is exposed as a bed rock, the Mesozoic Sedimentary formation which composes sandstone and limestone and the valley filled alluvial sediments (deposits). The Precambrian basement rock unit underlies the unconsolidated alluvial deposits (sediments) and the Mesozoic formations. It has been observed from the outcrop exposures and test pit dug that the basement bed rock unit is weathered and fractured. The detailed field observation test pit investigation and its descriptions are given in chapter 2 below.

Physiography

The Physiography of the study area is the Escarpment which is among the three major tectonically controlled Physiography of the eastern Harar. The Escarpment is the topographically ragged areas and with tilted blocks affected by faults. It marks the western, northern and eastern boundary of the area. The rock types in the Escarpment are lime stone and the basement. The project area is located in the alluvial plain. The morphology of the river is more of flood plain type. All the drainages start from the Escarpment and transport emotional material during rainy season.

Geological-Geotechnical Appraisal of Weir Site

General

The major geotechnical focuses carried out in this investigation incorporates the geomorphologic setup, geology, foundation rock units, water tightness, shear zone, slope failure, bedding and the availability of construction materials for the weir site, pond area and the main canal route.

The foundation rock units of the weir site and main canal route are the Precambrian rock, which is granitic gneiss. The gneisses composed of quartz, feldspars and biotite mica. This basement rock unit is highly weathered and it is overlain by thick alluvial deposit up to 10 m (Figure 2). Both proposed weir sites (Mawir-I and Mawir-II) are characterized by up to 3 m thick transported well graded sand deposits (Figure 1). The foundation is basement rock (weathered and fractured) overlain by those sand deposits (Figure 3). At the diversion weir there is high seepage due to the loose sand deposited over the weathered and fractured basement rocks. Along the main canal route there are soil gullies that could facilitate the loss of water by infiltration and percolation that contributes to seepage processes. The gullies along the main canal route are exposed due to erosion of the loose soil deposit in the preexisting canal line (Figure 3). There are also trees and shrubs found along the main canal lines. Every 200 meters along the main canal routes of the two weirs test pits were dug and detail lithological descriptions were done. The soil representative soil samples were also taken for further engineering laboratory test.

Figure 1: thick transported sand deposit at Mawir-I weir (left picture) and Mawir-II weir (right picture) sites

Figure 2: thick alluvial deposit with trees and bushes (left picture) and gullies along the canal route (right picture)

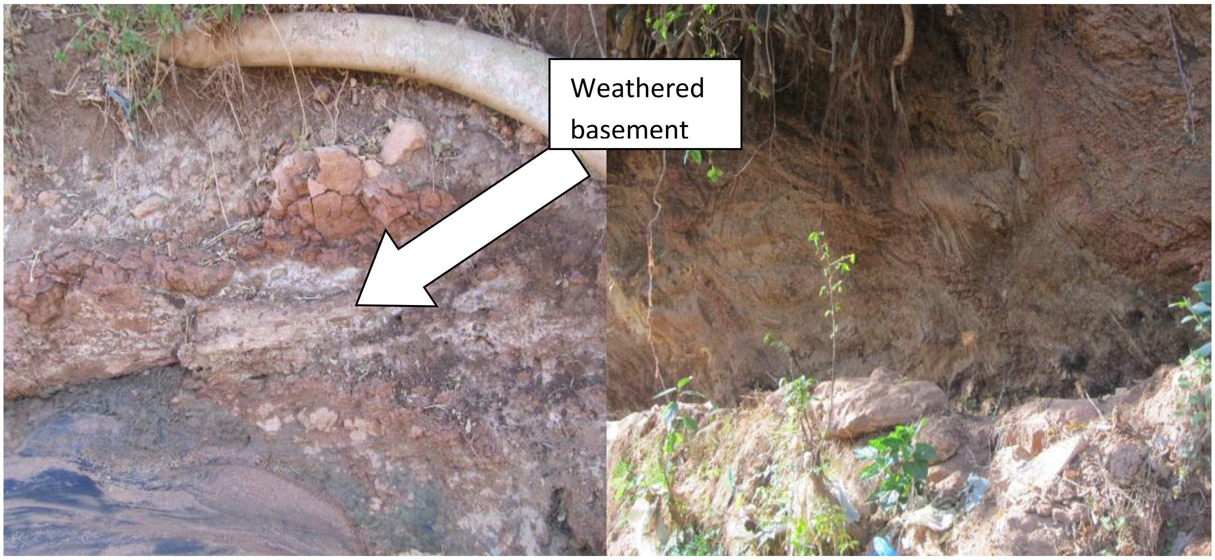


Figure 3: Fractured and weathered basement rocks along the canal route

Mawir-I Weir Site

Test Pits

Two 1mx1m test pits, MWRTP-1 and MWRTP-2 (Table-1) have been dug at the two ends of the weir axis. The subsurface condition of the weir site was investigated with the help of these test pits dug along the weir axis. No test pit has dug at the center of the weir axis due to water clogging into the test pit during digging through thick sand deposit along the river course where preexisting weir was done. According to the test pit description three major layers are characterizing the weir site. These are:
Layer 1: coarse to fine sand deposit,
Layer 2: black plastic clay layer,
Layer 3: weathered basement rocks

Layer 1 varies from coarse to fine sand depots. From test pit MWRTP-1, MWRTP-2 at the two ends of weir axis and the historical background of the existing weir, the sand deposit thickness varies from 0.4m at the right abutment, up to 3 meters at the centre and 0 thickness at the left abutment of the of the weir axis. Layer 2 is a black plastic clay layer at the right abutment of the weir MWRTP-1 has a thickness that varies between 0.4 to 0.7 m. The third layer is the bed rock which is the weathered basement complex underlying the sand and clay deposit. The lithological log of the weir site is summarized in Table 1 below.

Table 1: Summary of test pit along the weir axis of Mawir-I

Pit/Auger	X-UTM	Y-UTM	Z	LITHO-LOG Description	Remarks
MWRTP-1	187669	1029244	1697	Layer 1, 0-0.4m, coarse to fine sand deposit	at the right abutment of Mawir-I weir axis test pit 1
				Layer-2: 0.4-0.7 m: plastic clay soil	
				Layer-3: 0.7-1.0 m: Fractured and weathered basement rocks (quartzo-feldspatic basement rocks)	
MWRTP-2	187676	1029250	1695	Layer-1:0-0.2m: Weathered/Fractured quartzo-feldspatic gneiss	Left abutment of the weir axis test pit 2
				Layer-2: 0.2-0.8 m: Weathered biotite intercalated with feldspatic gneiss	

Mawir-II Weir Site

Test pits

Here also two test pits at the two ends of right and left abutment of the weir axis were dug. These are MWR2TP1 and MWR2TP-2. These test pits investigated generally four (4) soil layers. These are cited below.

Layer 1: black cotton soil
Layer 2: coarse to medium grained sand deposit
Layer 3: black plastic clay soil
Layer 4: coarse to medium sand deposit with gravel
Layer 5: weathered basement

Layer 1 is the top layered black cotton soil with thickness varies between 0-7m at MWR2TP1. The second layer is coarse to medium sand deposit that varies from 0.7 to 1.0 m in thickness. Layer 3 is a black plastic clay soil with thickness varies between 1.0 to 1.4m. The fourth layer is coarse sand deposit with gravel with thickness varying between 1.4 to 1.7 m. the description of the subsurface investigation at Mawir-II site is given in Table 2 below.

Table 2: Summary of test pit along the weir axis of Mawir-II

Pit/Auger	X-UTM	Y-UTM	Z	LITHO-LOG Description	Remarks
MWR2TP1	188517	1028913	1680	Layer 1, 0-0.7m,black cotton soil	This at the right abutment of Mawir-II weir axis
				Layer-2: 0.7-1.0 m: Coarse to medium sand deposit	
				Layer-3: 1.0-1.4 m: black plastic clay soil	
				Layer-4: 1.4-1.7 m: Gravel with coarse sand deposit	
MWR2TP-2	188527	1028926	1674	Layer-1:0-0.4 m: Coarse to medium sand with fine gravel deposit	Left abutment of the weir axis
				Layer-1:0-0.4 m: Coarse to medium sand with fine gravel deposit	

Main Canal

Mawir-I

The main canal is aligned on the right side of the river coarse and it stretches to about two kilometres downstream of the weir site. The main canal does not have a straight alignment and similar surface and subsurface properties. Due to this, the study and description of the main canal was investigated by conducting eleven auguring every 200 meters along the main canal of Mawir-I for subsurface investigation. The descriptions for each auger are given in Table 3 below.

Table 3: Summary of test pit along the canal route of Mawir-I

Pit/Auger	**X-UTM**	**Y-UTM**	**Z**	**LITHO-LOG Description**	**Remaks**
MW1A1	187681	1029235	1697	0-1.0 m Coarse to medium sand deposits	This is transported sand deposit at 90m distance from the downstream of Mawir-I Weir site. The sand deposits is underlain by the weathered basement rocks after 1 meter.
MW1Point 2			Weathered basement rocks outcrops exposure at 290 m from the weir site downstream		
MW1Point3				at the distance of 351m downstream of weir along the canal route line	Here there is overburden of up to 5-10 m thick alluvial deposit underlain by fractured and weathered basement rocks. There are also mall trees and bushes found along the canal rout.
MW1A2	188010	1028938	1693	0-2.0m black silt clay soil deposit	This is at 445m downstream from the weir site along the canal line. The place is serving as a pond to collect and reserve the water for the next farm land.
Pond2	188098	1028444	1694		This is the second pond site at 575 m distance downstream the weir site. The pond is placed about 3m below ground surface, and overlain by about 3 m thick alluvial

					deposit. It has similar layers of soil deposit with that of MW1A2.
MW1A3	188195	1028794	1691	0-0.3m Black cotton soil; 0.3-1.80m compacted reddish sand with silt soil	This is two layer soil, 2 samples were taken (MW1A3-1= 0.3m depth, MW1A3-2=0.5m depth.
MW1A4	188400	1028710	1690	0-0.3m Black cotton soil; 0.3-0.5m compacted reddish sand with silt soil	This is at 900 m downstream the weir site, and the soil types and the two layers are similar to MW1A3.
MW1A5	188464	1028547	1694	0-0.7m highly weathered quartzo-feldspatic gneiss	This at the place of 1.04km distance downstream from weir-I site along the canal route line.
MW1A6	188295	1028380	1695	0-0.3m quartz-feldpatic and boitite gneiss, 0.3m-0.4m feldspatic gneiss	this is at 1.06km downstream from the weir site
MW1A7	188264	1687	0-1.20m brown silt clay soil with gravels and pebbles, 1.2m-8m weathered quartzo-feldspatic biotite gniess	this is a hand dug well with water at 1.06km downstream from the weir site	MW1A7
MW1A8	188498	1028368	1687	0-0.5m sandy silt soil deposit with gravels and pebbles, 0.5m-0.55m weathered quartzo-	This area is covered with spares vegetation of small bushes and shrubs. It is at distance of 1.19km downstream from weir site and it is also the end of the canal

				feldspatic gneiss	route.

Mawir-II

This is the second weir site main canal route line. The same way as that of Mawir-I main canal subsurface investigation was carried out. The main canal of this weir site is also aligned along the right side of the river course. It stretches to about 2 kms downstream from the weir site. The left side of the canal route has very weak formation with collapsible and steep slope that cannot overcome the problem of flood during the rainy season. Table 4 below summarizes the test auger description.

Table 4: Summary of test pit along the canal route of Mawir-II

Pit/Auger	**X-UTM**	**Y-UTM**	**Z**	**LITHO-LOG Description**	**Remaks**
MW2A0	188548	1028896	1676	0-3m thick transported well graded sand deposit	This is at 50m downstream the weir site; and there is about 5m alluvial deposit to the right abutment along the canal route.
MW2A1	188728	1028802	1672	0-10.0m thick alluvial deposit with medium gravel	There is about 10 m thick alluvial deposit overlaying the basement rock, it is about 240m downstream from the weir site.
MW2K1	188897	1028646	1679	0-1.0m silt sand soil deposit with medium grade gravel (alluvial); 1-1.40m Weathered quartzo-feldspatic gneiss	This is Mawir-II weir site pond 1 site about 470m downstream from the weir site
MW2A2	188779	1028488	1678	0-1m brown silty sand soil deposit	About 1 m silt sand soil deposit overlaying the basement rocks, 500 m from weir site.
MW2K2					This is pond site along the canal route of Mawir-II weir site, it has about 5m thick clay deposit
MW2A3	188988	1028363	1672	0-1m silt sand with	This is about 727m from the weir

				medium gravel deposit; 1-1.5m weathered quartzo-feldspatic gnies	site
MW2A4	189058	1028163	1668	0-1m silt sand soil with coarse sand and medium gravel deposit; 1.0-1.40m weathered basement	This place along the canal line is good exposure of the surface that clearly indicates the canal route , it is about 931m downstream from the weir site
MW2A5	188993	1027954	1668	0-0.3m brown silt clay soil deposit with coarse sand; 0.3-0.4m highly weathered quartzo-feldspatic gneiss	This is about 1.08km downstream the weir site

Pond Sites

There are numbers of ponds along the main canal route. Pitting and sampling were conducted to investigate the pond area. It is observed from the pit description that the pond area is filled with black clay soils. Fig 3 below shows the pond area along the route line.

Figure 4: Pond area along the canal route.

Activities/research that should be conducted to give geotechnical recommendations

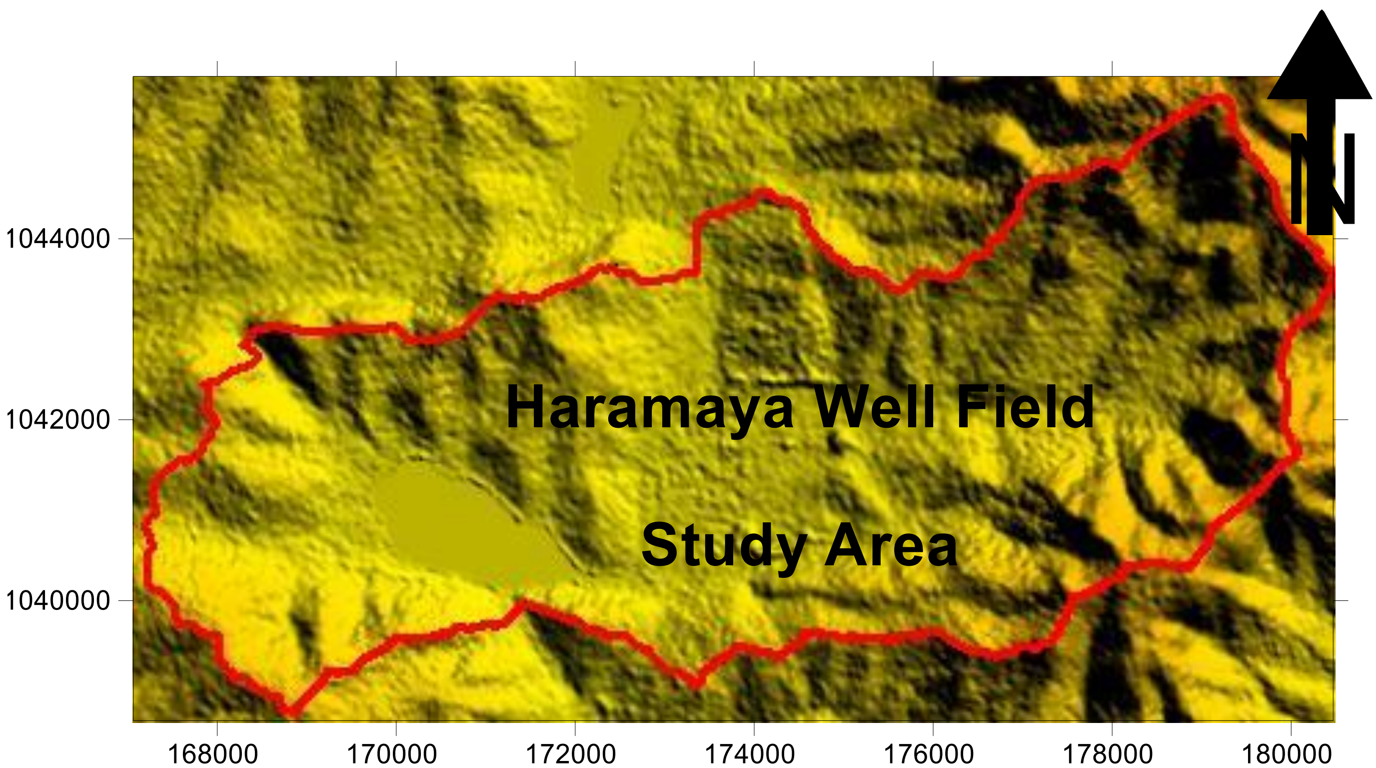
1. The soil should be tested in the laboratory for the following soil engineering properties: Atterberg Limit accordance with AASHTO T89, T90, Liquid limit, Plasticity Limit, Plasticity index, AASHTO Soil Classification Test, and Sieve Analysis.

2. Geophysical investigations, groundwater condition, and construction materials study.

Evaluation of Groundwater Productivity of Haramaya well field, Oromiya National Regional State, Ethiopia

By

Megersa Olumana and Guesh Zeru (PhD student)



Figur 1: Haramaya well field study area

Part I: Ground water resource

Introduction

Water is our most precious resources and an essential commodity to mankind and other living entities on the planet earth. Fresh water that supplied all demands is obtained from surface water and groundwater resources depending on their accessibility, availability, and reliabilities. In the study area that located in the Weynadega agro-climatic zones, Eastern region of the country groundwater is an irreplaceable resource for all water related economic activities of the region (small and major towns, University and local community) since Lake Haramaya was vanished 2004/05. Groundwater is the largest available reservoir of fresh water approximately 50 to 70 times more plentiful than surface water (Fetter**,** 1994) and it is the most important water resource on earth (Shalini et al., 2012), in buffering the effects of rainfall variability and inaccessibility (Calow et al., 2010). Groundwater occurs or found almost everywhere breath the land surface in every ecosystem throughout the world (Coker et al., 2008; OREGON, 2012 and IGCP, 2001), although it is a finite resource (Chatterjee et al., 2009) and have a great variation in its abstraction from place to place due to none uniform distribution of rainfall and characteristics of aquifers. Groundwater is an important and dependable source of water supplies in all climatic regions of the world because of its several inherent qualities (Todd, 2005) and many advantages (UNESCO, 2012).

In 21st century, the rapid rising in population and urbanizations, booming irrigation schemes and industrialization, the temporal variability, limited availability and less reliability of surface water; all economic activities tends to converges to groundwater resources across much of the world especially in Sub-Saharan Africa including the study area. According to (UN/WWAP, 2003; Villholth, 2006), in most parts of the developing world, rapid expansion in groundwater exploitation occurred between 1970 and 1990. Nowadays, it is the primary source of drinking water nearly half of the world's population or 2.5 billion People worldwide depend solely on groundwater resources (Kundzewicz & Doll, 2009; UNESCO, 2012). The use is likely continued to expand in developing countries and this led to dependent on groundwater sources globally in the future (Morris *et al*., 2003 and UN/WWAP, 2003). Based on research works in Ghana, Malawi, South Africa and Ethiopia (Calow et al., 1997; MacDonald and Calow, 2007) were predicted the future likely increase in demand for groundwater.

However, groundwater resource is often subjected to several natural and anthropogenic stresses on both unconfined and confined aquifers. Particularly in the developing countries the one and serious global concern and threatening the life of our future generations is over exploitation (UNESCO, 2012 and Kemper, 2004). The significant increment of widespread development and future unsustainable abstraction of water resource was illustrated by (Kundzewicz *et al.*, 2007; IPCC, 2009; Taylor et al., 2004; Taylor and Tindimugaya, 2009 and Hetzel et al., 2008) as expected stresses. Consequently groundwater level depletes globally by the day due to these twin stresses especially in Africa including the study area. This worried issue was stated by numerous studies (e.g. Shah *et al.*, 2000; Powell, 2012; Costa et al., 2003; Foley et al., 2005; Nilsson et al., 2005; Huntington, 2006; Zhang et al., 2007; Adam and Lettenmaier, 2008; Barnett et al., 2008; Sahoo and Smith, 2009; Wang, 2009; Vorosmarty *et al*., 2005; and Carter & Parker, 2009).

Despite of its key importance and obvious needs; a comprehensive research works regarding quantitative evaluation of these coupled natural and anthropogenic stresses acting on it and proper understanding of the hydro-geological set up of an area are limited relative to surface water in many developing nations like Ethiopia including the study area. Other additional pressures are the spatial and temporal changes in climate variability and change may modify the surface hydraulic boundary conditions that ultimately cause the water balance of an aquifer (e.g. sediment on Tinke Lake in the study area). The current and expected dramatic increment in climate variability & changes are also controlled the groundwater potentials and will be the future challenges. However, it received limited attention globally compared to surface water resources (Kundzewicz et al. 2007). Nowadays a wide array of scientific research has been carried out on the potential effects of climate variability and change on water resources globally (IPCC, 2007; USGS, 2009 and Milly and Others, 2005; Green et al., 2011 and UNESCO, 2008; IPCC, 2001) though, it is little.

In fact it is challenging and complex to distinguish between human and climatic stresses (Chen and Others, 2004; Hanson and Others, 2004 and Taylor, 2001). In addition to its difficulties (UNESCO-IHP, 2012, Bates 2008; IPCC, 2001 & 2007; Kundzewicz et al., 2008; Shah et al., 2000) was stated the knowledge gap and less attention received in this issues. Groundwater occurrence and movement is governed by subsurface characteristics (Dor *et al.,* 2011), rainfall pattern and the interrelation between recharge to and discharge from an aquifer (Freeze and Cherry, 2002; Butler, 2005). Such hidden nature makes difficult to visualize it.

Especially in Africa including Ethiopia due to the huge diversity in geology, climate and hydrology (Walling, 1996), the relationship between variable hydro-climatology and groundwater resources is not well characterized (Konikow, 2011).

Moreover, in any planning of groundwater development & designing effective and sustainable management strategies, estimation of groundwater recharge (addition of water to a groundwater reservoir defined by Taylor and Alley, 2001) and evaluation of available potentials are pre-requisite. The principal advantage is illustrated directly or indirect in many literatures (e.g. Alley *et al.,* 2002; Ahmed *et al.,* 2008; Darkwa et al., 2013; Healy and Cook, 2002; Lee et al., 2005; Ahmadi et al., 2013; Ordens et al., 2012). However, it is difficult and challenging tasks (winter, 2001; Scanlon *et al.,* 2002; Sanford, 2002; Scanlon *et al*. 2002 cited on Darkwa et al., 2013 and Ordens *et al.,* 2012) due to its widely varied with time and space.

Likewise, in the study area located in the Weynadega agro-climatic zones, in the Eastern region all water related economic activities of the region (small and major towns, Universities and local community) are mainly dependent on groundwater resources since Lake Haramaya was vanished 2004/05. Consequently demands and computation between water users and development of groundwater rises drastically and abstracted substantially to satisfy the short term agenda without understanding the hydro-geological set up, groundwater behavior & available reservoirs, future demands and stresses acting on it. However, effective and sustainable management of groundwater resource requires a research work on groundwater potential availabilities in relation to the human effect, climate effect, clear understanding of hydro-geological set up that ultimately controlled the groundwater occurrence and budget. This is the current demanded tasks globally including the study area, which was addressed in this study.

This study was conducted aiming to investigate the dynamics of groundwater system in accordance with quantifying the relative influence of climatic variability & change and abstraction on the course of groundwater level, to evaluate the groundwater productivity of the well field and to quantify the groundwater recharge of the well field.

Numerous studies have since been made in the study area (e.g. Solomon, 2002; Shimelis, 2003; Wagari, 2005; Geletu, 2006; Abudelaziz, 2006; Edo, 2009; Nata *et al.*, 2010; and Abebe, 2010) on lake water management; groundwater assessment and groundwater recharge estimations. However, research works with regard to the hydro-geological set up including sub-surface boundary conditions (whether the aquifer is opened or closed), groundwater flow patterns (i.e. how water enters the aquifer system, how water passes the aquifer system, how water stored in the aquifer system and how water leaves the aquifer system), aquifer characterization (type, number, capacity etc), groundwater recharge-discharge mechanisms and the relative effect of the two hydrologic stresses acting on it was not investigated at a local level which is the main agenda of this research work.

Nowadays there are a number of proposed statistical methods for distinguishing between natural and management induced impacts (over abstractions) including HARTT (Hydrograph analysis; rainfall time trend) for trend analysis of groundwater level. This powerful tool is applicable for unconfined aquifer system that enables to split these twin stresses. There are also a number of aquifer characterization methods including pumping test, laboratory analysis method and geophysical method. Similarly scientists have been conducting various researchers on recharge assessments in separate hydro-geological conditions, climatic zones all over the world that was documented on (Sharma, 1989; Lerner *et al.*, 1990; Scanlon *et al.*, 2002 and Merechal *et al.*, 2006). Among the wide variety methods developed; water balance methods, Darcy's law, tracer techniques, numerical modeling methods, empirical methods, water table fluctuation method (WTF) (De Vries and Simmers 2002; Lerner *et al.*, 1990; de Silva, 1998; Scanlon et al. 2002) are widely applied.

Therefore, to fill the knowledge gaps and reduce uncertainty regarding the predictions and impacts of climate change on groundwater resources, to evaluate the available groundwater potential and to set future groundwater management options, three experiments including Trend analysis of groundwater level using HARTT model, Aquifer characterization using integrated approaches of hydro-geological and geophysical was performed to provide the subsurface geological formations and groundwater recharge estimation using the widely applied water table fluctuation (WTF) was conducted in the well field. The finding provides essential background information and evidences about the geology and the present hydrologic state of an area which is vital in designing and planning sustainable management systems for water managers, multiple stakeholders including hydrologists, users, and policy makers to assess choices for long term water management policy.

The ability to understand and interpret changes in groundwater levels is essential for sound management of groundwater resources (Ferdowsian and Pannell, 2009). Accordingly, groundwater level changes of Haramaya lake well field area over the period 2000-2012 were analyzed in an attempt to separate the effect of climate from the effects of abstraction before and after the Lake Haramaya vanished (2004/05).

Materials and methods

Study area description: The study area Haramaya well field is situated on the eastern part of Ethiopia, Oromia Regional State, Haramaya Woreda, East Hararghe Zone, 21 km west of the city of Hararghe, and 505km East of Addis-Ababa (capital city of the country). It lies $9^0$22’ 03’’–$9^0$27’12’’ N and $41^0$58’14’’–$42^0$05’26’’ E. that bordered on the south by Kurfa Chele on the west by Kersa, on the north by Dire Dawa, on the east by Kombolcha, and on the southeast by the Harai region. with a total area of 50.07km^2 and elevation ranging from 2018m to 2422m a s l that characterized by Woina-Dega agro-climatic zone (Daniel, 1974). The mean annual rainfall of (1979-2012) is 775.9mm but value of 771.1mm was obtained for 2000-2012 that decreased by 4.8mm or 0.62%. The monthly rainfall is more than 100mm from April to September, except June 48.4 mm. The wettest month is August with 150.9 mm. The daily temperature ranges from about 10^{0}C to 25^{0}C. From the data of 2000-2012; the monthly rainfall is more than 100mm from April to September, except June 48.2 mm, the wettest month is August with 160.6 mm and the daily temperature ranges from about 11^{o}C to 24^{o}C.

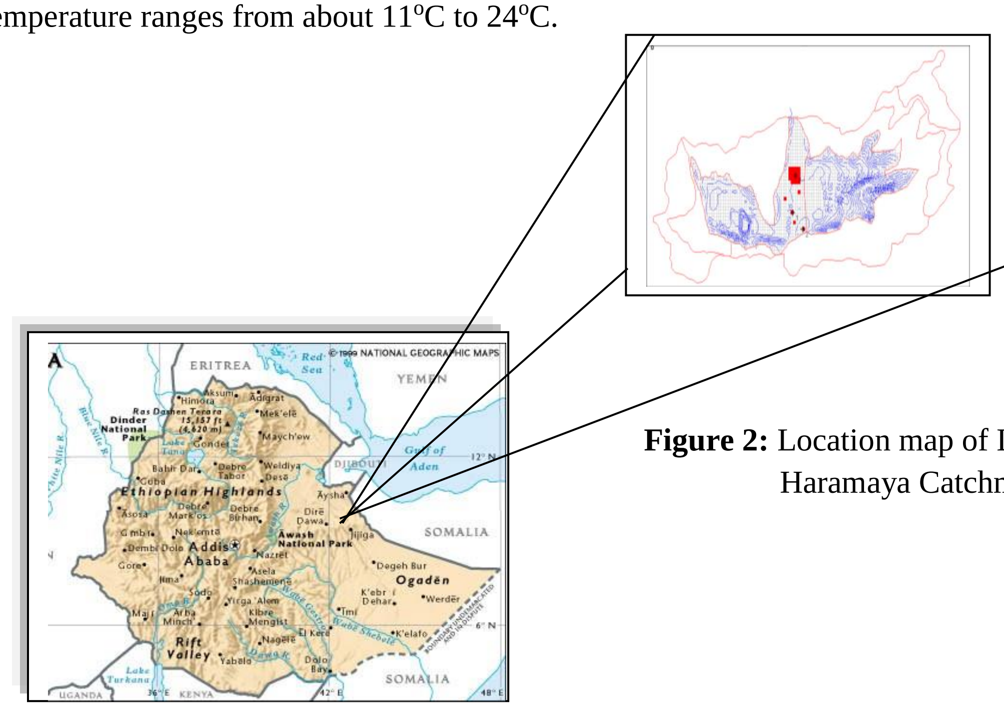


Figure 2: Location map of Lake Haramaya Catchment

Geology and hydrogeology: The geology of the region was summarized in the Hararghe Map Sheet (NC 38/9) by Geological Map of Ethiopia (GME, 2010) and Wabi Shebele Basin Master plan study in to three major Stratigraphic units including the Precambrian crystalline basement (mainly granite), Mesozoic sedimentary rocks (Adigrat sandstone and limestone) and recent Quaternary sediments (Figure-2.2) from older to recent. The Ethiopian geological survey (2010) was subdivided into three physiogrphic including Plateau areas, Rift escarpments and Rift Plain. The plateau was filled by lacustrine sediments forming flat highlands of Lake Haramaya, within mountain terrain. Moreover, Dainelli (1943) was summarized all investigation up to the year 1943 in his classical master piece about the geology of the Horn of Africa. The general geology and petrography of Hararghe Plateau were reported and discussed by many authors including (e.g. Gortani and Bianohi, 1937, 1938, and 1941; Von Zur Muhlen and Brom, 1943). Moreover, Alemu and Kebede, (1997-1998); Brook Lemma, (1991), Abdulaziz, 2006; Alemayehu et al., (2007); Nata *et al.,* (2010) were characterized the local geology of the study area.

The Precambrian crystalline basement (mainly granite) were exposed throughout the study area that overlying by Adigrat sandstone (Figure-2.2) covering about 46.3% of the total area of watershed. Adigrat sand stone overlying the basement complex is fine to medium grained less cemented, sorted or non-sorted at places cross bedded, yellow, reddish brown to white sandstone that formed during the Mesozoic period when subsidence of land mass and uplift of sea floor occurs that occupying an area of 7.2 km^2 having a moderate range of permeability and productivity. The Lake body is made of Precambrian crystalline rocks were filled by r**ecent** quaternary deposits of unconsolidated sedimentary rocks occupying the depression or low lying areas (Alemayoh et al., 2006; WWDSE, 2002; Karamara engineering, 2005; Nata, 2009; Geletu, 2009). The genesis of the unconfined aquifer system is the unconsolidated sediments occupying the undulated depression of basement rocks. The lower limestone unit is (Antalo limestone) occupying mountains and hills and this makes the exploitability of groundwater resource of the formation quite limited occupies only about 5% of the total catchment area.

Hydro-geology and Hydro-stratigraphy of the study area: This section integrates available hydro-geological information’s to create a hydro-geological, hydro-stratigraphic concept of the area. This concept is vital in understanding the regional and local settings, groundwater flow system and directions and the genesis of the aquifer system of the area. The hydro-geology of the area was characterized using integrated approaches of geological well logs, geophysical survey, trend analysis of groundwater level and surface geological maps (Figure 2.3).

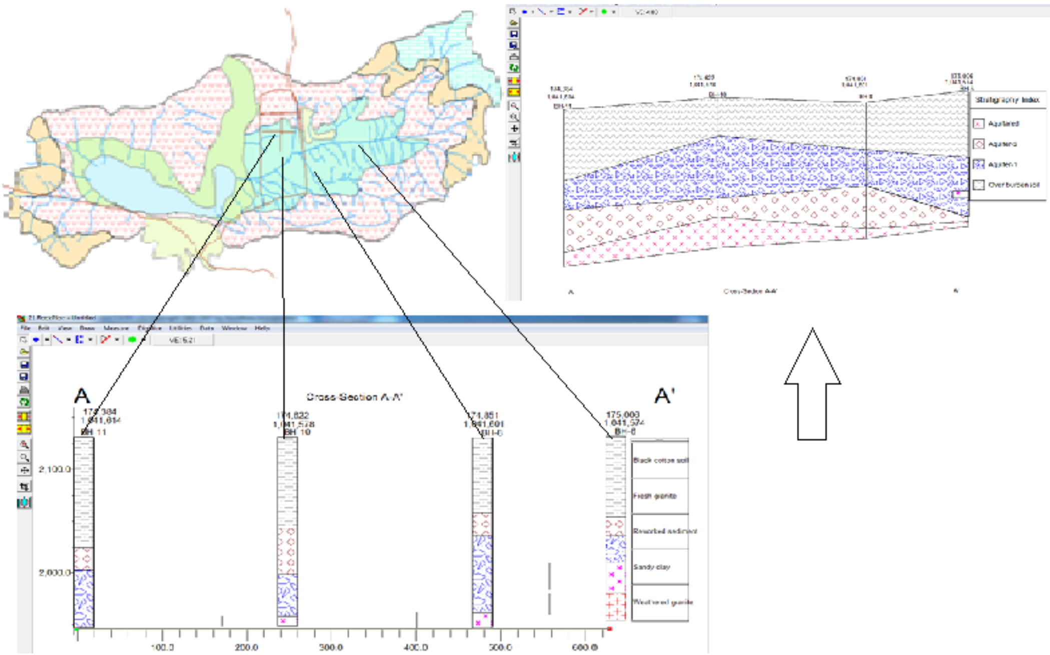


Figure 3: Geological map, well location, and geological well log

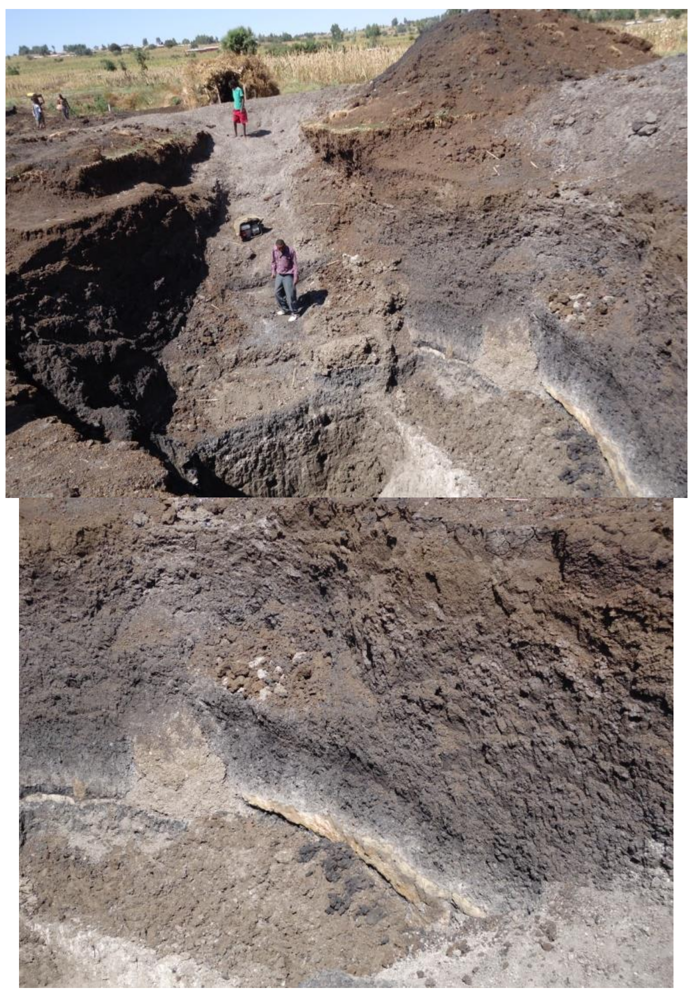


Figure 4: Hand dug wells found in the study area at a depth of 8m

The hydro-geological set up is characterized by porous, single, unconfined aquifer and closed boundary condition throughout the perimeter and on the lower bed except on the northern boundary interconnected with Lake Tinke. It is characterized by three hydro-stratigraphic units including upper top dry cotton soil, unconsolidated sediment, weathered and slightly fractured basement rocks and the massive bed rocks. From the hydro-geological point of view the alluvial sediment (most important aquifer), high fractured and the moderate to less fractured and weathered basement rocks are the water bearing formations of the area.

The top dried soil is composed of clay, silt and fine sand having an average thickness of 13m which is well compacted, less permeable and less conductive. The alluvial sediment are composed of sand, pebbles & rock fragments, silt and clay deposits (Alemayoh et al., 2006) having a thickness ranging from 17 to 35m. The hydraulic characteristics of the unconsolidated sediment covered the depression or low lying areas occupy 34.4% of the study area. There are nineteen (19) shallow and deep wells ranging from 13-72m depth, 924 hand dug wells and two springs on eastern side (at the contact between sand stone & basement rock) and western sides average discharges of 0.5l/s were exist. All boreholes (19 borehole) and more than 98% of hand dug wells are located in these sediments. Among the wells in the unconsolidated sediment of the watershed, data of seven wells of Harer Town Water Supply and Sewerage Authority and nine (9) wells owned by Haramaya University are available and the researcher used these data to evaluate the productivity of these aquifers.

As confirmed from all wells the hydraulic characteristics of the basement rock units are massive with small shallow vertical joints having low productivity and all of them have maximum water column of 1m.

While the Mesozoic rocks (Sandstone and Limestone) rock units are found on the upper part of the study area by covering an area of 9.8 km^2 together found occupying mountains and hills having quite limited, exploitability of groundwater resource though there are a few number of high discharge springs characteristically emerge at the contact between sandstone and underlying basement. This characterizes the moderate productivity nature of these aquifers (Tesfaye, 1993).

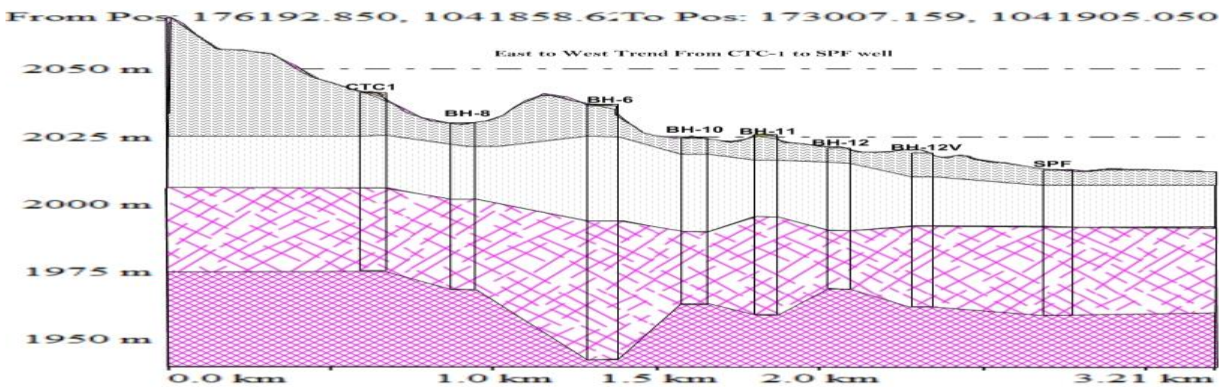


Figure 5: Hydro-geological cross section developed along C-C' from figure 3.

The major sources of groundwater recharge of the study area is from runoff generated from high elevated mountainous area and direct infiltration from precipitation on the alluvial and lacustrine plain (no any runoff goes out of the well field) and seasonal sub-surface influx from Tinke Lake along the Northern boundary. Similarly well logs and VES's reveals that weathered granite (secondary permeability features and is hydraulically connected to the unconsolidated quaternary sedimentary layers). The estimated transmissivity and hydraulic conductivities are 32, 269, & 12.6m^2/day and 0.8, 8.4, & 0.21m/day, respectively (Table 7).

Data and model analysis: To come up with the final objectives of this study; Rainfall data, monitored groundwater level and pumping rate, well data and geophysical data primary and secondary vertical electrical sounding (VES) were collected and analyzed.

Trend analysis in groundwater level

Over the last eight (8) years, groundwater levels of the well field show steady long term declines that may be attributed to changes in recharge or changes in the process governing recharge (e.g. rainfall) and human effects. However, the relative contribution of the above mentioned factors on the declining of groundwater levels was uncertain. In this unconfined aquifer system which is directly correlated with rainfall trend analysis of groundwater level that accounts the impact rainfall variations (above/below the average) on the course of groundwater level. The attempt enables to decompose the relative influence on the course of groundwater level to describe the relevant hydrologic processes and planning better groundwater management strategies.

The objective of this experiment is mainly to assess the hydro-meteorological trends and trends of groundwater potential and understand the aquifer uniformity and source of groundwater budget. Rainfall data correlate well with groundwater level changes in unconfined aquifers (Ferdowsian et al., 2001, Yesertener, 2008). These effects were identified from the observed hydrograph of four non-production wells (BH-7-12-10 & HW-3) and four production wells (HW-1-2-4-5-6) simulated using HARTT model for 11 years (2002-2012) before and 8-years

(2005-2012) since Lake Haramaya vanished in 2004/05). Declining in water table of Haramaya well field (study area) is attributed to slight decreasing in rainfall and dramatic growing groundwater uses for the periods.

Rainfall and groundwater data

Rainfall data

Monthly based rainfall, from Haramaya gauging station recorded from 1979-2012 E.C for 33 years (one year missed data) was collected and based on the Ethiopian climatic season. The data was categorized in to four seasons, summer, spring, the dry season and Belg to investigate the climatic and water level trends.

Groundwater level data: Out of nineteen (19) wells available in the well field monitored groundwater level from eight (8) wells located at 500-980m distance away from abstraction wells was considered for reliable trend estimators. One data points representing water level was selected for each wells and various time series were formulated which is vital to minimize uncertainties of model output induced by the selected data points & sample sizes.

An auto-regressive statistical model HARTT (Hydrograph analysis; rainfall time trend) has been applied to investigate the spatial variation & temporal trends of groundwater level only. In this case, the potential impact of groundwater discharge was examined indirectly.

Autoregressive (HARTT) model with the dependant variable’s past moving average

The method for statistically estimating trends in groundwater levels called HARTT (Hydrograph Analysis: Rainfall and Time Trends) developed by Ferdowsian et al. (2001) was adopted to simulate the effect of rainfall on the underlying groundwater level using the solvers HARTT-XLS software package (Figure 3.1). The program is easy to apply and eliminates bulky data operations (Chapman et al., 2007) and enables to separates the effect of typical rainfall events (in this case typical drought) from underlying time trends of groundwater level and the lag between rainfall and its impact on groundwater level over time. The approach was widely applied by different researchers (e.g. Ferdowsian et al., 2002, Peterson & Western, 2011 and Yihdego et al., 2011) in simulating the impact of climate variability and changes (rainfall) and human interventions on groundwater level for development of better groundwater management strategies.

The approach is applicable, especially in unconfined aquifers systems that rainfall data correlates well with groundwater level changes (Ferdowsian et al., 2001, Yesertener, 2008). Though, it is not 100% guaranty, the analysis or model provides sound evidences about the hydrological stresses from its coherence or deviation of the spatial distribution of the dependent variable (water level) and independent variable (rainfall and abstraction). To minimize the uncertainties of model prediction the method calls for assumptions including the trend is typical to average rainfall conditions, it is less reliable for deep wells, lateral groundwater inflow is insignificant with respect to rainfall (that may not be detected the impact of rainfall easily).

HARTT model requires historic monthly rainfall (at least 10 years) at least to the end of the month from the last reading (monitored water level data) having the same data format (Ferdowsian et al., 2001). In this case, available eleven years (11) and eight years (8) of monitored water level data was simulated using rainfall data of 33 years (1979-2012) and 13 years (2000-2012) independently to investigate the effect sample size earlier than monitoring water level. To predict the long term groundwater level these data range was modeled at annual based (limited to simulate seasonally).

To forecast long term groundwater level monitored data of more than 20 years from observation wells representing the system are required. Otherwise monitored water level data of less than 10 years and data from production wells may be biased. However, to simulate groundwater table fluctuations trend analysis using four years of groundwater data 2002 to 2006 and using monitored groundwater level data from two production wells of two years observation period was carried by (Mitchell, 2009) and by Nott *et al.* (2004), respectively and they get comparable results with the observed level.

Likewise, in this local unconfined aquifer of 50.07km^2 due to limitations of long term monitored data only the eleven years (11) and eight (8) years of available data from three non-production wells of HU and four production wells of HU & HW were used, respectively in this model. The three non-production wells were installed for production purpose initially, however due to pump problem and geological problem (collapsing) HU was used for monitoring purposes. These wells are located at 640m, 700m and 980m distance from production wells and 500m, 800m, and 630m distance from each other.

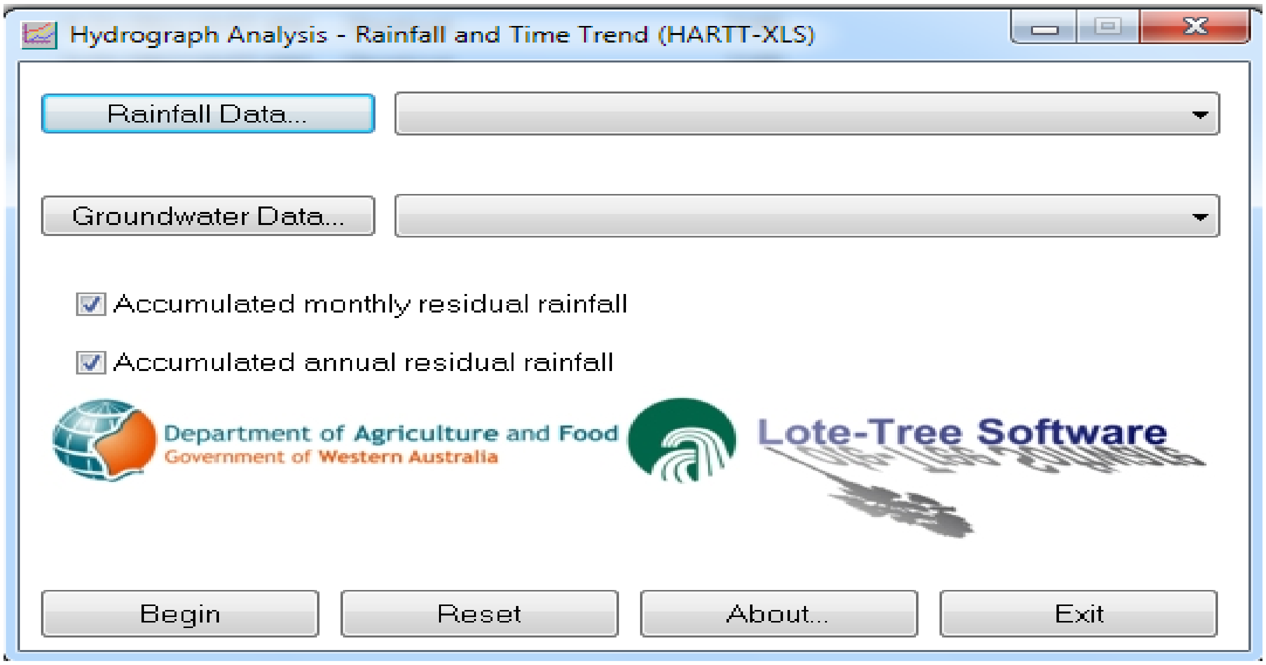


Figure 5: Hydrograph Analysis-Rainfall and Time Trend computer program

Rainfall is represented in the model (HARTT) as an accumulation of deviations from the average rainfall as accumulative monthly residual rainfall (AMRR) and accumulative annually residual rainfall (AARR) equation (3.1 & 3.2) respectively. The principal concept of AMRR and AARR is defining the influence of rainfall on the groundwater level by considering the residuals of the rainfall (monthly or annual), the time-lag between accumulative residual rainfall and its impact on groundwater that represented as:

$$AMRR_t = \sum_{i=1}^{t}\left(M_{i,j} - \bar{M}_j\right) \qquad (3.1)$$

Where, $M_{i,j}$ is rainfall in month *i* (a sequential index of time since the start of the data set) which corresponds to the j^{th} month of the year *j*, *M* is mean monthly rainfall and *t* is months since the start of the data set. This equation (4) requires frequent observation data than the AARR in equation (3.2).

Accumulative annual residual rainfall (AARR; mm):

$$AARR_t = \sum_{i=1}^{t}\left(M_i - \frac{\bar{A}}{12}\right) \qquad (3.2)$$

where, $\bar{A}$ is mean annual rainfall (in mm).

Because of the constant value of ‘Ā’ (in this case 66.27mm for data of 1979-2012 and 60.05 for data of 2000-2012), the fluctuations in *Mi* are not moderated as they are for AMRR and provides a seasonally adjusted cumulative rainfall. Subsequently AARR has higher within year fluctuations but less in AMRR. In other words, the AMRR variable tends to have relatively low within-year fluctuations because, in calculating AMRR, the fluctuations in actual rainfall tend to be offset by seasonal variation in average monthly rainfall. This implies that data from shallow wells are expected to be well correlated than deep groundwater levels which typically have seasonally fluctuating water tables in this case (e.g. BH-3, BH-4). On these mentioned wells the annual and seasonal fluctuation ranges from 8.7 to 12.3m and from 5.4 to 9.3m, respectively.

Simulated groundwater level can be also governed by the previous water level in a well in addition to rainfall impacts. This variable was incorporated by Greene (1993) as third explanatory variables ($K_3 \times MA_{t-L2}$) which are the lag between rainfall and past moving average of groundwater level in the regression model equation (3.3). HARTT analysis (using moving average) captures the overall system lag. The lag times suggested by the HARTT analysis are indicative of maximum time lag for the groundwater system as a whole, behind rainfall (Yihdego and Webb, 2010).

To predict the depth of long term groundwater level and to define correlation between rainfall and groundwater fluctuations at a given accumulative residual rainfall ($AMRR_t$ or $AARR_t$) that attained at the highest r^2 between the observed and simulated groundwater levels was used. The model is fitted to the groundwater level data as:

$$\mathbf{Depth_t = k_0 + k_1 \times ARR_{t-L1} + k2 \times t + k3 \times MA_{t-L2}} \qquad \textbf{(3.3)}$$

where Depth is depth of groundwater below the ground surface, *t* is months since observations commenced, L is length of time lag (in months) between rainfall and its impact on groundwater, and k_0, k_1 and k_2 are parameters to be estimated. Parameters of the regression coefficients k_0 is approximately equal to the initial depth to groundwater, k_1 represents the impact of above or below average rainfall on the groundwater level, k_2 is the underlying time trend of groundwater rise/fall over time and k3 represents the impact of past groundwater levels. The value of L is estimated separately for each well by selecting the value that results in the highest r^2 of the regression, which is higher for shallow wells than deep wells. The expression $K_2 \times t + k_3 \times MA_{t-L_2}$ represents the long term trend of groundwater rising or falling over time (Table 17). The regression allows for the separation of lagged cumulative rainfall effects $\mathbf{k_1 \times ARR_{t-L1}}$, from the trend $\mathbf{k_0 + k2 \times t + k3 \times MA_{t-L2}}$ (Ferdowsian *et al.*, 2001b).

The relationship between groundwater trends and rainfall equation (3.3) uses the residual rainfall (AMRR & AARR) and the lag between rainfall and groundwater dynamics to define a correlation between climate and groundwater fluctuations. Based on data sets of earliest recorded water level (in this case rainfall data before 2005 or 2000-2005) construction of dependent and independent variables was conducted for both AMRR and AARR to provide long lag effects of rainfall on groundwater to be detected (3-7months were detected). Lags of up to a few years were investigated (Yohannes and Webb, 2010).

In shallow wells AARR can be substituted by AMRR in the regression model if the model produces a higher r^2 values (*L* and other parameters will be selected at higher value of r^2). Thus *L* does not necessarily represent the lag until either the first impact or the largest impact of rainfall on groundwater level, but the lag that produces the highest statistical correlation (maximum r2 and minimum p-value). Therefore in this study, the selected wells are depth ranging **between 39m to 66m** drilled in the unconfined aquifer. The HARTT also may therefore be compromised by factors such as geological and geographical characteristics of the monitored sites. For a number of estimated parameters, HARTT finds the best delay at the maximum (r^2) and minimum (p-values).

Different statistical parameters and hydrographs were obtained from the simulated model of eight wells. From the hydrograph (figure 6) a falling trend of groundwater level even when effect of rainfall (ARR) is positive on the right beginning from 2006 with range of time lag (3-5 months) was observed. On the other hand, falling of groundwater level when the rainfall impact is negative from mid of 2004-mid of 2006 and an immediately respond of groundwater level to the highest rainfall value of 2006 without any delay time was observed.

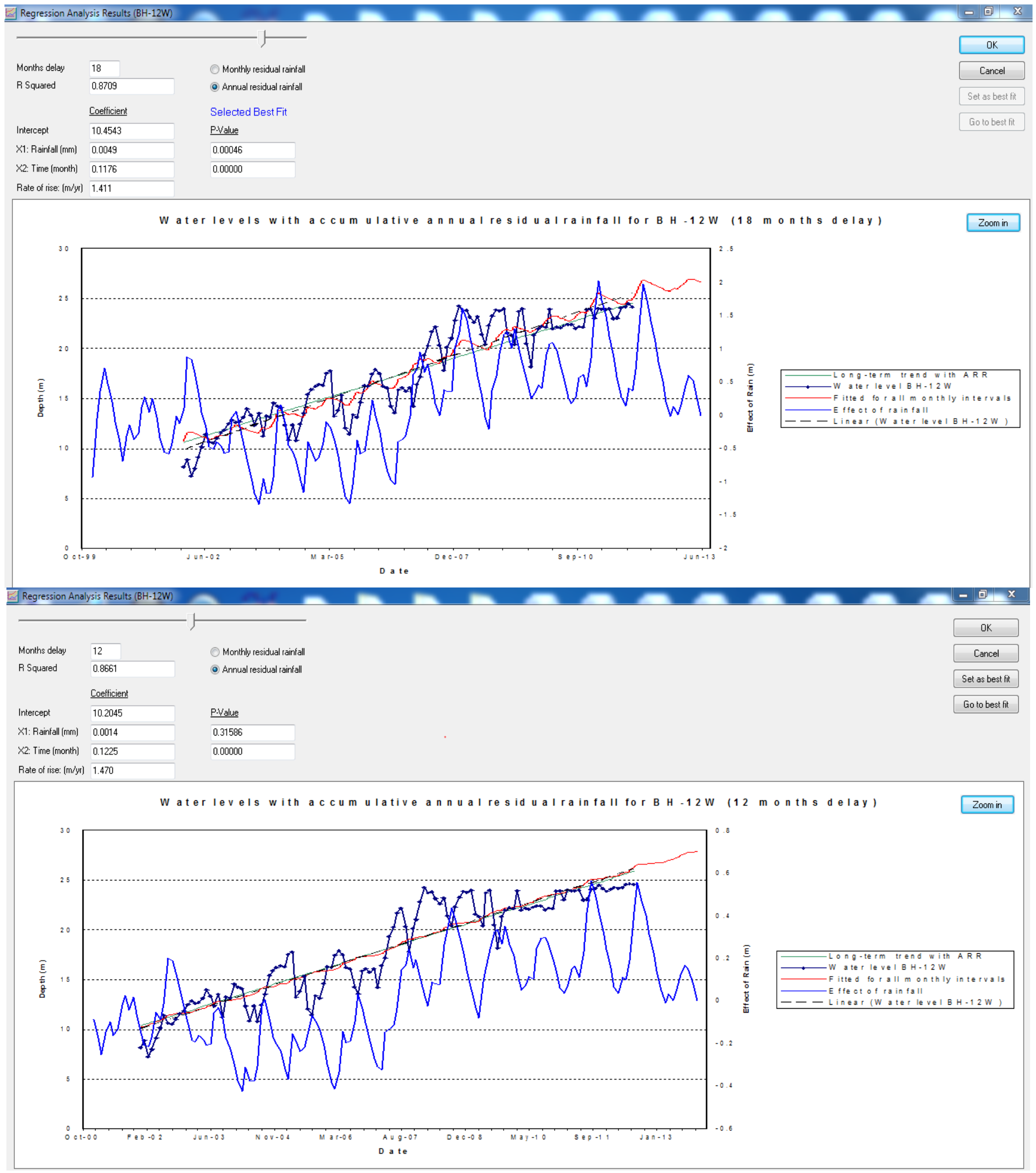


Figure 6: Hydrographs of different data point: first date (a) and mid value (b) using 1979-2012.

The negative impact of rainfall from 2002-mid of 2005 (relative drought) indicates that falling of water level is due to the slight decreasing in ARR. On the other hand, water level rises when decreasing rainfall pattern of ARR from mid 2002 to 2004 down (may be due to the Lake Haramaya effect or delay time of 2000-2004). Deviations of rainfall value from the average would have resulted in short-term fluctuations in the groundwater level, centered on the stable long-run equilibrium level (e.g. figure 3.3).

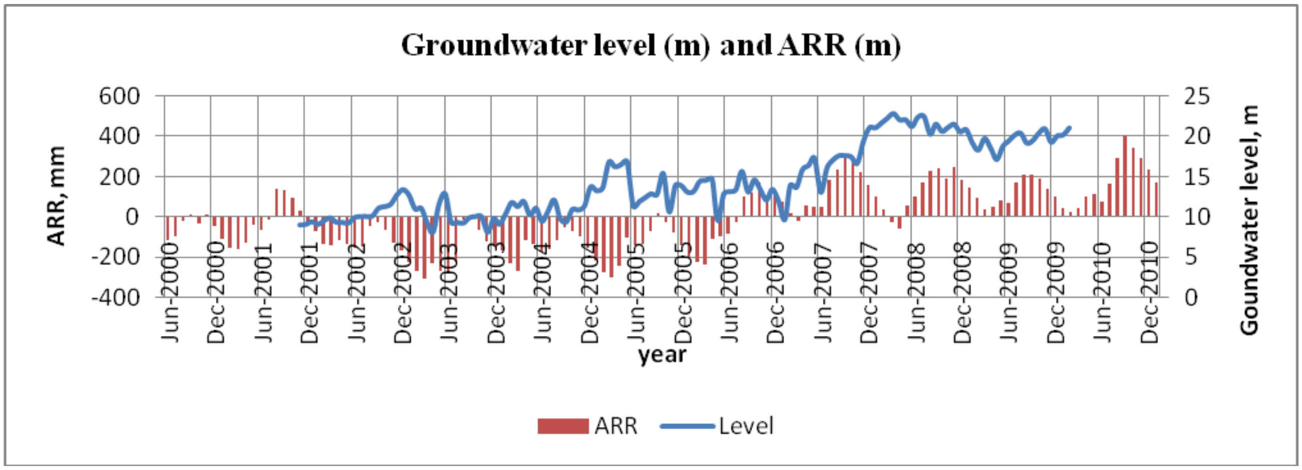


Figure 7: Hydrographs of ARR Vs Groundwater level using rainfall data of 2000-2012.

Similar to the hydrographs of CDFM or ARR and total rainfall, Hydrographs of HARTT (figure 8) indicates negative rainfall impact (May 2002 to Dec 2006) on the left side while positive on the right side (up to 2012 even when the actual rainfalls are decreasing, for example 2009 & 2012 have minimum total rainfall values) due to the ARR values. However, groundwater level declined on same range for 1mm of rainfall deviated from the average, groundwater level rise for positive and falls for negative value of effect of rainfall in ARR (m). Cumulative residual rainfall (ARR) have a rising trend while the groundwater level sill have a falling trends though the falling rate of groundwater level decreases from 2009-2012.

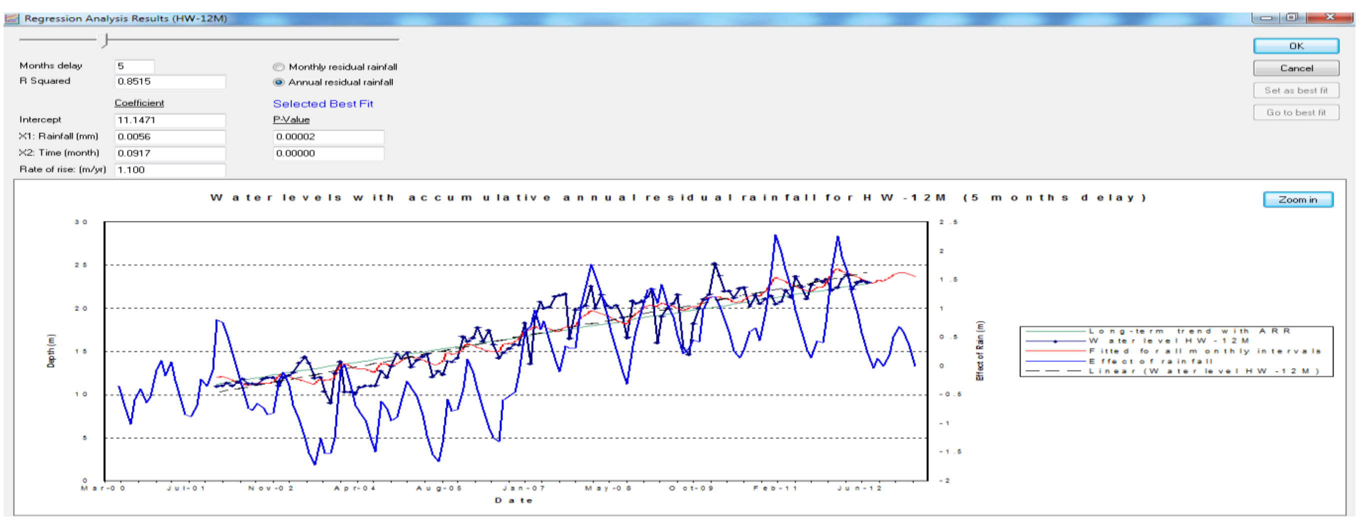


Figure 8: Hydrographs of HARTT at 5 months delay

To split the rainfall impact on the underlined groundwater level and the other direct or indirect factors likely forcing the long term groundwater level four different steps was followed to come up with the main findings. First two time series of rainfall data 33 years and13 years (1979-2012 & 2000-2012) and all months of eight (8) monitored water level data, second using same range of rainfall data but monitored water level data of dry and wet season, third monitored water level of wells varied in depth and other layer properties and fourthly rainfall data of above & below the average value of the two data range (1979-2012 & 2000-2012) for the eight (8) wells were simulated using similar steps.

Table 1: Over all model result and parameter estimated

Term	HARTT output and unit	Ferdowsian et al., 2001a
Regression Coefficient	C (mm)	K0
Coefficient of Rainfall	Acc. Residual Rainfall (-)	K1
Coefficient of Trend	Time (month) (mm/month)	K2

In this case prior to applied the HARTT model the presence of significant trends in rainfall (33 and 13 years) and eight (8) years of groundwater level was examined using Mann-Kendal test for trend.

In all cases the presence of significant impacts of rainfall on the underlining groundwater level and lag time the coefficient of determination of parameters of maximum (r^2) and minimum (p-value) obtained from the HARTT was used (Table 18 & 7). Parameters of r^2 value (indicating degree of fit, 1 at perfect fit) and p-value (indicates the level of significance of each variable by assessing whether the means and measure of dispersion of two variables are statistically different from each other). If the p-value is < 0.05 and then the variable is significant and highly significant if p-value <0.01, while insignificant if p-value>0.05 for the rainfall variable which is the null hypothesis cannot be rejected as there is no relation between the cumulative residuals of rain and the observed hydrographs. This is possible if factors other than rainfall affected the observed groundwater levels.

Similar result of the two coefficients (k1 & K2) cannot obtain when simulated at annual and seasonal based. It is expected to overestimate these coefficients (creates over confidence for additional abstractions) or may be under estimate (dry) that creates generates fear or frustrate the people & policy makers). This makes difficult in selecting the appropriate value (minimal uncertainties or errors) for model prediction.

Therefore, to select the appropriate values with a minimum error the model runs so many times and then the simulated groundwater level was compared and calibrate with the observed k0 and with observed water level of 2012 and 2013. The deviation of k0 (C=intercept) from the initial groundwater level ranges from 0.21-0.68m (average 0.45m) which is insignificant and greater than 84% are well correlated. This indicates the simulate model is reliable for prediction of long term groundwater level. The impact of rainfall on groundwater level indicates delaying time to reflect the effect of ARR on the water level. The simulated value varies from well to well and obtains a range of 3-13 months. In all wells, the impact of rainfall (k1) and underlying groundwater level (k2) reveals positive values, implies there is a direct and positive correlation between rainfall and underlying groundwater level in 84% and 76% if 13 years 33 years of rainfall data are used, respectively. The variation is due to the effect of sample size of rainfall (affecting ARR).

Accordingly, the simulated model using eight (8) years of groundwater level with 33 years of rainfall data reveals that 76% of wells are well correlated with the model (r^2 =0.26 to 0.738 and p-value =0.00001 to 0.0423). The model result reveals that the two variables dependent (water level) and independent (rainfall) are correlated well at an average r^2=0.85 and p-value=0.0002 at average value of 4-month lag-time. While, the other 18% of wells were falling by 3.2-3.6m/year (r^2=0.67-0.79 and p-value 0.0897 to 0.047) (Table 3.2).

Similarly, trend analysis was conducted for these wells using water level data of 2005-2012 rainfall data of 13 years (2000-2012) to detect the groundwater trend of pre-post of Lake Haramaya vanished. Consequently, 84% of wells were well correlated (at r^2 =0.56 to 0.87 and p-value = 0.0001 to 0.002) table (3.2 & 3.3). Like the previous model different parameters that deviated in magnitudes (L=12months, r2=0.5739, C=14.49m, x1=0.0012 at p-value=0.645, x2=0.1082 at p-value=0.0000, and rate water level rise/fall of 1.299m/year) were obtained. Having similar delay time, deviation of parameter values between AARR (higher magnitude) and AMRR (lower) was observed.

Trend

The HARTT model reveals on average groundwater level in Haramaya well field declines by 13.75m within the past 8 years (1.72m/year) that may be attributed to decreasing in rainfall, increasing discharge or other factors including decreasing storage properties (compaction of the alluvial sediment). Both the AMRR and AARR (mm) was used for interpretation though the magnitude of fluctuation in AARR is higher within year of fluctuations than that of AMRR. However, various model results of falling in water level was obtained from different sample size, selected data points etc presented above.

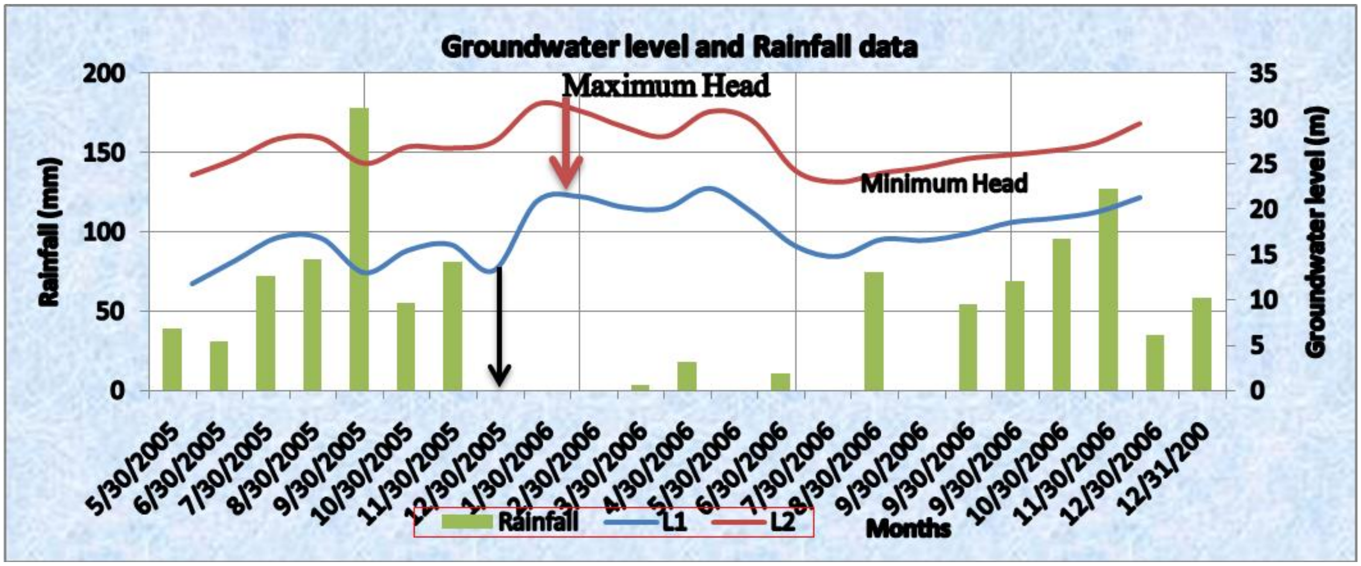


Figure 9: hydrographs of annual rainfall and groundwater level

Hydrographs of annual rainfall and groundwater level

Water level falls by 13.28m and 10.63m from March 2006 to August 2008 and from March 2006 to Jan 2011 respectively in opposite to the upward rising trend (ARR). As we can observed from hydrographs of (Figure 3.2 & 3.3) a continuous falling of groundwater level from late 2006-2012 was observed while rainfall effect is positive (rising up ward) which implies the falling in groundwater level is not due to falling trends of rainfall below average value.

The continuous falling trend of head 1.1m/year (8.8m/8 year (e.g. HW-1) indicates that though there is a rising effect of rainfall on groundwater level by 1.82m/year, this rising value plus additional 1.1m from storage a totally of 2.93m head was lost annually may be due to pumping, out flux, leakage, etc. While the observed value indicates falling heads of (14.64m/8 year = 1.83m/year), which is 1.83m head was lost from storage annually. This implies that groundwater level rise due to the effect of k1 though that offset by other factors. Annually the impact of 13 years of rainfall causes the water level to rise on average by 1.51m/year or 1.51*8 years =12.092m. However, the rise was counterbalance by abstraction and other factors including evaporation (not examined in this study) and a time component and leaving an average decline of 0.99m/year =7.92m/ 8 year.

The simulated falling in groundwater level ranges from 1.1m/year & 1.78m/year and on average 1.72m/year was considered. In addition to the value obtained from aquifer characterization using geophysical method, the closed boundary of the well field (side way & deep) were confirmed using the HARTT model presented previously (there is no any groundwater exchange regionally or deep). Comparing the two parameters (climatic & non-climatic) 66% of the falling level accounts in response to abstractions while the rest 24% are due climatic impact and 10% is due cumulative effects of the other factors.

Table 2: Estimated HARTT parameters of 8 wells

Id	ho(m)	K0(m)	K1(m)	K2 (m/month)	Falling rate	Observed falling head	Δ h
HW1	17.85	19.084	0.045	0.159	21.467m/8year	24.02m	2.553m
HW2	10.6	12.981	0.0002	0.224	15.31m/8year	14.75m	0.56m

Moreover, in significant trends of groundwater level were obtained from the HARTT model from these wells deeper than 40m and wells shallower than 40m (Table 3.1). These wells may be getting other additional recharges from nearby, irrigation back water etc. For example for years 2006-2009, HW-6 is not directly fluctuated with season, which may imply, there is additional recharge gets from influx of Lake Tinke on the northern boundary. Due to the drawback of HARTT model, Output of zero trend that may indicate equilibrium conditions and shallow wells (less than 15m depth) that affected evaporation and evapo-transpiration were not considered to predict water level.

Lag time

The impact of rainfall on groundwater level fluctuation may not be response instantaneously; the response may vary from zero (for shallow wells) to a year of lag time. **A**n extended value model result (especially time lag ranging 7-45 months) which is less reasonable and shorter time lag ranging from 3 to 7 months was obtained using 33-years and 13 years of rainfall data respectively was obtained. The impact of recharge time, geological structures, well interference, geologic formation between layers, topography, rate of abstractions, location, well depth (shallow & deep), are similar, but the discrepancy may be attributed to sample size (water level & rainfall), season (wet & dry), selection of data point (affecting AARR or AMRR). The shortest delay will result in the best fit, but will mask the impacts of other factors (rainfall and time) (Ferdowsian and Pannell, 2009) and this is challenging to select a suitable delay between the dependant variable and its past moving average. Though, HARTT analysis (using moving average) captures the overall system lag it may therefore be compromised the above mentioned factors. The hydrograph shows various slopes and length of lags (Table 3.2 & 3.3). The identified lag time was improving our knowledge of the hydrogeology and thus groundwater flow systems of the well field. The possibilities of recording large lag time lags of up to a few years were investigated (Yihdego et al., 2010).

According to (Raiber et al., 2009; Bennetts et al., 2003) if the delay period estimate was not meaningful, like unrealistic lag estimate from the physical existing knowledge of the area for bores located near eruption points which were identified as areas of preferential recharge**,** implies that the effect of rainfall was not well simulated and hence the trend estimate was not reliable either. From the model output as the delay time shifts down (to 1 or 2months) or shifting up (to 9 months) manually from the best fit, varying the estimated parameter (r2, C, k1, k2 and p-value) was observed (Table 3.2).

To have clear evidence about the effect of aquifer properties on the magnitude of time lag and to minimize the model uncertainties and to maximize the model accuracy for prediction parameters, various sub-surface geological cross-sections (Figure 4.4 &4.5), SWL, and estimated hydraulic parameter (k, T, b, sy) land use, evaporation and evapotranspiration was examined indirectly. Accordingly 87% of the average value of aquifer hydraulic properties well, locations and depth are well correlated and gets still no any significant difference in all wells and cross-sections. Moreover, a direct correlation of fluctuation and rainfall, maximum falling rate on these wells of higher discharges were observed.

Table 3: Estimated aquifer parameter from pumping test by Karamara engineering consultancy, (2005)

Id	Depth (m)	SWL(m)	Screen Length(m)	Water Column(m)	Q (l/s)	T(m2/d)	K(m/d)
Well 1	47	2.2	24	44.8	10.3	124.8	2.8
Well 2	65	14	27	51	4.5	122.5	2.4
Well 3	39	3.8	18	35.2	10	106.1	3
Well 4	52.3	4	18	48.4	18	269.3	5.6
Well 5	53	2.9	24	50.1	18	337	6.7
Well 6	53	8.9	24	48.1	18	360	7.6
Well 7	53	9.5	24	44.1	18	367	8.4

There are no any significant variations in aquifer parameters, depth, screen length, SWL and discharge rate from well to well.

Rainfall impact

To calculate the effect of rainfall on groundwater level (K_1) parameter and anticipated rise/fall in precipitation yields a prediction of groundwater level rise/fall. The value of (K_1) identified from HARTT is 0.46m rise/fall in groundwater level for 1mm of rainfall summarized in (Table 3.2 & 3.3). The values of impact of rainfall variable k1 ranges from 0.26 to 0.64m/mm at an average r2 of 0.76 & p-value of 0.0063 and average 4months of lag time that correlated **76%** and 84% of wells using 33 & 13 years of rainfall data respectively.

On the other hand the time trend variable in units 0.141m/months was multiplied by 12 to convert the rate of rise per year and obtained the underlying groundwater level falling or rising and on average 1.72m/year **(**13.75m in the past 8 years**).** This indicates as compared to the time trend, the declining in groundwater level due to ARR below average (0. 46m) is statistically insignificant (27%). The auto-regressive model (HARTT) showed that the groundwater course can be explained by climate variable only 27% of the total declining in groundwater level. Though the magnitude of rising/falling varies from well to well the course of groundwater level is governed by the underlying time trend and other factors. This implies there is no any significant falling trend of rainfall from 2000-2012 while groundwater level is falling significantly from 2005-2012. The overall result of the model, though water level reveals impacts of rainfall to rising by 59.13m (positive) and to decline by -44.57m in 8 year (negative). Cumulatively the model indicates a rising of water level by 14.56m in the past 8 years if there are no any abstractions and other factors.

Table 4: Estimated parameters of regression coefficient of 8 wells & rainfall data of 1979-2012

Well Id	Depth		BFD (months)			ARR (mm)			Time (month)	
	initial	Final	AARR			Rain fall			Time trend, K2	
	K_0	Final	L	R^2	c	K3	K1	p	value	p
W-1	7.6	22.74	14	0.65	14.09	2.83	0.0057	0.0897	0.24	<0.000
W-2	24.17	30.99	22	0.51	27.11	2.402	0.0097	0.00047	0.27	<0.000
W-3	9.9	23.495	12	0.26	10.25	2.926	0.0125	0.0513	0.244	0.00141
W-4	10.22	21.375	22	0.738	10.99	4.071	0.0114	0.00031	0.339	<0.0000
W-5	8.905	24.945	11	0.6287	17.667	4.701	0.0255	<0.0000	0.392	<0.0000
W-6	7.43	19.475	20	0.457	10.657	2.592	0.00927	0.00443	0.216	<0.0000

Table 5: Statistical estimated parameters from BH-12 using water level data of 2002-2012

Delay time in (month)		1(not best fit)	2 (not best fit)	7 (best fit)	9 (not best fit)
r^2		0.7772	0.7762	0.7901	0.7818
C (m)		8.9578	9.2907	10.4763	9.8498
AARR	X1/K1(mm)	-0.0014	0.0003	0.0073	0.0032
	p-value	0.45565	0.88981	0.00481	0.07487
Time	X2/K2 (month)	0.1286	0.1230	0.107	0.1137
	p-value	0.0017	0.0033	0.002	0.07487
Rate of rise (m/year)		1.543	1.474	1.208	1.364

- x2/k2 (underlying groundwater level in m), p-value >0.05 (which indicates in significant)
- C (represents the intersection of simulated linear water level and observed water level)

The other parameters such as increasing sediment volume that decreasing recharge rate and led to increasing pond time in the Lake body & evaporation may affect indirectly. In this study wells shallower than 20m that affected directly by return back of irrigation water was not considered. Moreover, there is no significant trend (not detectable) from 2005-2012 in land use, evaporation the term evapotranspiration (e.g. Abebe, 2010; Edo, 2009; Wagri, 2005 and Aman, 2013). Factors including evaporation from (open water during rainy, dugs all over the year, irrigation water) but not from water table and evapotranspiration factor calculate before/after the monitoring beginning by (Solomon, 2003; Wagari, 2005; Abebe, 2010) are increased by 1.6% which is insignificances.

Therefore, we can conclude that groundwater declines continuously on average by 13.75m (model result) 0.46m (3.68m/8 years) due to rainfall decreasing and while the remaining 10.07m/8 year declines due to other factors (may be Q).

Summery

Trend analysis in groundwater level was carried in Haramaya well field to investigate the long term trend of groundwater level in response to the two hydrological stresses and to decompose the sensitive parameters using HARTT based on various time series rainfall, monitored water level, well depth, and hydraulic parameter, aquifer thickness, pumping rate, location, and top soil thickness separately.

The finding reveals that though there is an insignificant effect of rainfall on the course of groundwater level, the annual rising in water level due to recharge is counterbalance by other components and leaves an average declining of water level by 1.72m/year for the period 2005-2012. Therefore, groundwater storage within the unconfined aquifer can be estimated by multiplying the aquifer surface area by the saturated thickness (b) of the aquifer and the specific yield (Sy) of the aquifer materials.

$$\text{Groundwater Storage Volume} = (\text{aquifer surface area})(b)(Sy)(3.6)$$

The average saturated thickness of the aquifer is 31m, average aquifer area is 7Km^2 and estimated specific yield is 11%. For full capacity of the well field the total aquifer thickness will be considered, while for the available storage the annual declining in groundwater level was taken in to account. The total volume at full capacity is 23870000m^3.

However, in the past 8 years the average groundwater level declined by 13.75m. Consequently the groundwater potentials of the well filed (7km^2) is 13282500m^3 which is decreased by 10587500 (1323438m^3/annually). This implies having other factors constant, the available head will be served only for 17-20 years. But, if the rate of discharge for irrigation or domestic exceeds beyond the current rate, rate sediment flow to the lake body grows, etc the groundwater potential will be degraded before the above time table (may serve only for 15 years).

Part II: Aquifer characterization

Introduction

Aquifer (confined or unconfined) is a rock unit (unconsolidated or unconsolidated) that is able to hold and transmit water at rates fast enough to supply reasonable amounts of water to wells (Fetter, 1994). An aquifer can be compared to a bank account (USGS, 2003; USGS, 2008). Freeze & Cherry (1979) apply the term aquifer only to formations that contain economic quantities of water.

Groundwater occurrence, movement and circulation in an aquifer depend on these mentioned characteristics and source of recharge depends on aquifer type (Fetter, 2001). In this study aquifer characterization of Haramaya well field was conducted mainly to provide clear subsurface geological maps, to define the aquifer type-number and extent, to define the boundary conditions and groundwater recharge-discharge mechanism and to provide hydraulic properties of the aquifer system.

Characteristics include the aquifer geometry, hydraulic conductivity, transmissivity, storativity and specific capacity (Barnie, 2010). Moreover, it describes extent of aquifer system (vertical/lateral), depth to the bed rock and water bearing zone & its thickness, type, extent and their hydraulic characteristics though it is varied in fractured and prose medium, regional, and local etc.

Previously aquifer characterization and parameter estimation was carried out using pumping tests by (KRC, 2005) and using surface geophysical (electrical resistivity) methods by WWDSE, (2003). However, the pumping test method that was applied provides parameter values of cumulative lithology rather than the aquifer position and the vertical electrical sounding conducted provides only the layer thickness, resistivity's and depths.

To avoid these limitations and to minimize uncertainties integrated approaches of hydro-geological (pump test, well geological log data) and geophysical (resistivity methods) was implemented to characterize the aquifer system and to estimate aquifer hydraulic parameters. Integration of lithologic logs, geophysical logs and hydraulic tests are critical in characterizing heterogeneous aquifers (Paillet and Reese, 2000).

Although there is no a universal method of characterization in all hydro-geological set-up nowadays, there are a number of aquifer characterization methods. Including pumping tests, slug test were, laboratory and in the field and geophysical methods were illustrated by many researchers (e.g. Ahmed *et al.,* 2008; Butler, 2005; Freeze and Cherry, 1979; Kelley and Mares, 1993). An integrated approach of hydro-geological and geophysical methods was applied to minimize the uncertainties of several limitations of each method.

The utility of geophysical methods in defining subsurface aquifer properties and hydro-geological site characterization, in determination of depth, thickness and boundary of an aquifer and in determination of groundwater potential have been illustrated in numerous studies (e.g. Chen *et al.,* 2001; Arabi et al., 2011). A lot of geophysical investigations have been carried out all over the world for groundwater investigation, aquifer characterization and parameter estimations (e.g. Ezeh et al., 2010; Anudu et al., 2011; Opara et al., 2012).

The theoretical and practical background to geophysics and its potential benefits has been extensively reviewed by (Butler, 2005 and Obiora and Ownuka, 2005) and practiced by different researchers (e.g. Tizro *et al.,* 2008; Alile, 2008; Nwankwo *et al.,* 2010; OKORO *et al.,* 2010). Basic outlines of geophysical methods are also given in standard hydrogeology text such as that by Fetter (1980). Particularly geo-electrical resistivity techniques has been extensively used for a wide variety of groundwater exploration problems, characterizing subsurface hydro-geologic variations (e.g. Mousa, 2003, Ibrahim *et al,* 2004; Youssef *et al.*, 2004; Al-Abaseiry *et al.*, 2005; Hosny *et al.,* 2005; Alotaibi and Al-Amri, 2007; Nigm, *et al.,* 2008; Niwas and de Lima 2003).

In this study surface geophysical, particularly geo-electrical method of Vertical Electrical Sounding (VES) using Schlumberger array that were adopted by many investigations (e.g. Okolie et al. 2005; Oseji et al. 2005 and Khalil and Monterio, 2009: Asfahani, 2007; and Onus, 2003) was applied to provide the subsurface formation and to formulate relations between aquifer properties and electrical resistivity's.

Experiments: Surface geophysical survey using vertical electrical sounding (VES)

Electrical methods are intensively used by geophysicists for evaluation of deep subsurface. A total of 27 Vertical Electrical Soundings **(**VES) were carried out by (WWDSE, 2003) at selected sites of appropriate points using SAAS 4000 Terammeter using Schlumberger electrode configuration with maximum half current electrode separation (AB/2) ranging from 230m to 1100m (N-S trends) and 300m to 1000m (E-W trends) and potential electrode (MN) from 1 to 80 m (Figure 3.1).

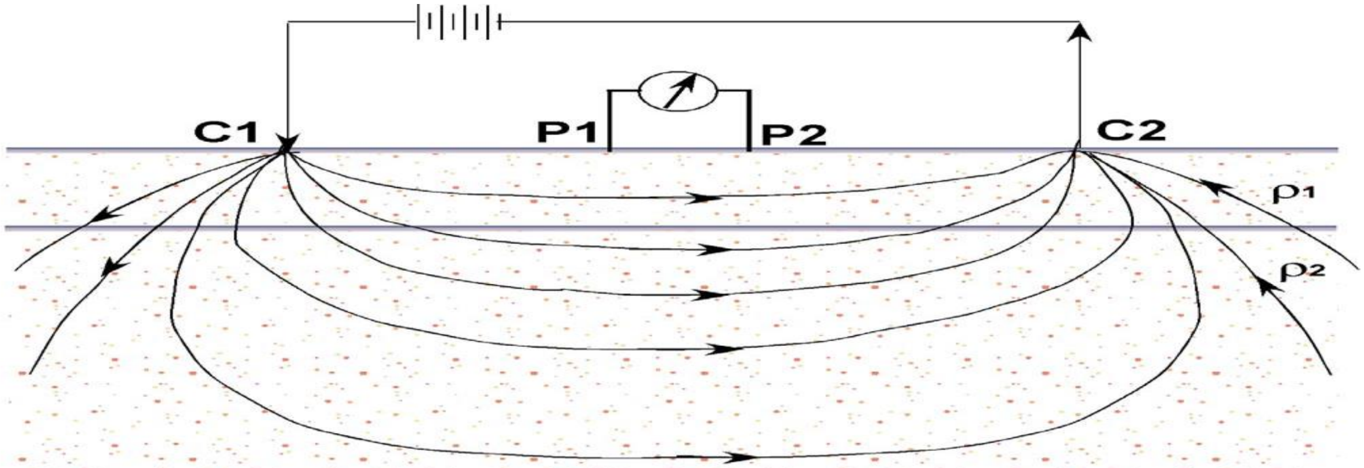


Figure 10: Theoretical representation of Schlumberger electrode configuration

In Schlumberger array the geometric factor (K) is given by the empirical relation stated by (Keller and Frischknecht, 1966). Since these measurements are made over a real heterogeneous aquifer system (obtained from log and surface geological map), the true resistivity of symbol ρ was replaced by apparent resistivity (ρ_a), a measurement was attempted using the Schlumberger configuration and provides apparent resistivity (ρ_a) calculated using equation (4.1):

$$\rho_a = 2K\frac{\Delta V}{\Delta I} \qquad (4.1)$$

where ρa= apparent resistivity on Ohm m, K=geometrical factor for the half Schlumberger configuration given from equation (2) below:

$$\mathbf{K} = \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{(2MN)} * \pi$$

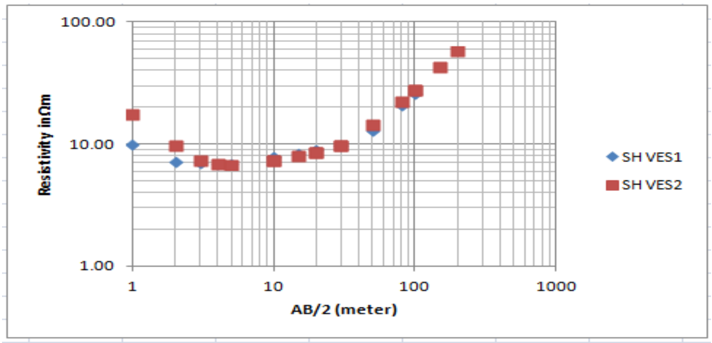
(4.2)

where AB and MN are shown in Figure 1 and π=3.14

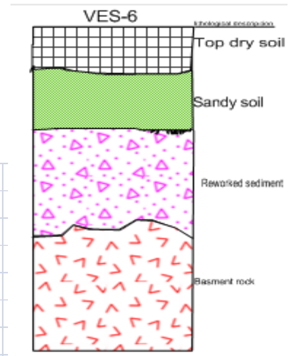
To examine the uniformity and lateral continuity of the aquifer system, presence of deeper confined aquifer and presence of up or down ward leakage, gradient and uniformity of the basement formation additional 15 VES was conducted along the surface in flow & out flow, near wells having well log and other locations.

The data obtained is usually plotted as a graphical as apparent resistivity against half electrode spacing. The electrode spacing at which inflection occurs on the graph provides an idea of the depth to the interface (opara et al., 2012). According to (Vingoe, 1972), a usual approximation is that the depth of interface is equal to two third (2/3) of the electrode spacing at which the point of inflection occurs. Accordingly a maximum of 35-120m penetrated depth (depth limitation is associated with attaining higher value of resistivity which is granite bed) were obtained in this study.

To have a clear view of the subsurface geology and hydro-geology the surveyed VES at different locations was categorized in to four groups, such as resistivity value <10, 10-50, 50-200 and >200 Ω. m. then geo-electric cross-sections (pseudo section) using the true resistivity's were constructed to interpret in terms of layer thickness and number. To minimize uncertainties & errors of VES result (introduced by tools limitation, skills, interpretation etc) and to describe in terms of geological formation, lithology/stratigraphies, VES survey nearby to 14 existing well having available geological well logs was carried out. These VES's are calibrated prior to decide the number of layers and their thickness obtained from the VES data in the well field (e.g. VES-6 was calibrated by BH-8 figure 11).



ρw	h	b
6	2	2
12	4	6
57	30	36
34	12	48
12	40	88
200		



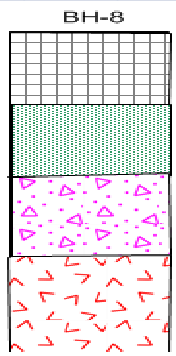


Figure 11: Litho logical log of VES-6

Accordingly, greater than 80% of well log and VES's are well correlated and consequently, geological cross-section from well log and pseudo section from VES a total of four layers ranging in thickness from 27m to 42m (Figure 4.2) was recognized. The presented cross-sections of the well log and VES data reveals same the first layer but in the second layer of the resistivity sounding reveals low resistive value seams saturated layer indicates compacted (sticky) clay calibrated using log data.

Data interpretations

Three interpretation procedures such as curve matching with master curves and auxiliary point charts (Bhattacharya and Patra, 1968) was carried out to obtained both quantitative and qualitative interpretations of vertical electrical sounding. This often led to the generation of geo-electric layers of pseudo-section (figure 4.2 and 4.4) to enhance the interpreted layer number & thickness, aquifer depth and frequency. In addition to this manual interpretations, an iterative least squares inversion program, RESIST (Velpen, 1988) or computer matching technique with IPI2Win software was adopted. The apparent resistivity values (ρ_a) obtained from equation (2) were plotted against semi-current electrode spacing (AB/2) using IP12 WIN REST software developed by (Ezomo, 2004–2007) to determine the layer number, thickness and resistivity.

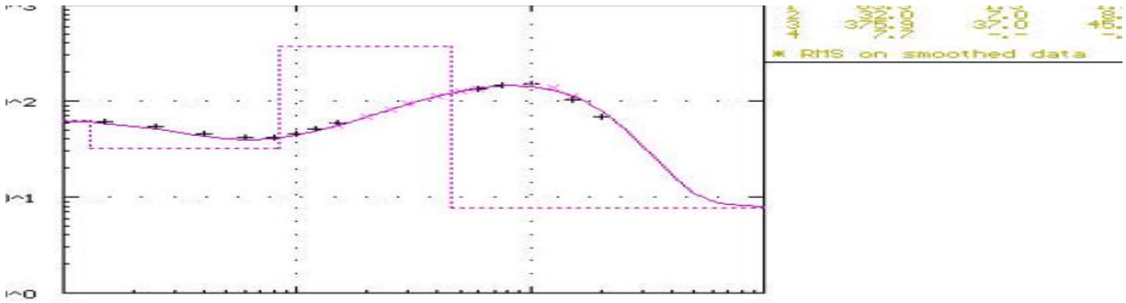


Figure 12: Interpreted VES data as AB/2 Vs apparent resistivity along X and Y axis, respectively

For qualitative interpretation, pseudo-apparent resistivity cross-sections along A–A” (figure 4.2) for VES locations of S_{13}, S_{12}, S_{10} and S_3 was constructed using IPI2win v.2.0 software. Interpreted master curves are mostly belonging to four layered curves, namely A, H, K and Q type and a maximum of 4-6 layers were identified from the computer model output. As a result similar output with an error 2.3-3% both manually curves matching and computer based output was obtained. From the repeatedly interpretation and analysis the different vertical stratigraphy (geological) was grouped four hydro-stratigraphic units was constructed based on their hydraulic properties. The upper less productive zone, the middle highly productive aquifer zones (major aquifer layer) and the lower weathered basement rocks less productive and massive granite (non productive).

The topmost layers have a slightly variable thickness (0.5 to 1.5 m) and the resistivity varies between 16 and 46 ohm-m, it represent the top dry sediments (Figure-4.4). The second layer is characterized by low resistivity’s (6.5–10 ohm-m) may be due to composing of finer materials, clay or silt- clay and its thickness ranges from 25 to 35 m. The third layer is marked by a moderate resistivity, 71 ohm’s-m (may be attributed as a response of coarser unconsolidated sediment) with an average thickness of 27m. From the available subsurface geological information (well log data), it is related to a saturated coarse material possibly sand and/or sand with gravel. The uniform resistivity of this layer may also indicate the resemblance in water bearing capacity and yield of the aquifer underneath (e.g. VES8–VES10). As observed from the geological log and VES data, the aquifer system is characterized by single, unconfined porous medium composed reworked sediments of clay, silt, sandy clay, rock fragments and pebbles, bounded on top by cotton soil and underlined by basement rock of undulated surface elevation.

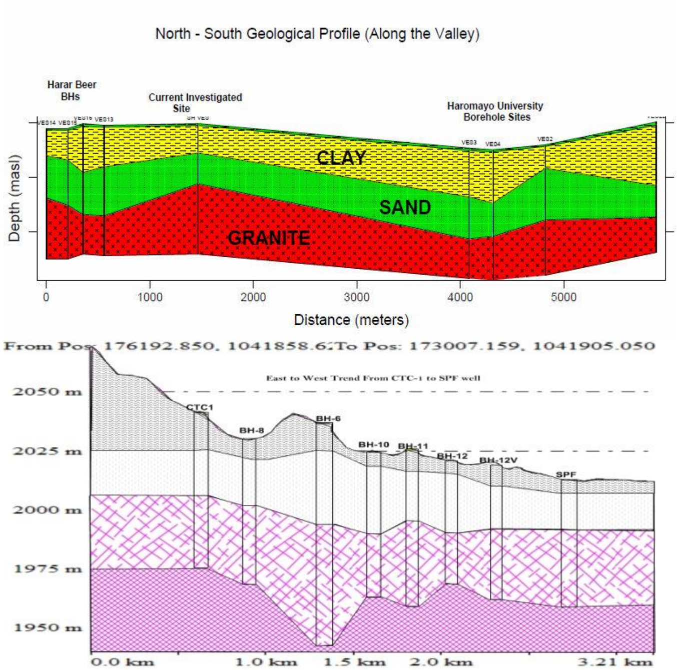


Figure 13: Pseudo-apparent resistivity cross-sections along A – A" & Cross-section along east west trend

The bottom deepest electrical zone with resistivity varying between 321 and 361ohm's-m is related to a poorly permeable unit. The thickness of unconsolidated or alluvial sediment varies laterally from 20m near the workshop (VES11 and **VES12**) to a maximum value of 60m towards the meteorological station (VES5–VES10) (Figure-4.4) that attains maximum thickness from east to west. The asymmetry in thickness may be attributed to asymmetry in subsurface elevation of the bedrock, or due to variations in rates of erosion and deposition. The variation in the resistivity values along the respective layers on the geo-electric section could possibly be related to the variation in grain size, degree of sorting, compaction and moisture content of the sediments. The geo-electric sections in all profiles indicates that the surveyed areas are underlain dominantly by a succession of low-moderate and high resistivity layers which may be correlated to a stratigraphy of fine coarse and massive basement (granite) respectively.

Six vertical electrical Sounding (VES) investigations were conducted by (KEC, 2005) in the well field. The survey indicates the presence of an average of 35meters thick lacustrine sediment which was notably very close to the well logs recorded after drilling. Similarly many other VES conducted in University compound (HU) and northeast of the compound in Damot River identified an alluvium aquifer ranging 20-35meter.

Aquifer type and boundary conditions

The sub-surface boundary conditions between Haramaya dry Lake and Lake Tinke (cross-section B-B') and at the out flux system to Wabishebele catchment (cross-section C-C') was investigated in addition to the surface topography of the well field. Four VES's on the northern boundary trending East-West and four VES on the southern surface out late were carried out. Seasonally along the 2-4m surface topographic difference (when, Tinke Lake is full in rainy season, flows to Haramaya dry Lake) the two Lakes were interacted. However, by now (study period) surface water of Lake Tinke is already disappeared or vanished due to over extraction and siltation.There is no any surface flow towards Lake Haramaya and due to a number of hand dug wells drilled at the vicinity of proviuos Lake Tinke, the subsurface flow may be stopped up. Moreover, if the available 3-5m surface topographic difference in the out late of Lake Haramaya filled by sediment, surface run off goes out of the system southwards.

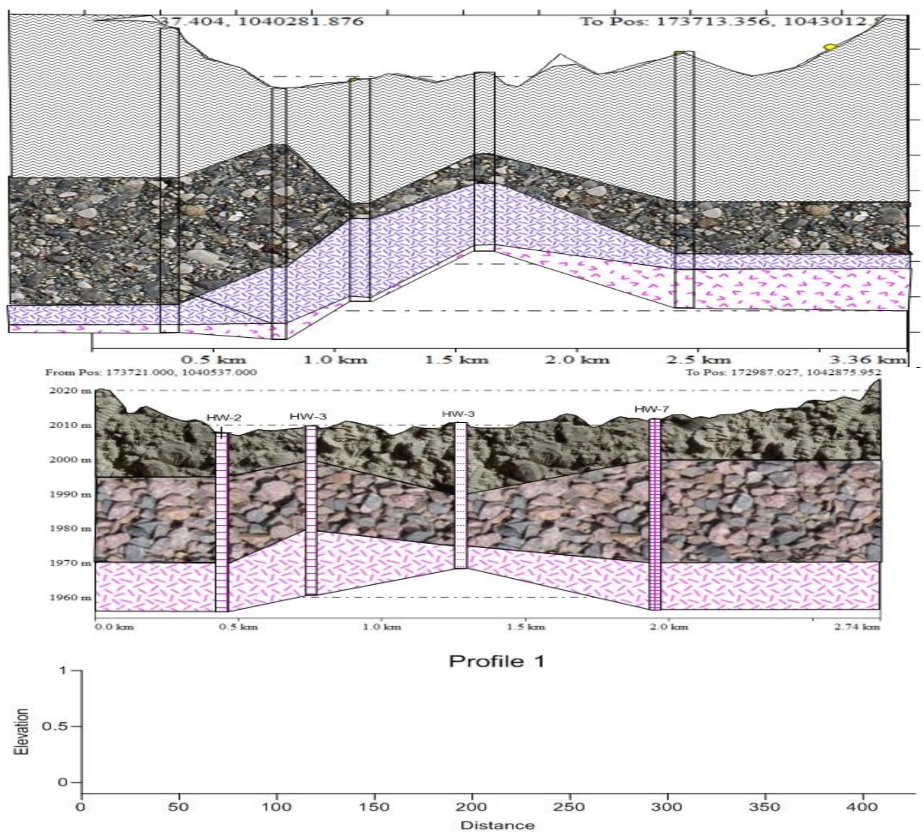


Figure 14: Cross-section showing subsurface interconnection between Lake Tinke & Haramaya

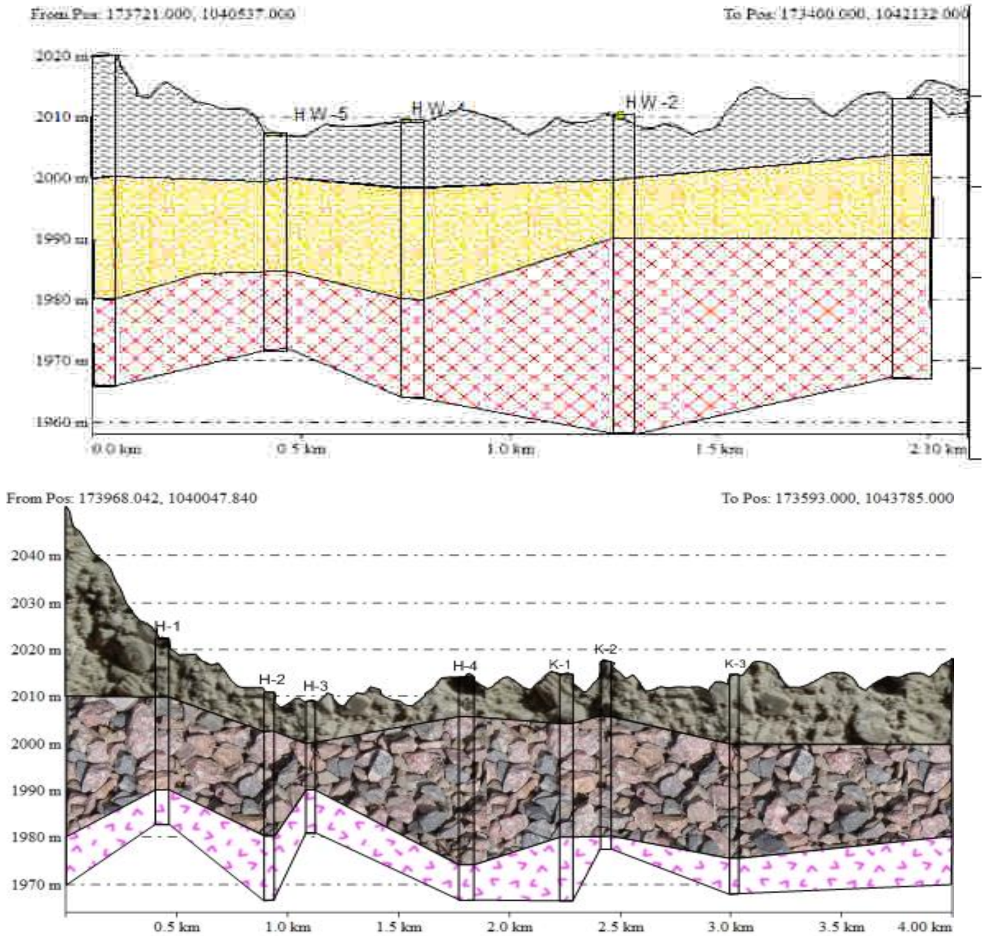


Figure 15: Cross-section showing bed rock topography

Therefore, the finding reveals that the aquifer system is porous medium, unconfined aquifer systems, closed throughout the boundary and on the lower base (granite bed rock) except opened boundary along the north interconnected with Lake Tinike by 4-7m in thicknesses. The thickness of sub surface interaction examined using hand dug wells (8-10m depth) drilled at the boundary within Lake Haramaya and dug wells drilled 200m and greater far from the boundary. The varies cross sections developed from well log and VES's reveals that surely indicates the general groundwater outflow from Lake Tinke to south East of the aquifer (Haramaya dry Lake) seasonally through the layer 17m-21m depth of 4m thickness and calculated water level gradient (Δh) of the traverse shows 4.75m. The average width was taken to 100-180m and average estimated transmissivity of 53m^2/day, using Darcy's Law (Q=T dh/dl x width) the estimated subsurface flow of 50350m^3/day could be added as ground inflow to the water balance of the Lake Haramaya.

In addition to the geological and hydro-geological information, the insignificant value of upward or down ward leakage of groundwater to or from the system was confirmed from the hydrograph analysis of groundwater trend (1st chapter) which indicates groundwater level fluctuation is directly or well correlated with rainfall at certain time lag. If the doubt is true that there is a fracture or some leakages (up or down wards) the result obtained from hydrograph for different season may reflect the reveres (not correlated).

Estimation of hydraulic parameters of aquifer from vertical electrical sounding (VES)

The interpreted VES data reflects only the layer number and layer thickness but not provides directly the aquifer hydraulic properties (K, T, S, Ss, Sy, and etc). Proper evaluation and understanding of the presence of various layers, aquifer type, number, boundary conditions etc understanding of the none climatic natural stresses (geology, tectonic etc) affecting groundwater potentials of the well field are critical and pre-requisite in quantifying aquifer storage properties, available groundwater reservoirs, its future sustainability's, and in accurate estimation of aquifer recharge.

Hydraulic properties of the aquifer system of the well field have been obtained from pumping tests of nine (9) wells by different drilling companies and professionals. However, the obtained values from each well are cumulative effects of the whole formation. Now to evaluate the productivity of each layer and water bearing zone separately, aquifer hydraulic parameter from vertical electrical sounding was implemented in addition to the available parameters estimated from pumping test data. Two approaches; Modified Archie, (1942) and Da-Zarrouk parameters estimatore that represents and simulates the natural earth conditions or non-uniform aquifer materials was applied.

Da-Zarrouk parameters estimator

The application of surface geophysical method in combination with pumping tests at a few locations provides cost effective and efficient alternative to aquifer parameter estimation (Soupois et al., 2005, cited in Okoro et al., 2010). Determination of aquifer properties hydraulic conductivity and transmissivity is best made on the bases of data obtained from pumping tests of wells (Opara et al., 2012).

Da-Zarrouk parameter estimator is a standard method in estimating aquifer properties. The concept of the Dar-Zarrouk parameters (transverse unit resistance and longitudinal conductance) was applied by (Ekwe et al., 2006; Opara et al., 2012) in porous media to determine aquifer hydraulic characteristics within the middle Imo River basin in Nigeria. The applicability of the method for estimation of aquifer hydraulic parameters has been extensively discussed by different researchers (e.g. Keller and Frischnechk., 1979; Koefoed, 1977; Niwas and Singhal,1981) and adopted by many investigators (e.g. Ekwe, 2010; ezeh, 2011; EI *et al.,* 2010; Opara *et al.,* 2012 and Ezeh & Ugwu, 2010).

Niwas and Singhal (1981) have established an analytical relationship between aquifer transmissivity and transverse resistance on one hand, and between transmissivity and longitudinal conductance on the other by combining the Darcy's law equation (1) & Ohm's law equation (2) (cited on Opera et al., 2010).

$$Q = KIA \tag{4.3}$$

$$\bar{J} = \delta\bar{E} \tag{4.4}$$

where K = hydraulic conductivity, I = hydraulic gradient, A = cross sectional area perpendicular to the direction of flow, J = current density, E= electric field intensity, σ = electrical conductivity (inverse of resistivity) and $\bar{J}$ is the current density, $\bar{E}$ is the electrical field intensity and σ is the electrical conductivity = 1/ρ, ρ being the resistivity. This general relation for natural formation like the study area was developed by (Ezeh, 2011) based on the concept of a clear analogy exists between mathematical descriptions of the process of groundwater flow and electrical transmission. The electrical current flow (J) in a conducting medium is governed by Ohm's law and the groundwater flow in a porous medium, by Darcy's law. The electro-hydrological analogy between these two phenomena is widely accepted (Freeze and Cherry, 1979; Fitts, 2002; Singh, 2005 as cited in Ezeh, 2011). The combine equation expressed as:

T_r= K*h=K(R/ρ)=K*σ*R=K*(S/ σ) (Niwas and Singhal (1981)) (4.5)

The relation is called Dar-Zarrouk parameter estimators, which have been shown to be a powerful tool during the interpretation of groundwater survey data (Zohdy et al., 1974). This relation established by Niwas and Singhal (1981) between aquifer hydraulic parameter and vertical electrical sounding data was used in estimating aquifer hydraulic parameters of Haramaya well field.

In areas of known aquifer layer thickness and layer resistivity (Maillet, 1974) is the first to define the concept of these parameters and subsequently called them the Da-Zarrouk variable (R) and Da-Zarrouk function (S).

R=h*ρ and S=h/ ρ (Maillet, 1974) (4.6)

Aquifer transmissivity for all the sounding locations in the study area including no boreholes were computed from the relation below:

T_c = K * h (Henriet, 1976) (4.7)

where T_c is calculated Transmissivity in m2/day, h is aquifer thickness obtained from VES interpretation T = aquifer transmissivity from pumping test, R = Transverse resistance of the aquifer, and S = Longitudinal conductance.

In areas of similar geological setting and not vary greatly in water quality, the product Kσ remains fairly constant (Niwas and Singhal, 1981; Onuoha and Mbazi, 1988, Onu, 1995; Ezeh, 2010). Using this concept the knowing K values from existing wells and σ values deduced or extracted from sounding interpretation for the aquifer at borehole locations has been used to calculate (calculate the Dar-Zarrouk parameter estimators) or value of conductivity equation **(4.8)** for areas of not borehole available. Therefore the hydraulic conductivity (K) of aquifers where no boreholes exist is obtained from the relation below:

K= A constant/δ (Niwas and Singhal, 1981) **(4.8)**

Where K = Aquifer hydraulic conductivity in m/day, σ = Conductivity (inverse of resistivity).
In this study the hydraulic conductivity (K) obtained from pumping test data (Table 3.1) and formation conductivity (σ=1/ ρ_a) sounding interpretation near existing boreholes were used to calculate transmisivity.

On the basis of the pump test analysis, average transmisivity and hydraulic conductivity value of the quaternary sediments range between 11.26-121.23m^2/day and 0.313-4.71m/day respectively while parameters obtained from Dar-Zarrouk parameter estimators calculated from VES are different slightly in thickness 'h' ranges from 43.96-71.09m^2/day and 2.2-2.38m/day respectively.

Kozeny-Carman-Bear relation

To minimize the uncertainties of parameter estimation above, the Kozeny-Carman-Bear method was applied as a second approach. Kozeny-Carman-Bear simulating the **r**elation between the geo-electric and hydraulic properties, formation factor (F) and hydraulic properties, formation resistivity (ρ) and hydraulic conductivity (K) and relation between aquifer resistivity and conductivity of water based on relation between variables of formation factor and resistivity of aquifer material by applying Archie's Law (1st & 2nd).

Archie's Law (Archie, 1942) illustrates the relationship between electrical resistivity and porosity, fluid saturation and fluid type in a rock have many assumptions. Archie (1942) developed empirical formula for effective resistivity of rock that relates the bulk resistivity of a fully saturated granular medium to its porosity and the resistivity of the fluid within the pores using the formula:

$$\rho_a = \alpha * \rho_w * \emptyset^{-m} \qquad (4.9)$$

where ρo is the bulk resistivity, ρw is the fluid resistivity, φ is the porosity of the medium, *m* is known as the cementation factor and the coefficient *a* is associated with the medium and its value in many cases departs from the commonly assumed value of one**.**

For fully saturated aquifer system the following relation was powerful method

$\rho = a * \varphi^{-m} * S^{-n} * \rho_w$ (4.10)

where, ρ effective formation resistivity; ρ_w pore water resistivity; φ porosity; S–saturation

For clay free medium, the $\frac{\rho_o}{\rho_w}$ ratio is called as the intrinsic formation factor, F_i. Therefore, equation 1 can reformulated as (2). The empirical formulas are adopted by (Vinegar, H.J., Waxman, M.H. (1984).

$$\boldsymbol{n} = \boldsymbol{e}^{\frac{1}{m}ln(\alpha)+\frac{1}{m}ln\left(\frac{1}{F_i}\right)} \qquad (4.11)$$

The coefficients ‘a’ and ‘m’ values should, ideally, be determined for each site under investigation.

Where, ρ_o = bulk rock resistivity, ρw = pore-water resistivity.

The value of constant “a & m” were prepared from literatures e.g. as discussed by (Worthington 1993 or…..etc) and value ranges from a – 0.5-2.5; m – 1.3-2.5; n ~2. Or a = empirical constant (0.6 < a < 1), m = cementation factor (1.3 poor, unconsolidated) < m < 2.2 (good, cemented or crystalline), θ = fractional porosity (vol liq. / vol rock).

The aquifer system consists of clayey/silt, sand material enhanced with rubbles and gravels (unclean sand/ clayey sands and a mixture of sand-rubble-gravels). These deviations from clay-free, clean, consolidated sediments, the assumptions make the equation invalid (Worthington 1993). For this reason, the (Waxman, 1984) model or modifications of the Archie’s equation were required (equivalent to Waxman-Smits model (1968) for clayey sediments) and was considered to calculate the apparent formation factor Fa known as ratio of bulk resistivity to fluid resistivity.

$$F = \frac{\rho_o}{\rho_w} = a\emptyset^{-m} \qquad (4.12)$$

To compute the formation factor of clay composed aquifer system, the bulk resistivity’s (ρ_o) resistivity of the formation obtained from 1D resistivity inversion (figure-3.2) and resistivity of water in the aquifer. The objective of the inversion is to obtain a model of subsurface electrical resistivity whose response fits the field data (apparent resistivity values) within the limits of data errors and moreover correlates well with all available data, especially geological information (Santos & Sultan, 2008).

A total of 8 groundwater samples (Measured Electrical Conductivity (EC)) from bore wells nearby to the conducted VES were collected to compute the groundwater resistivity's (ρw). The electrical conductivity of water measured near the point of VES (Table-18 above) was converted to fluid resistivity using Archie's law; the measured electrical conductivity's were converted in to resistivity of water using the relation:

$$\rho_w \ (\Omega m) = 10^4/\sigma w \, (\mu \text{ mhos } cm^{-1}) \text{ (Ezeh, 2011)} \qquad (4.13)$$

In this study, the empirical relationship defining bulk resistivity of a saturated porous rock, in sedimentary rocks, resistivity of pore fluid is probably most important factor controlling resistivity of whole rock and assumed the aquifer system is fully saturated pre-developments. Prior to aquifer parameter estimation; the computed bulk resistivity, aquifer thickness, aquifer resistivity, formation factors were summarized in (table-8 below).
The formation factor (F_a) is calculated by dividing earth resistivity or bulk resistivity to water resistivity for a clay free formation.

$$F = \frac{\rho_o}{\rho_w} \qquad (4.14)$$

Fa is the formation factors, ρ_o is earth resistivity or the resistivity of the brine saturated formation, and ρ_w is the water resistivity measured nearby wells (e.g BH-3-8-6-11, HW-1-2-3-5). F_i which is the y-intercept can compute from graphs of $1/F_a$ Vs ρ_w as $1/F_i$ and BQv/F_i is the slop of the best fit line.

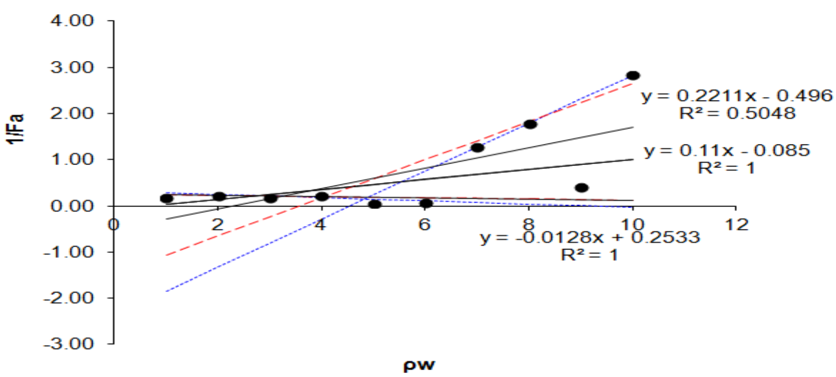


Figure 16: Best fit between the parameter 1/F V, s and $\rho_{w.}$

Therefore, the calculated hydraulic conductivity (K) and transmissivity (T) using equation (4.18) ranges from 3.23-5.12m/day and 100-234m2/day, respectively.

$$K = \left(\frac{\delta_w g}{\mu}\right) \cdot \left(\frac{d^2}{180}\right) \cdot \left[\frac{\phi^3}{(1-\phi)^2}\right]$$

(4.18)

Where d is grain size, δ_w is fluid density (commonly 1000kg/m3), μ and is dynamic viscosity (from review). Therefore, from the aquifer characterization point of view the average aquifer parameters value K, b, T, Sy are 5.67m/day, 27m, 124m^2/day and 11%, respectively.

Part III: Groundwater Recharge Estimation

Introduction

In any planning of groundwater development and designing effective and sustainable management strategies, estimation of groundwater recharge and evaluation of available potentials are pre-requisite. Estimation of groundwater recharge provides quantitative volume of water enters to the aquifer system, which is vital in understanding the available potentials and in setting amount of water to be abstracted safely without aquifer mining and dewatering.

The considerable importance of quantification of natural rates of groundwater recharge for efficient groundwater management, in evaluating groundwater resources, in planning sustainable groundwater development, was illustrated directly or indirect in many literatures (e.g. Alley *et al.*, 2002; Ahmed *et al.*, 2008; Darkwa et al., 2013; Healy and Cook, 2002; Lee et al., 2005; Ahmadi et al., 2013; Ordens et al., 2012).

Groundwater recharge is an addition of water to a groundwater reservoir (Taylor and Alley, 2001and Simmers, 1988). Source of groundwater recharge may be naturally from rainfall or sub surface influx (depending on aquifer type), irrigation return flow and seepage from streams, canals, and reservoirs.

Accurate estimation of groundwater recharge is difficult and challenging because it occurs on a wide variety of scales and time (winter, 2001; Scanlon *et al.*, 2002; Sanford, 2002 and Scanlon *et al*. 2002 cited on Darkwa et al., 2013). Therefore, the choice of appropriate method depends on the conceptualization of the flow system and the specific objective and extent of the study, hydro-geological set up.

Nowadays there are a number of recharge estimation approaches that have been widely applied under different climatic and hydro-geological conditions all over the world (e.g. Scanlon *et al.*, 2002 and Merechal *et al.*, 2006) were documented. According to Scanlon et al. (2002) cited on Lee et al. (2005), typical methods of estimating recharge ratios involve physical, tracer or numerical modeling approaches (an appropriate method should be selected based on various factors such as hydro-geological conditions and scale of interest. There are several uncertainties with each approach for estimating recharge.

In this study these mentioned tasks, current demands and supplies and future sustainability's avoiding aquifer dewatering was carried out in the well field which is vital though it is difficult and challenging. From the obtained from aquifer characterization and trend analysis, the study area is characterized by single, porous & unconfined aquifer system. The small shallow vertical joints of Precambrian rock units have low productivity aquifers (Abudel aziz, 2009). The limestone and sand stone rocks found occupying mountains and hills covering an area of 9.8 km^2, have quite limited exploitability of groundwater resource (Tesfaye, 1993).

In the study area recharge estimation using Chloride Mass Balance Method (Edo, 2009) and using water balance method by (Abebe, 2010; EWWDSE, 2003; Karamara, 2005) was conducted in the well field. However, the estimated result varied greatly and contradicts to each other. To minimize the significant degree of uncertainty, (Misstear, 2000) and (Scanlon et al., 2002) were recommends to employ more than one recharge estimation methods.

Data

Rainfall data

In the study area, Haramaya well field estimation of groundwater recharge using water table fluctuation method was carried out following the trend analysis in groundwater level and aquifer characterization. Monthly based rainfall data was collected from Haramaya gauging station recorded from 1979-2012 E.C for 34 years. But, to simulate the groundwater fluctuation in nine (9) wells the data of eight (8) years was organized to 2004-2012 & considered for analysis). Based on the Ethiopian climatic season, the data was categorized in to four seasons, summer, spring, the dry season, and Belg to investigate trends of each well.

Groundwater level data

Monthly average water level data of two successive years from four (4) non-functional wells and four production monitored by (Karamara, 2005; Harar, 2006), from 6 wells monitored in 2009/10 by (Abebe, 2010), and monitored data from 9 wells of two years (2011 to 2012) in the study period was organized to characterize the groundwater level fluctuations of the area. The groundwater level data was categorized in to different time series' parallel to the rainfall time series. Otherwise, the model output is affected significantly and leads to the right or miss-conclusion on the long term trend and predicted future water level.

Model Analysis

In this unconfined aquifer system quantitative estimation of groundwater recharge using the most widely adopted technique of water table fluctuation (WTF) developed by (Healy and Cook, 2002) and modified water table fluctuation (WTF) suggested by (Moon et al., 2004) was carried out on the area of 50.07km^2. The study provides sound information's for water managers, decision makers and planners. The method is best applied in an unconfined aquifer, short term water level rises occur in response to individual storms showing quick responses to precipitation events (Healy and Cook, 2002; Scanlon et al., 2002; Moon et al., 2004). And can be calculated using:

$$R = S_y \frac{dh}{dt} = S_y \frac{\Delta h}{\Delta t}$$

(5.1)

where R= Recharge (mm/month), Sy= Specific yield, Δh = Change in water table height (mm), Δt = Time interval (month). The modified water table fluctuation methods are:

$$\alpha = \frac{h_1 + h_2 + \text{--------} + h_n}{p_1 + p_2 + \text{---} p_n} * S_y = \frac{\Sigma h}{\Sigma p} * S_y = R$$

(5.2)

where α is recharge ratio, h_1, h_2, ….., h_n is the water level rise for each precipitation event, and P_1, P2, P_3, ….., P_n is the precipitation at each time interval, Σh is the total water level rise due to the cumulative precipitation, and ΣP is the cumulative precipitation in the period corresponding to water level rise (Δh).

This modified WTF method was employed for recharge estimation in hard rock area (Lee et al., 2005).

The volume of groundwater recharge from rainfall can be estimated using rising in water level multiplied by specific yield of the aquifer formation and area of planar aquifer. Estimated recharge may underestimate or over estimate as compared to storm duration, intensity, topography etc. However, many researchers (e.g. Darkwa et al., 2013; Healy and Cook, 2002; Lee et al., 2005; Risser *et al*, 2005; Simmers, 1988; Scanlon *et al.*, 2002 and Kinzelbach *et al.*, 2002). The method is limited for regional scale recharge estimation that sensitivity to influences other than recharge (Jie et al., 2011), in accurate estimation of specific yield (Lerner, 2003; Martin, 2006), and many assumptions incorporated (Healy and Cook, 2002). However, it is easy to be utilized, cost effective, simple, requiring few non-deterministic data mentioned above (Ahmadi et al., 2013).

Estimation of specific yield

Following the determination of water level fluctuation data due to rainfall event estimation of specific yield was carried out which is vital great in water resource managements. The value varied with grain size of aquifer materials and depth of alluvial aquifer. There are a number of methods to quantify a specific yield including; pumping test (single or multi wells), laboratory analysis, literature review, etc but both have their own limitations. The method of pumping test to determine specific yield was applied by various researchers (e.g Remson and Lang, 1955). At an effective testing time of 48 hours, 72hours were also applied by (Meinzer, 1932). The specific yield may be determined during the course of an equilibrium pumping test by comparing the volume of dewatered material in the cone of depression with the total volume of discharge water (Irwin et al., 1955) to determined specific yield from pumping test method.

The method primarily used for unconfined aquifers is presented below. Pumping test method to determine specific yield of unconfined aquifer was presented by Remson and Lang (1955). The method involves the determination of the volume of dewatered material in the cone of depression during the course of a pumping test. The specific yield is then determined by comparing the volume of dewatered material with the total volume of discharged water. The calculation of the volume of dewatered material requires the solution of an exponential series that converges very slowly and is, therefore, time consuming (RAMSAHOYE *and* LANG, 1993). (RAMSAHOYE *and* LANG, 1993) was developed a formula to estimate the specific yield from pumping test as:

$$V = \frac{\pi r^2 e^{4xTs/Q}}{\frac{4\pi T}{Q}} \qquad (5.3)$$

$$= \frac{Q\pi r^2 e^{4xTs/Q}}{4T}$$

Taking the logarithm of both sides of equation 12 produces

$$\log V = \log \frac{Qr^2}{4T} + \frac{4\pi Ts}{Q} \log e$$

(5.4)

$$\log V = \log \frac{Qr^2}{4T} + \frac{5.45Ts}{Q}$$

(5.5)

The specific yield is the volume of water pumped during the test divided by the gross volume of dewatered material within the cone of depression.

$$S = \frac{Qt}{7.48V}$$

(5.6)

where S is specific yield, Q is the average discharge rate of the pumped well, in gallons per day, t is the time, in days, since pumping began, V is the volume of dewatered material, in m^3.

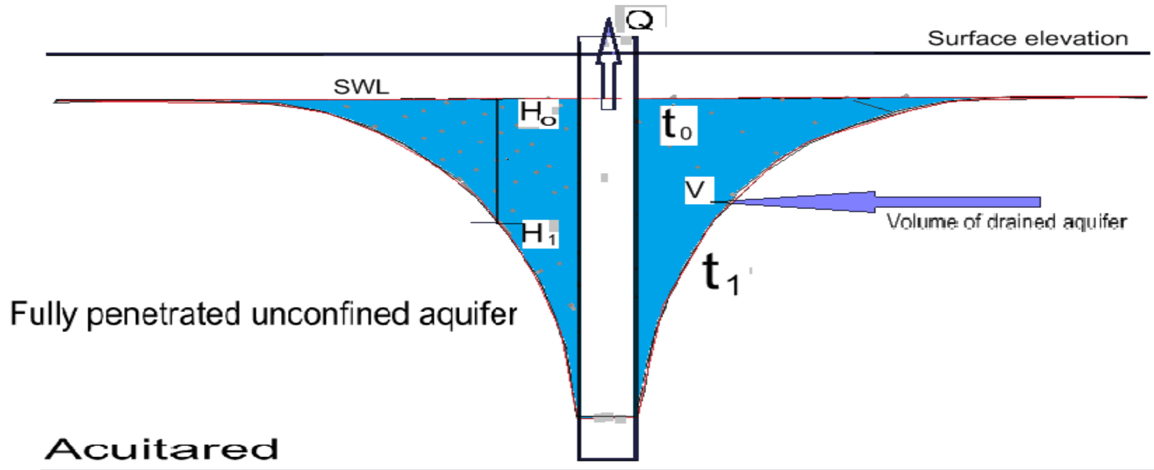


Figure 17: Con of depression and q from unconfined aquifer graph, shows flow line, draw dawn, con of depression, Q, etc as below.

Jacob (1950) showed that if the draw downs in an unconfined aquifer are small compared to the initial saturated thickness of the aquifer, the condition of horizontal flow towards the well is approximately satisfied, so that Equations 4.1 to 4.3 can also be applied to determine the aquifer properties. The Theis-Jacob method is based on this phenomenon. Cooper and Jacob (1946) showed that for the straight-line segment, Equation 4.1 can be approximated by

$$S(r,t) = \frac{2.3Q}{4\pi KH} \log \frac{2.25KHt}{r^2 S}$$

(5.7)

with an error smaller than 1% **2% 5%** 10% for llu larger than **30 20** 10 **7**

as the drawdown difference (As = s(r,t2) - s(r,tl)) per log cycle of time (log t2 –logt2=1), rearranging the above equation gives

$$KH = \frac{2.3Q}{4\pi \Delta S}$$

(5.8)

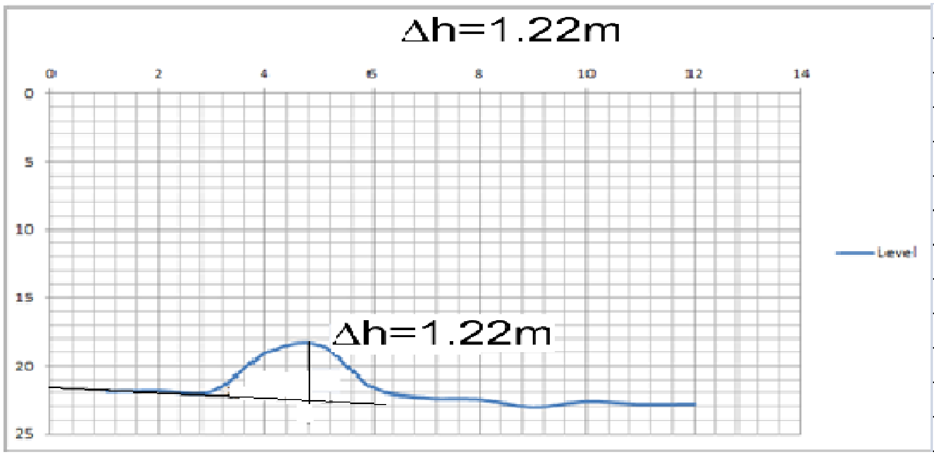
If this line is extended until it intercepts the time-axis where s(r,t) = O, the interception point has the co-ordinates s(r,t) = O and t = to. Substituting these values into Equation **4.3,** after rearrangement, gives

$$S = \frac{2.25KHt_0}{r^2}$$

(5.9)

Accordingly the calculated values of specific yield calculated from 9 wells using pumping test method ranges between 5% and 18% with mean value of about 11%. This specific yield values were used as initial value in parameter estimation.

The rise in water level during the recharge period was obtained as the difference between the peak of the rise and the low point of the extrapolated antecedent recession curve at the time of the peak (figure 5.1). The Δh for all wells was computed with graphical approach as the difference between the peak water level during a recharge event and the extrapolated level to which water levels would have declined if the recharge event had not occurred. The recession curve is the trace that the well hydrograph would have followed had there not been any recharge (Delin *et al.*, 2006). The obtained Δh in the well field using the graph (Figure 5.1) ranges in value from 0.8 to 1.76m at an average value of 1.27m (2005), 1.18m (2007), 0.8m (2008) 1.76m (2009), and 1.37m (2011) was obtained using same method. The average value of rising in water table of specific time interval is 1.23m (2005).



Date	Level
Jan	21.88
Feb	21.83
Mar	21.86375
Apr	19.07222
May	18.4675
Jun	21.58143
Jul	22.33
Aug	22.42333
Sep	23.00
Oct	22.57
Nov	22.78
Dec	22.75

Figure 18: Estimation of Δh using the rescission curve of hydrographs of water level fluctuation

Different value of change in water level (daily, monthly and annual) based were obtained. Hydrographs of the well field monitoring between January 2005 and August 2012 indicated a water level declined by 16.45m in the past 8 year. However, the main information this hydrograph conveys concerns daily fluctuation rather than long-term change in average levels. During dry periods, e.g. 2007-2009, water levels often fell more than 2.5m/year below ground level while during the wet years of 2006, 2010 groundwater level rise by 1.84m and 1.36m/year respectively.

Table 6: Cumulative precipitations, water level rise, and recharge ratios of four monitored wells

Wells	BH-12	BH-7	BH-10	HW-3
Σh (mm)	1.22m*1000	1.14m*1000	0.93*1000	0.67m*1000
ΣP (mm)	348.7mm	348.7mm	348.7mm	348.7mm
Σh/ΣP	3.5	3.3	2.67	1.92
Recharge ratio (%)	38.5	36.3	29.34	21.14

Recharge ratio (%) =Σh/ΣP*S_y, S_y calculated from pumping test ranging 5% to 18% was used. The monitored water level data of the relatively rainy months (wet) and these of dry months was considered first. Consequently the mean annual recharge calculated using equation (5.1) ranging from 22.7-43% and an average value of 32.82% was considered.

However, to get more accurate and reliable recharge values and to minimize uncertainties modified water table fluctuation (WTF) suggested by (Moon et al., 2004) was carried out as second case equation (5.2). The challenge faced when applied this method was selection of best months that have rainfall and monitored water level data. Because there is a time lag between the effect of rainfall and groundwater level was obtained from HARTT model in chapter one. Therefore, to account this lag time and to minimize the estimated gap monitored water level data of full one year and rainfall data of same period was considered instead of selecting rainy and non-rainy season. As a result a range of recharge ratio 27-38% of the annual rainfall was obtained and an average of 34% was considered.

Groundwater discharge rate

The groundwater discharge rate of each well was categorized seasonally in to pumping in dry period and wet period, monthly (to see the time of non-recharge) and annually. To account the effect of pumping for these production wells used in the analysis, the modified WTF method was applied to evaluate the potential overestimation of recharge arising from neglecting the effect of pumping rates and time variant and compared the result. The method was applied for specific site characteristics or to meet particular objectives have been proposed before (e.g. Crosbie et al. 2005; Moon et al. 2004; Cuthbert 2010). The WTF method relies on water table fluctuations, which can reflect phenomena other than groundwater recharge, for example pumping (e.g. Healy and Cook, 2002).

The general inverse relationship between pumping and rainfall, whereby pumping decreases during periods of sustained rainfall (and recharge). An overestimation of recharge is expected if equation (5.10 & 5.11) is applied without accounting for the influence of pumping. A modified version of the WTF method was subsequently adopted in which a correction to account for pumping-induced water table rise, qR* (LT^{-1}), is calculated as:

$$q_{R*} = \frac{Q_{PRP} - Q_{DPR}}{AS_y}$$

(5.10)

where QPRP ($L3T^{-1}$) is the average pumping rate during successive months of no recharge (i.e. when groundwater levels are falling), QDRP ($L3T^{-1}$) is the average pumping rate during successive months of recharge (i.e. when groundwater levels are rising) and A (L^2) is the planar area of the basin.

In this case, groundwater abstraction and monitored groundwater level from 4 wells (Hararghe water supply wells) and (Haramaya University compound) for two successive years of (2005-2006) and (2011-2012) respectively was used to quantify the groundwater recharge by accounting the pumping induced water table rise. But the corrected recharge is then given as qR–qR*(LT^{-1}) (Ordens et al., 2012), qR is obtained using equation (5.11).

$$qR_* = \frac{234{,}000 - 93{,}000}{7000000 * 0.11} = \frac{141000}{770000} = 18.3\%$$

As a result a range of recharge ratio 23-35% of the annual rainfall was obtained and an average of 31% was considered.

Tables 7: mean monthly rainfall of 2005-2012

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Mean	**16.39**	**12.91**	**37.93**	**106.57**	**98.81**	**48.41**	**113.86**	**158.68**	**111.69**	**47.33**	**30.75**	**11.94**

Table 8: Calculated recharge ratio from the three wells

	BH-3	BH-8	BH-10
Recharge Area	0.340022	0.2446575	0.58515591
50.07km2	17239124	12404133	29667404.5
At 7km2	2400556.5	1727281.7	4131200.7
Recharge at 11% Sy	2160364.9	1554455.7	3717846.6

The modified method produced comparable recharge estimates with those estimated using the water balance method by Abebe (2009) and Edo (2009) estimated using Chloride Mass Balance methods.

Conclusion and recommendation

Conclusion

Data from three experiments, trend analysis, aquifer characterization, and recharge estimation, was used to determine groundwater potential and available volumes. Two statistical parameters results were obtained from the HARTT model analysis using rainfall data series of 2000-2012 and 1979-2012 having single data series of groundwater level (2005-20012). The HARTT model reveals declining groundwater level by 13.75m during the past 8 years. The finding of aquifer characterization reveals that the aquifer system have closed boundary except on the northern, where it has contact with Lake Tinke and it is confined by granite rocks at the base indicating that there is no upward or down ward leakages. Moreover, the aquifer system is characterized by porous medium, unconfined, single with an average thickness of 31m and areal extent ranges from 7.06 to 5.76km^2 (down ward). The average estimated hydraulic parameter using various methods (Ss, Sy, T, and K) are 0.0013, 11%, 123m2/day and 4.5m/day, respectively. Moreover, the finding shows that source of groundwater potentials of the well field are only from precipitation (i.e. surface water only, it does not get any regional recharge).

The groundwater recharge rate for each of the observation wells was calculated by multiplying the water level rise with the specific yield values. As a result, a range of recharge ratio of 22.7-43% (average 32.82%), 23-35% (average 29.85%), and 27-38% (average 34%) was noted using WTF, modified WTF, and modified WTF with pumping effects, respectively. The average recharge value of the three methods was considered as 31.62% of the annual rainfall, which showed a wide range of value with the previously estimated values by by various researchers in the well field including (EWWDSE, 2003; KEC, 2005; Edo, 2009 and Abebe, 2010) were 672750m3/year or (21.3 l/sec), 1.15million m^3/year or about 3200 m^3/day, 121.95mm/a, 16% using Chloride Mass Balance Method and 2.832 Mm^3/year or 39.1% of annual precipitations, respectively.

The study showed that groundwater potential of the area declined by 1323438m^3/annually which is greater than the recharged amount of 847000m^3. This implies that having other factors constant, the available head will serve only for 17-20 years. But, if the rate of discharge for irrigation or domestic use exceeds beyond the current rate, if the rate of sediment flow to the lake body grows, etc the groundwater potential will be degraded before the above estimated time and may serve only for 15 years.

Recommendations

Based on the previous and the present research findings, the following points were identified and recommended:

- Additional geophysical surveying to examine the presence of down ward/upward leakage and geological resistivity log (video camera) to calibrate the available well logs.
- Analysis of groundwater level fluctuations from satellite and remote sensing data to compar with the result obtained from trend analysis and actual raw data of fluctuation in groundwater level.
- Investigating the potential rate of sediment collected on the Lake body and then assessing the potential effect for disappearance of Lake Haramaya and on the groundwater potentials,

- Groundwater modeling (steady & transient) to calibrate the potentials of the well field and evaluating the historic groundwater management and designing long term strategies.

Since the water from the watershed is the only source for the groundwater as well as the surface water, planning for how to minimize the current aquifer deterioration/or aquifer mining is vital to recover the groundwater level and should be done simultaneously with the watershed management activities. Efforts to restore the surface water of the dead lake by neglecting the groundwater condition may not be effective and fruit full.

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Biogas Production System Design, Bottling in CNG Cylinder, and its Feasibility

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Funded by HrU Governement Research Grant

Abstract: *The research was concerned with designing of Biogas Production System, Bottling in CNG Cylinders and studying its Feasibility by crosschecking field survey and data analysis. The field survey data support the opinion about the importance of constructing biogas plant for University where the 8000kg biomass is gathered from ten thousand students' night soil and four hundred cattle's. The study indicates that at optimum condition 529* $\mathrm{m}^3/\mathrm{day}$ *volume of biogas is obtained from 8,000 kg of biomass. The 529m*^{3} *volume of biogas produced per day can substitute 19,837.5kWh of electricity. Compressing biogas reduces storage requirements, concentrates energy content and increases pressure to the level needed to overcome resistance to gas flow. As a result of installing compressor for this system,* $529\mathrm{m}^3$ *of biogas volume is stored in 68m*^{3} *of pressure vessel and the pressure increased to 1600kpa from 110.64kpa. In this study, it was possible to see that the Biogas System Design for the campus is financially as well as economically feasible as the NPV is positive and benefit cost ratio is greater than one.*

Introduction

Problems of growing energy consumption and diminishing supplies of fossil fuels has led to researches of the use of renewable energy sources and, consequently, the development of new technological processes of energy production. One of the renewable energy resources is the biogas produced from green energy crops and organic waste matters. Conversion technologies for the production of energy from biomass can be classified as biological or thermal (Claasen et al., 1999). The choice between the technologies depends strongly on the material properties together with the social and economic situation. Anaerobic digestion is one of the biological technologies to produces renewable and clean energy (i.e. biogas) from biomass. Besides, it conserves the fertilizer value presented originally in the waste (VanVelsenand Letting, 1980). The production of biogas from the biomethanation process depends strongly on temperature. Anaerobic digestion can be achieved under psychrophilic (<25c^o), mesophilic (25-45c^o) or thermophilic (>45c^o) conditions. Digestion under the thermophilic condition has many advantages such as higher metabolic rates and effective destruction of pathogens and weed seeds (Van Lier, 1995).

Biogas is a mixture of gases produced during anaerobic decomposition of organic materials. The main gaseous by product is methane (CH_4), with relatively less CO_2, ammonia (NH_3), hydrogen sulphide (H_2S), nitrogen and water vapour. The composition of the gases depends on the chemical composition of the substrate (Bates, 2007). Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 to 750° C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas (Sathianathan, 1975). Its calorific value is $20\,MJ/m^3$ and burns with 60 percent efficiency in a conventional biogas stove (FAO/CMS, 1996). Designing a biogas system requires the services of a project designer experienced with these systems.

All components of a biogas system must be gas tight. Gas leaks are dangerous because certain mixtures of methane gas and air are explosive. Therefore, the design, construction, and operation of these systems should be undertaken only by experienced or carefully trained personnel. There are different types of biogas systems. Biogas plants can be classified based on:

- Feeding method
- Type of construction
- According to geometrical shapes etc.

The success of biogas plants (projects) at an area depends on: availability of organic materials, cost of constructing, found energy sources and its costs, experience, knowledge, ambient climate conditions especially temperature, and acceptability for people constructing these plants.

The digestion of organic matter by anaerobic microorganisms occurs naturally in the wet environments where there is no oxygen found as: - swamp, bottom of lakes, inside wastewater net pipes and landfill (British Biogen, website).The evolved gas from anaerobic digestion of organic matter was noticed and used very early by ancient Chinese by burning the gas given of when vegetables and manures were left to decompose in a closed vessel. Also other reports point to the using of biogas during 10^{th} BC century in Assyria and 16^{th} century in Persia for heating bath water (British Biogen, website). In the last centuries many scientists appeared who interested in anaerobic digestion process by studying the evolved gases, anaerobic microorganisms, substrate and other affecting conditions and factors. From these scientists: Van Helmont, Benjamin Franklin, Volta, Beachans, Pastuer and especially Sir Humphry Davy who indicated that methane is one of the gases that generated from anaerobic digestion in 1808 (British Biogen, website).

In 1859, the first biogas plant was constructed in India, while the first plant appeared in England in1895 (British Biogen, website). The biogas production and use began in 1970s in America (Oregon Office of Energy, 2002). Biogas plant was constructed in Ethiopian, Ambo Agricultural College to generate energy required for the purpose of welding in1957/58. During the period 1980 – 2000 more than 1000 biogas plants have been constructed to government institutions, private sector and communities, where most of them were established for demonstration purposes. But the awareness and practices didn’t go beyond such places (MoguesWorku, 2009).

Statement of the Problem

Energy is a means for performing activities. For the humanity, energy is a vital component of development. There are two types of energy sources on the Earth:

i. Conventional energy sources and
ii. Renewable (non-conventional) energy sources.

Conventional energy is obtained from a static storage such as fossil fuels, nuclear reactions etc. It remains static bound in position until it is released by human actions. These are finite and non-renewable. On the other hand, non-conventional energy is obtained from natural sources, which can be continuously formed. Solar energy, wind energy, Geo thermal energy and bio energy fall into this category. The following factors are driving forces for research in renewable energy resources for households use:

- The oil crisis of the 1970s due to depletion of convectional fuel,
- Cost increment of kerosene fuel,
- Health risk of using convectional fuel and
- GHG emission

The key concerns that guided searching for alternative energy sources are that such alternative energy sources are: renewable, safe, locale specific, cheap, decentralized and appropriate.

Objective

The general objective of this study is to design biogas production system and ensure whether it is financial consistent or not. More specifically, the study has the following objectives:

- Biogas production System design
- Estimating biogas production
- Estimating cost of plant
- Evaluate and compare energy choice
- Construct the plant if it is feasibly

Significance of the research

The following are some of the socio economic impacts that resulted from constructing biogas plants:

- Provide new job opportunities.

- Using renewable energy source from materials that should be disposed of, decreasing paid money for getting energy from other sources like kerosene, natural gas etc and so saving family income.
- Using produced biogas reduces the quantity of imported kerosene and other energy sources which save money for government.
- Using digested organics for fertilizing crops reduces the used amount of manufactured fertilizers, which save money for both farmer and government. Also this using enhances crops production, which will increase the farmer income.

Methodology

To fulfill the objectives of this study, the following methodology has been used.

i. **Beginning phase: Desk study**
    - Collection of secondary data & information from Literature
    - Preparation of questionnaires for primary data collection

ii. **Investigation and data collection phase: field study**
    - Primary data collect from different sectors

iii. **Data Analysis, Interpretation and Report Preparation**
    - Once the field and desk activities would complete, all the data collected from the field and secondary sources crosschecked, verified, analyzed and interpreted using appropriate theory

Literature Review

Historical Background of Biogas

Biogas technology was introduced in Ethiopia as early as 1979, when the first batch type digester was constructed at the Ambo Agricultural College. In the last two and half decades around 1000 biogas plants, ranging in size from 2.5 m^3 to 200 m^3 were constructed in households, community and governmental institutions in various parts of the country. Up to 2008, approximately 40% of the biogas plants that were constructed are not operational due to a lack of effective management and follow-up, technical problems, loss of interest, reduced animal holdings, leave of ownership, water problems, etc.(NBP,2008).

Human Excrements

In most cultures, handling human excrement is loaded with taboos. Thus, if night soil is to be used in a biogas system, the toilet in question should drain directly in to the system so that the night soil is fermented without pretreatment. Human excreta are potential raw material for biogas production. One adult at ordinary diet will produce from 100-250 grams of night soil per day. On a vegetable diet, an adult will produce from 300-400grams a day. Night soil is usually neutral to slightly alkaline in pH, 24-27% TS (Dry weight) with a C/N of 6 to 10, nitrogen 4 to 6 %, VS 85% of TS (Krishna, 1987).Biogas production from human night soil is, averaging $0.02-0.03m^3/day$ from 200grams on a wet weight basis at 70% CH_4 (Krishna, 1987).

Biogas Composition & Properties

Biogas is a mixture of gases evolved from digestion process of organic matter by anaerobic bacteria at anaerobic conditions (i.e. without oxygen) (Mattocks, 1984). Most studies about biogas indicate that methane (CH_4) and carbon dioxide (CO_2) are the main components, where the ratio of methane ranged between 50 - 80% and the ratio of carbon dioxide range is 20 - 50% (EREC, 2002). Other components of biogas that may be found in small amounts (traces) are: Hydrogen (H_2), Nitrogen (N_2), Hydrogen Sulfide (H_2S), Carbon monoxide (CO), Ammonia (NH_3), Oxygen (O_2) and water vapor (H_2O) (Schomaker et al., 2000).

Table 1: Composition of Biogas (source: FAO/CMS, 1996)

Substance	**Symbol**	**Percentage (%)**
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5.0-10
Nitrogen	N_2	1.0-2.0
Water Vapor	H_2O	0.3
HydrogenSulphide	H_2S	Traces

Methane and carbon dioxide are odorless and colorless gases. Hydrogen sulfide is colorless but it has an odor of rotten eggs in addition to its toxicity (FAO/CMS, 1996). Carbon dioxide, hydrogen sulfide, ammonia and water vapor considered corrosive substances (Schomaker et al., 2000). In general; biogas with all its components is colorless, odorless and lighter than air (FAO/CMS, 1996).

Application of Biogas

Biogas is more convenient to use than traditional fuels, such as fire wood, dried dung and even kerosene. It gives a hot, clean flame that does not dirty pots or irritates the eyes, as does the smoke from other fuels. The composite from the plant can be used for fertilizer. Biogas can also be used in engine to drive machinery and water pumps. The concept of replacing wood fuel and petroleum oils by alternative fuels, such as biogas has encouraged governments in various countries to set up biogas programs. Eg. India, China and Nepal etc. for cooking, lighting, heating running engine, electricity (power) etc. (GTZ, 1999).

Normally, the biogas produced by digester can be used as it is just in the same way as any other combustible gas. But, further treatment or conditioning is required, for example, to reduce the hydrogen sulfide content in the gas.

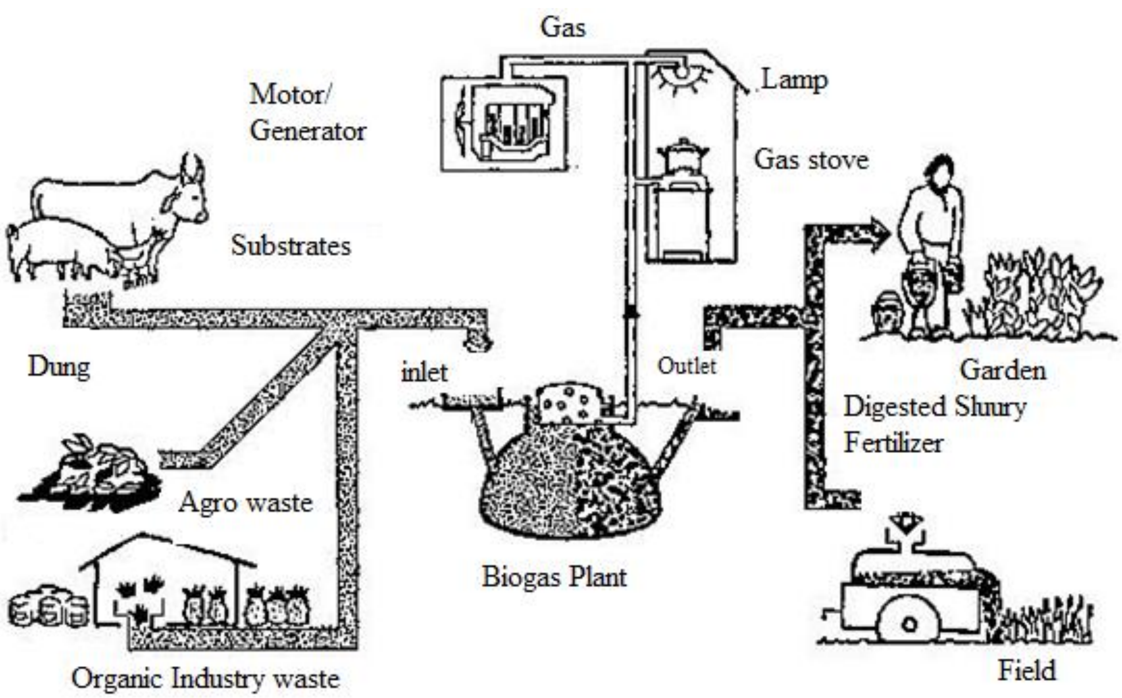

Figure 1: A Typical Biogas System Configuration (Source: GTZ, 1989)

The Benefits of Biogas Technology

Well-functioning biogas systems can yield a whole range of benefits for their users, the society and environment in general:

- Production of energy (heat, light, electricity)
- Transformation of organic waste into high quality fertilizer
- Improvement of hygienic conditions through reeducation of pathogens, worm eggs and flies
- Reduction of workload, mainly for women
- Environmental advantages through protection of soil, water, air and forested vegetation
- Micro-economic benefits through energy and fertilizer substitution, additional income
- Macro-economic benefits through decentralized energy generation, import substitution and environmental protection.

Microbiological Process in Biogas

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane producing bacteria. The whole biogas process can be divided into three steps. These are:

- Hydrolysis
- Acidification and
- Methane formation

Hydrolysis

In the first step (hydrolysis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids (Ghaly et al., 2000).

Acidification

Acid producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultative anaerobic and can grow under acid conditions. To produce acetic acid, they need Oxygen and Carbon. For this, they use the Oxygen solved in the solution or bounded oxygen. Hereby, the acid producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction (Schink, 1997).

Methane formation

Methanogenes involved in the third step, decompose compounds to low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), in ruminant stomachs and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial general. The main difference lies in the makeup of the bacteria's cell walls (de Mes et al., 2003).

Factors Affecting Anaerobic Process

There are many factors affecting the digestion process inside the digester and the quantity of produced biogas. These are: microbes balance, temperature, substrate type, stirring, total solids or moisture, carbon/nitrogen ratio (C/N), time remaining of organics inside the digester, acidity (pH), and the presence of activators or inhibitors (Mattocks, 1984; FAO/CMS,1996). Any drastic change in these factors can adversely affect the biogas production. So these parameters should be adjusted within the desirable range to operate the biogas plant efficiently (Chatterjee, 2007 and Marchaim, 1992).

Microbes Balance

Methanogenes convert simple acids and hydrogen that produced by fermentative bacteria species into methane gas and carbon dioxide; this means there should be stable ratios between the different types of anaerobic bacteria population. For example; if the acidogenic bacteria population increases more than the appropriate ratio then there will be an excess accumulation of acids inside the digester which will increase acidity (pH fall down) causing deactivation or stop acting of methanogenes and so the digestion process. In contrast; if the population of acidogenic bacteria decreases significantly, there will be no enough acids for methanogenic bacteria which will decrease biogas production (Mattocks, 1984;FAO/CMS, 1996; Schomaker et al.,2000).

Substrate type

Anaerobic bacteria can digest all organic materials but they differ in the time interval required for complete digestion. That is, some are easily digested and in short time (from few to many days) while others are hardly digested and in long time (months or years) and this is according to the compounds from which the organic matter is composed (Mattocks, 1984;FAO/CMS, 1996).

Carbon to Nitrogen ratio (C/N ratio)

C/N ratio means the ratio of carbon element amount in organic matter to its content of nitrogen element amount (FAO/CMS, 1996). The best C/N ratio is 20-30 atoms of carbon for each atom of nitrogen (20-30carbon atoms: 1 nitrogen atom) (Mattocks, 1984; FAO/CMS, 1996; EREC, 2002). High or low C/N ratio will effect negatively on the digestion of the substrate. Substrates with a too low C/N ratio lead to increased ammonia production, results in toxic effects, and inhibition of methane production. A too high C/N ratio means lack of nitrogen, from which negative consequences for protein formation and thus the energy and structural material metabolism of the microorganism result. A high carbon nitrogen ratio is likely to acidify and bring about the failure of fermentation.

Materials with high C/N ratio should be mixed with those of low C/N ratio to bring the average ratio of the composite input to the desirable level (Karki and Gautam, 1994). It is recommended that, if C: N ratio is high the gas production can be improved by adding nitrogen in the form of cattle urine or by fitting a latrine to the plant (Fulford, 1988).The carbon nitrogen ratio of pig and cattle manure is suitable, while that of human and chicken dung is low for effective digestion. The carbon nitrogen ratio of fresh vegetation is high and this ratio is getting very high in old vegetation, therefore these materials should be mixed in proper proportions in order to start the fermentation process and raise the yield of biogas. Accordingly, biogas production varies as per the carbon/nitrogen ratio of the feeding material (EAEDPC/SNV Ethiopia, 2008).

Temperature

Methanogenes can act on the substrate in wide range of the temperature from below freezing to above 57.2℃ (EREC, 2002). There are three ranges of temperature at which digestion process can be occurred and these ranges are (Mattocks, 1984):

- Low temperature range (Psycrophilic bacteria range): less than 35℃
- Medium temperature range (Mesophilic bacteria range): ranged between 29℃and 40℃
- High temperature range (Thermophilic bacteria range): from 50℃ to55℃.

According to another source (FAO/CMS, 1996), the optimum temperature for the digestion process is 35℃. In general the higher temperature inside the digester the less time required for completing digestion of organic materials (more production of biogas) since more methanogenic bacteria are working upon substrate and also more destruction for diseases causing microbes. The temperature inside the digester should be stable, since the methanogenic bacteria are highly sensitive toward changes and variations of temperature inside the digester especially at high temperature ranges(51.7-39.4℃) where the productivity of the biogas dropped significantly, while it drops gradually at low temperature range (35-0℃)(EREC, 2002).That is, a sudden or fast temperature changes reduces the production of biogas or may be stop its production, so temperature monitoring is essential especially for biogas plants work at high temperature range and may additional heating system or advanced digester isolation is required.

The biogas plants in Ethiopia are expected to be operated in mesophilic range because the temperature in most regions of the country is within this range (EAEDPC/SNV Ethiopia, 2008).

pH value

pH value is an important parameter affecting the growth of microbes during anaerobic digestion. pH value of the digester should be kept within the desired range of 6.8-7.2 by feeding it at optimum loading rate. Acetate and fatty acids produced during digestion tend to lower pH of the digester liquor. However, the ion bicarbonate equilibrium of carbon dioxide in the digester exerts substantial resistance to pH change. This resistance to the change in pH is known as buffer capacity, is quantified by amount of strong acid or alkali added to the solution in order to bring about change in pH. Thus the presence of bicarbonate helps to prevent adverse effect on the microorganisms which result from low pH caused by excess production of fatty acids during digestion. Proteins and other organic compounds, as well as bicarbonate, take part in the buffering capacity and the resistance to the changes in pH (Chatterjee, 2007).

Naturally, in the first few days the pH falls as a result of producing acids by acidogenes. After that, pH rises gradually as a result of nitrogen digestion (forming $NH4^{+}$). Then the pH stabilized between 7.2 and 8.2 where production process of biogas stabilized also (FAO/CMS, 1996).The characteristic of the feed night soil has pH value 6.9 to 8.4(Joon Moo Hur,2001).For adjusting pH value, acidic materials as sodium bicarbonate should be added to the digester contents (or with loaded organics) in the case of significant pH rising while lime or any other basic material can be added in the case of pH falling (Mattocks, 1984).

Stirring

Optimum stirring substantially reduces the retention time. Stirring is very important for completing digestion process and enhancing biogas production. Since stirring break down the scum formed on the surface of digester contents and prevent the bacteria from stagnating in their own waste products (Mattocks, 1984).

Stirring is more important for large scale biogas plants. Stirring for digester contents of small plants could be done manually by steel rods from substrate introducing pipe, or by paddles while large scale plants require more sophisticated stirring system as gas recirculation and mechanical stirrer. Good mixing of organic wastes with water before introducing the slurry into the digester enhances the digestion process (Mattocks, 1984; FAO/CMS, 1996)

Total Solids

Total solids mean the amount of solid particles in the unit volume of the slurry and they usually expressed in the percentage form (FAO/CMS, 1996). Mattocks (1984) pointed that the percentage of total solid should be between 5% and 12% while other source reported that the best biogas production occur when total solid is ranged from 7% to 10% because of avoiding solids settling down or impeding the flow of gas formed at the lower part of digester (FAO/CMS, 1996). Therefore; dilution of organic substrate or wastes with water to achieve the desirable total solids percentage is required.

Hydraulic retention time (HRT)

Most anaerobic systems are designed to retain the waste for a fixed number of days. The number of days the materials stays in the tank is called the hydraulic retention time. The required time for complete digestion of the substrate inside the digester depends on the type of the substrate, substrate particles size, stirring and mainly on the temperature of the digester (Mattocks, 1984;FAO/CMS, 1996).

In general the highest digester temperature and the finest substrate particles size the shorter retention time. According to the most reports about anaerobic digestion process the retention time of 40 to 60 days is satisfied for digesters work at temperature range between 20℃ and35℃ (EREC, 2002; Mattocks, 1984 and FAO/CMS, 1996).

Inhibitors and Activators

Presence of some substances in the contents of the digester below certain concentrations may activate the digestion process and so increasing the biogas production, but at higher concentrations it may become inhibitors. For example, presence of NH_4 from 50 to 200 mg/l stimulates the growth of microbes, where as its concentration above 1500mg/l produces toxicity (FAO/CMS, 1996). Results of other study pointed that adding small amount of nickel metal (as nickel chloride) to rice straw substrate stimulate its biogas production while nickel larger amount gives opposite results (TRI, website). The presences of some substances can kill anaerobic bacteria as antibiotics, drugs and other medical wastes (Mattocks, 1984).

Digester Loading Rate

The digester loading indicates how much organic material per day has to be supplied to the digester or has to be digested. The digester loading is calculated in kilograms of organic dry matter per cubic meter of digester volume per day (kg ODM/m^3/day).Long retention times result in low digester loading. If the digester loading is too high, the pH falls. The plant then remains in the acid phase because there is more feed material than methane bacteria.

Basic types of biogas plant

Biogas plants can be classified based on:

- Feeding Method
- Type of construction
- According to geometrical shapes
- According to orientations of inlet and outlet
- And according to buried position

Based on feed method they are classified as (FAO/CMS, 1996):

- Batch feed plants
- Semi continuous
- Continuous feed plants

Batch plants are filled completely and then emptied after a fixed retention time. The major disadvantage, their gas output is not steady. To achieve a more or less uniform rate of biogas production, several digesters must be operated in parallel i.e. filled at staggered intervals.

Batch plants are suitable for digesting straw, fibrous material with high solids content, usually in areas with low annual rainfall, and for use as simple demonstration plants (GTZ, 1989).Continuous feed plants are those in which there is a continuous through flow of biomass, resulting in a near constant volume of slurry in the digester. Such plants are feed once or twice a day.

The advantage of continuous feed plants is that the bacteria receive a regular supply of substrate and are therefore able to generate a more constant supply of biogas. The problem is that buoyant constituents tend to form a stiff layer of scum that impedes biogas production and may even plug up the plant. That drawback can be countered by installing suitable agitators and lengthening the retention time (GTZ, 1989).Continuous feed biogas plants are sized on the basis of the desired retention time for the organic material, in combination with the digester load, which in turn is a function of the existing temperature and type of substrate (GTZ, 1989).

Based on the type of construction biogas is classified as:

- Fixed dome plants
- Floating drum plants
- Plastic covered bag plants

Fixed domed and floating drum biogas plants are two basic types of tested biogas plants that have gained wide spread acceptance (Mattocks, 1984).

Fixed dome plant

A fixed dome plant comprises a closed, dome shaped digester with an immovable, rigid gasholder and a displacement pit (expansion chamber). The gas collected in the upper part of the digester. Gas production increases the pressure in the digester and pushes slurry into the displacement pit, from where the slurry flows back to the digester as soon as gas is released. The volume of the expansion chamber is equal to the volume of gas storage.

Gas pressure is created by the difference of slurry levels between the inside of the digester and expansion chamber. When gas is extracted, a proportional amount of slurry flows back into the digester. The gas pressure does not remain constant in a fixed dome plant, but increases with the amount of stored gas. Consequently, a special purpose pressure controller or a separate floating gasholder is needed to achieve a constant supply pressure. The digesters of such plants are usually made of masonry, with paraffin or bituminous paint applied to the gas filled area in order to make it gastight (GTZ, 1989).

Fixed dome plants must be covered with earth up to the top of the gas filled space as a preventive measure (internal pressure up to 0.1-0.15 bar). As a rule, the size of the digester does not go beyond 20 m^3, corresponding to a gasholder volume of $3-4m^3$.The earth cover makes them suitable for colder climates, and they can be heated as necessary (GTZ, 1989).

The digester is filled through the inlet pipe up to the bottom level of the expansion chamber. The level of original filling is called the zero line. Under the anaerobic condition biogas is produced. The following figures (2.2, 2.3, 2.4 and 2.5) show the basic element and some models of this design (GTZ, 1989).

Advantages fixed dome plant:

- It has low cost compared to floating drum type as it uses cement and no steel.
- It has no corrosion trouble (problem)

- Heat insulation is better as construction under the beneath the ground, temperature is be constant.
- The design is compact, it saves space of construction
- Less need of maintenance

Drawback fixed dome plant:

- Gas production per cubic meter of the digester volume is less.
- Gas pressure fluctuates substantially and is often very high. This makes complicates gas utilization
- Plant often not gas light (porosity and cracking often cause irreparable leaks.)

Fixed dome plant is only recommended in cases where experienced biogas technicians are available for building them, and when the user is amply familiar with how the plant operates (GTZ, 1989).

Floating drum plant

The main components of this design are nearly the same as that of fixed dome design, but the difference is in the system of biogas collection. In this design, the biogas collected inside mild steel drum that adjusted over the top of the digester. This drum moves up and down according to the biogas pressure rise up under gas pressure, that is; when the quantity of biogas increases, the drum moves up and as the biogas consumed it is moved down (FAO/CMS, 1996).

Figure 2 shows a schematic diagram for a water jacket floating drum design show one of the applied floating drum plant.

Advantage:

- Floating drum plants are easy to understand and operate
- They provide gas at a constant pressure
- Volume of stored gas visible directly
- Few mistakes in construction

Drawback:

- High construction cost of floating drum
- Many steel parts liable to corrosion, resulting in short life(up to 15 years)
- Maintenance intensive due to the necessity of periodic painting & rust removal.
- If fibrous substrates are used, the gasholder shows a tendency to get “stuck” in the resultant floating scum.

Floating drum plants can be recommended as mature, easy to operate, and functionally capable means of producing biogas, particularly when reliability is demand more than inexpensiveness. Water jacket plants are universally applicable and especially easy to maintain (GTZ, 1989).

Fixed dome design costs less than floating drum design and it is of less repair requirements. Floating drum design provides biogas with stable rate or pressure while the biogas rate in fixed dome design is variable (Mattocks, 1984; FAO/CMS, 1996).

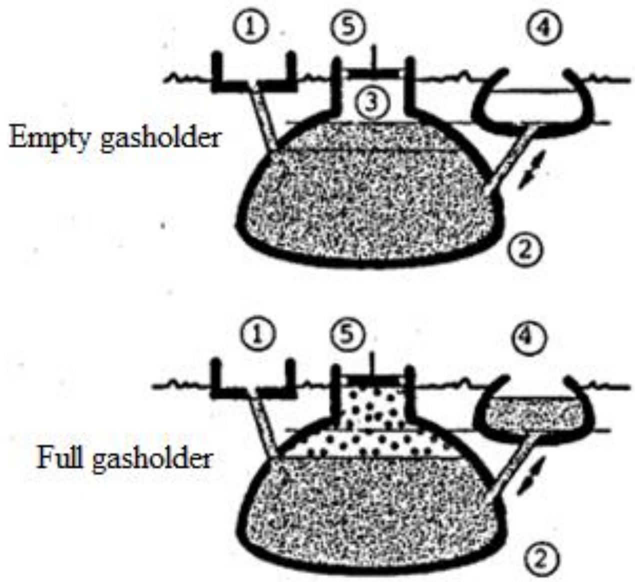

Figure 2: Basic function of a fixed dome biogas plant, 1 Mixing pit, 2 Digester, 3 Gasholder, 4 Displacement pit, 5 Gas pipe (Source: OEKOTOP (sited in GTZ, 1989:62))

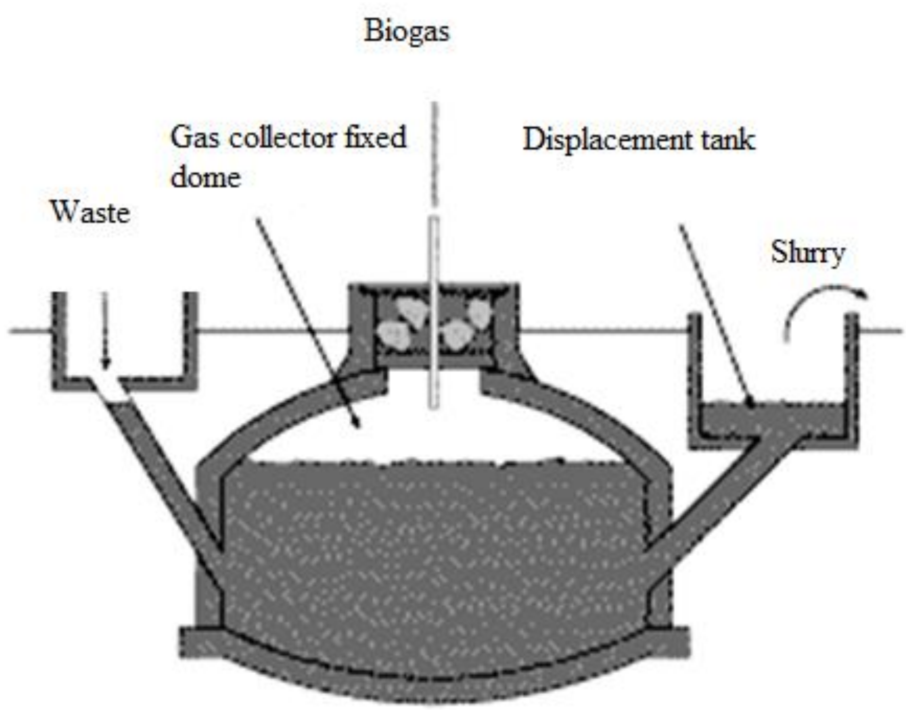

Figure 3: Chinese fixed dome plant (Source: Medyan, 2004)

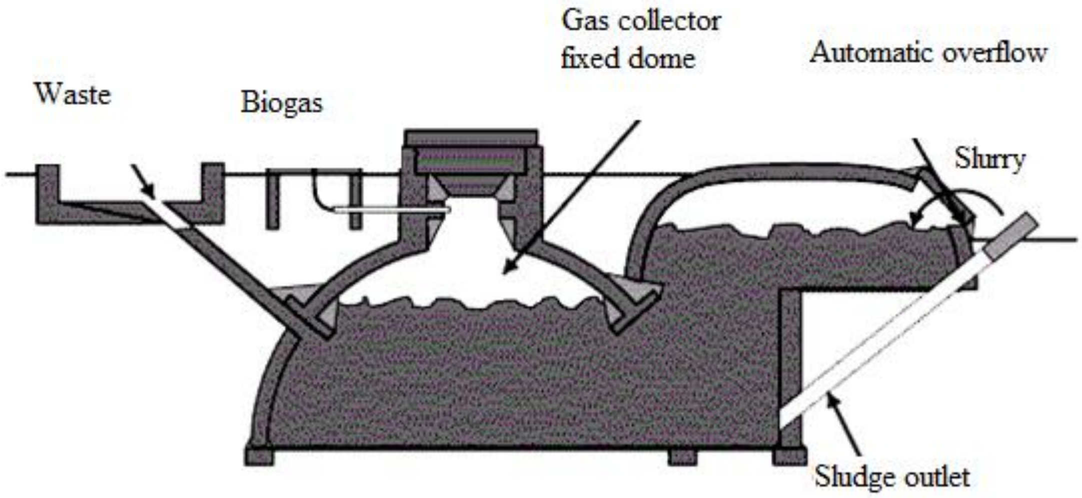

Figure 4: Fixed dome plant Camartec design (source:Medyan, 2004)

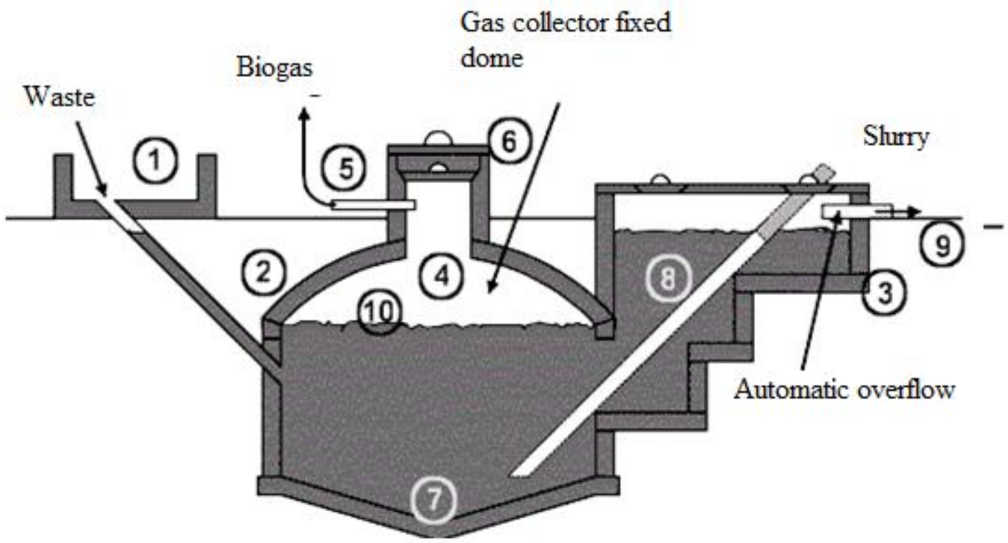

Figure 5: Fixed dome plant Nicarao design: 1. Mixing tank with inlet pipe and sand trap, 2. Digester, 3. Compensation and removal tank, 4. Gasholder, 5. Gas pipe, 6.Entry hatch, with gastight seal, 7. Accumulation of thick sludge, 8. Outlet pipe , 9. Reference level &10. Supernatant scum, broken up by varying level (source: Madyan Adel, 2004)

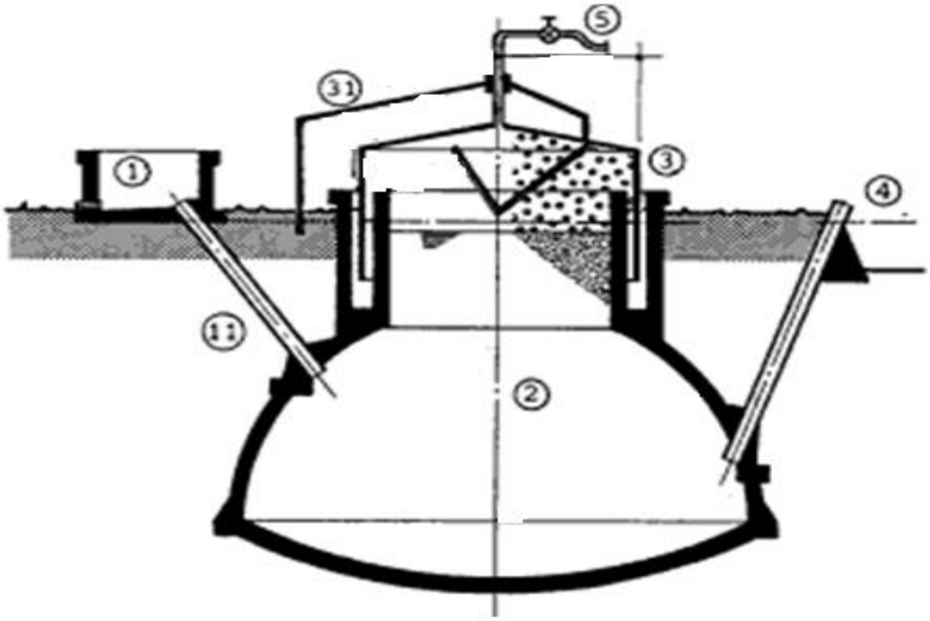

Figure 6: Floating drum plant 1.Mixing pit, 11.Fill pipe, 2.Digester, 3.Gasholder, 31. Guide frame, 4. Slurry store, 5.Gas pipe (Source: Madyan Adel, 2004).

BIOGAS TECHNIQUE

Design Constraint

When selecting a design, the following operating requirements need to be considered.

- Type and composition of organic material which determines the choice of process.
- Knowing demand for biogas and fertilizer, in addition to available substrate quantities, which determines the size of the biogas plant.
- Cost of material building
- Economy of labor input for building and operating the plant.
- Knowledge and experience of the organization or person promoting the biogas plant.

Sizing of Biogas plant

To calculate the size of a biogas plant, certain characteristic parameters are used. These are as follows:

- Daily fermentation slurry feed (substrate input) (S_d),
- Retention time (RT),
- Specific gas production per day (G_d), which depends on the retention time and the feed material.

The following additional concepts and parameters are also used in the theoretical literature:

Dry matter (DM): The water content of natural feed materials varies. For this reason the solids or dry matter content of the feed material is used for exact calculation.

Organic dry matter (ODM or VS): Only the organic or volatile constituents of the feed material are important for the digestion process. For this reason, only the organic part of the dry matter content is considered. Most favorable ODM value desired is 8%.

Constrains for Biogas Technology Dissemination

The main constrains that faces dissemination of biogas technology in most societies are:

i. Cost for constructing biogas plants and long the time period (relatively) required for pay back the capital.
ii. Instability of biogas production and fall of biogas production in cool months.
iii. Experience required for constructing biogas digesters.
iv. Found of some toxic components (usually in trace quantities) in biogas, especially hydrogen sulphide and ammonia (British Biogen, website).

Parts of Biogas Plant

Biogas plant consists of the following main components:

- Mixing pit (tank)
- Inlet and outlet
- Digester
- Gasholder
- Slurry storage(Compost tank) (detail in section 5.2.5)
- Gas pipe, valve and accessories

Depending on the available building material different variants of the individual components are possible. The following section shows the detail explanation of each component.

Mixing Pit (tank)

In the mixing pit, the substrate is diluted with water and agitated to yield homogeneous slurry. The fibrous material is raked off the surface, and any stones or sand settling to the bottom are cleaned out after the slurry is admitted to the digester

The useful volume of the mixing pit should amount to 1.5-2 times the daily input quantity. In the case of a biogas plant that is directly connected to animal housing, it is advisable to install the mixing pit deep enough to allow installation of a floating gutter leading directly into the pit

Inlet and Outlet

The inlet (feed) and outlet (discharge) pipes lead straight into the digester at a steep angle. For liquid substrate, the pipe diameter should be 10-15 cm, while fibrous substrate requires a diameter of 20 - 30 cm. Plastic or concrete pipes are preferred (GTZ, 1989).

Both the inlet and the outlet pipes must be freely accessible and straight, so that a rod can be pushed through to eliminate obstructions and agitate the digester contents. The pipes should penetrate the digester wall at a point below the lowest slurry level (i.e. not through the gas storage). The points of penetration should be sealed and reinforced with mortar.

The inlet pipe ends higher in the digester than the outlet pipe in order to promote more uniform flow of the substrate. In a fixed dome plant, the inlet pipe defines the bottom line of the gas holder (Fig.3.2 (1)). In a floating drum plant, the end of the outlet pipe determines the digester's slurry level (Fig.3.2 (2)) (GTZ, 1989).

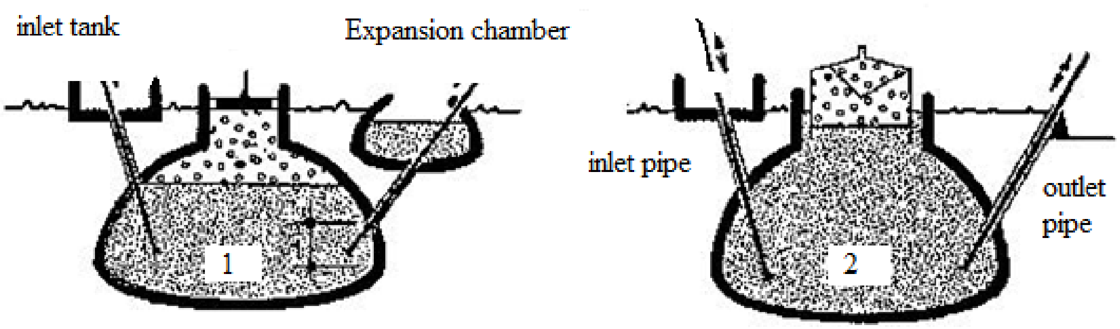

Figure 7: Inlet and outlet for fixed dome (1) and floating drum plants (2) (Source: OEKOTOP (sited in GTZ, 1989:71))

Digester

Digester tank is an area where the biomass is stored and fermentation takes place. When the biomass ferments with sufficient retention time, it will produce a biogas. Digesters shape can be in different form. The digester of a biogas plant must accommodate the substrate and bacterial activity, as well as fulfill the following structural functions (GTZ, 1989):

- Accept the given static forces
- Provide impermeability to gas and liquids
- Be durable and resistant to corrosion

As a rule, the digesters of simple biogas plants are made of masonry or concrete. Such materials are adequately pressure resistant, but also at risk to cracking as a result of tensile forces. The following forces act on the digester:

- External active earth pressures (p_E), causing compressive forces within the masonry
- Internal hydrostatic and gas pressures (p_W), causing tensile stress in the masonry

Thus, the external pressure applied by the surrounding earth must be greater at all points than the internal forces ($p_E > p_W$)(GTZ,1989).

Sizing digester

The size of biogas plant depends on the quantity, quality, and kind of available biomass and on the digesting temperature. The size of the digester, i.e. the digester volume (V_d), is determined on the basis of the chosen retention time (RT) and the daily substrate input quantity (S_d)

$$V_d = S_d \times RT \tag{3.1}$$

$$S_d = m_{biomass} + m_{water}$$

Where, V_d = Volume of digester

S_d = Daily substrate input

RT = Retention time

$m_{biomass}$ = Mass of biomass

m_{water} = Mass of water

Fixed dome gasholder

A fixed dome gas holder can be either the upper part of a hemispherical digester or a conical top of a cylindrical digester (e.g. Chinese fixed dome plant). In a fixed dome plant the gas collecting in the upper part of the dome displaces a corresponding volume of digested slurry. The following aspects must be considered with regard to design and operation:

- An overflow into the compensation tank must be provided to avoid overfilling of the plant.
- The gas outlet must be located about 10 cm higher than the overflow level to avoid plugging up of the gas pipe.
- A gas pressure of 1mwc or more can develop inside the gas space. Consequently, the plant must be covered sufficiently with soil to provide an adequate counter pressure.

Gas pipe, valve, and accessories

Galvanized steel water supply pipes are used most frequently, because the entire piping system (gas pipe, valves and accessories) can be made of universally applicable English/U.S. Pipes with nominal dimensions of (1/2") or (3/4") are adequate for small to midsize plants of simple design and pipe lengths of less than 30 m. The diameters of the pipes are depending on the required flow rate of biogas through the pipe line and the distance between biogas digester and gas appliances. Long distances and high flow rates lead to decrease of the gas pressure. The longer the distance and the higher the flow rate, the higher the pressure drops due to friction. The pipe should be laid straight as far as possible with minimum joints and bends.

Table 2: Appropriate pipe diameter for different pipe lengths and flow rate (maximum pressure loss < 5 mbar) (Source: GTZ, 1999)

	Galvanized steel pipe			**PVC**		
Length [m] → **Flow rate[m^3/hr]** ↓	20	60	100	20	60	100
0.1	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"
0.2	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"
0.3	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"
0.4	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"	$^1/_2$"

0.5	$^1/_2$ "	$^1/_2$ "	$^3/_4$ "	$^1/_2$ "	$^1/_2$ "	$^1/_2$ "
1.0	$^3/_4$ "	$^3/_4$ "	$^3/_4$ "	$^1/_2$ "	$^3/_4$ "	$^3/_4$ "
1.5	$^3/_4$ "	$^3/_4$ "	1"	1"	$^3/_4$ "	$^3/_4$ "
2.0	$^3/_4$ "	1"	1"	$^3/_4$ "	$^3/_4$ "	1"

The values in this table show that a pipe diameter of (1") is suitable for flow rates up to1.5m^3/h and distances up to 100 m (Galvanized steel pipe). Therefore one could select the diameter of (1") as single size for the hole piping system of small biogas plants. Another option is to select the diameter of l" for the main gas pipe and (1/2") for all distribution pipes to the gas appliances. When installing a gas pipe, special attention must be paid to:

- Gas tight, less friction type joints
- Line drainage, i.e. with a water trap at the lowest point of the sloping pipe in order to empty water accumulation
- Protection against mechanical impact

The biogas coming from the digester is saturated with water vapor. This water vapor will condense at the walls of the pipeline. If this condense water is not removed regularly, it will ultimately clog the pipeline. Hence, a water drain has to be placed in the pipeline. The position of the water drain should be vertically below the lowest point of the pipeline so that water will flow by gravity to the trap. Water can be removed by opening the drain. This has to be done periodically (GTZ, 1999).

BIOGAS COMPRESSION

Compressing biogas reduces storage requirements, concentrates energy content, and increases pressure to the level needed to overcome resistance to gas flow. Sometimes the production pressure of a biogas source does not match the pressure requirements of the gas utilization equipment. Compression can eliminate the mismatch and assurance the efficient operation of the equipment. Moreover, large biogas systems rely on compression to reduce the size of the gas storage facility or to transport the biogas to a pipeline. The choice of either a blower or compressor depends on the amount of pressure increase needed (James L. Waish et al., 1988).

Biogas compressor

Compressing biogas requires a gas compressor suitable for flammable gases. These differ from regular compressors in several respects (James L. Waish et al., 1988).

- The cylinder is located further from the crankcase
- Free of non-ferrous metal
- Condensate control
- Condensate washed out on suction side,
- Passageways are provided to vent leaks away from the crankcase and prevent explosions
- Inlet and exhaust ports are designed to let contaminants pass through instead of collect in the compressor.

Parameters for Selection of Biogas Compressor

In order to determine what type of compressor system is needed to accomplish the job, a variety of detailed data is needed to be discerned. As a minimum, a precise understanding of the following data is required:

- Gas being handled
- Flow rate
- Suction and discharge pressure
- Site elevation (or local barometric pressure)
- Suction temperature and Capacity

Calculating Compression ratio

Compression ratio (R) is the ratio of discharge pressure to suction pressure:

$R = \frac{p_d}{p_s}$ (Remember p_d & p_s must be "absolute" values)

A single stage compressor has only a single R value. A two stage compressor has three R values.

R = Total compression ratio for the compressor

R_1 = Compression ratio for the first stage

R_2 = Compression ratio for the second stage

$$R = \frac{p_d}{p_s},\ R_1 = \frac{p_i}{p_s},\ R_2 = \frac{p_d}{p_i}$$

p_s = Suction pressure

p_d =Discharge pressure

p_i =Inter stage pressure- the pressure between the1st and 2nd stage of the compressor.

Choosing one stage or two stage Compressor

The choice of the proper number of compression stages is largely based on the compression ratio. Here are some guidelines for choosing the proper number of stages:

Table 3: Compression ratio vs. Proper number of Stages (Source: NPC, 1993)

R value	No of Stages
1-3	Single stage
3-5	Single stage, occasionally two stage
5-7	Two stage, occasionally single stage
7-10	Two stage
10-15	Usually two stage, occasionally three stage
15 +	Three stage

In this study:

The Compressor fulfills the following criteria might be used for compression purpose.

- The gas being handled is biogas
- Power = 18.18kW
- Flow rate = 1.8m^3/hr
- Suction pressure: The pressure at the compressor inlet expressed P_s= 1.106bar
- Discharge pressure: The pressure at the compressor discharge expressed P_d= 16bar
- Suction Temperature = 33 ℃
- $R = \frac{17.013}{2.12}$ = 8.025, Stage two Compressor

Energy Density and Storage Volume

As the biogas is compressed to higher pressures, its mass is pushed into smaller volume. This raises the energy density of the gas and reduces the required storage volume. Note that the energy densities are much higher for biogas that has the H_2S, CO_2 and water vapor removed (100% methane). Keep in mind that the higher the compression ratio, the higher the costs associated with compressing the biogas. For adiabatic compression, with no heat transfer across the system boundary (Q = 0), the thermodynamic relation is given by (W.Z.Black & J.G.Hartley, 1995):

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$ 4.1

Where

γ = adiabatic ratio C_p / C_v = 1.3 for biogas

V_1 = initial volume of biogas that the plant produce per day.

P_2 = the compressed raw biogas pressure (16bar) the selected ability of

Compressor.

V_2 = volume of pressure vessel

The known values are:

$V_1 = 529m^3$/day, P_1 = 110.64kpa, P_2 = 1600kpa

$110.64 * 529^{1.3} = 1600 * V_2^{1.3}$ V_2 =?

$V_2 = 68m^3$

Therefore, to ensure steady supply of compressed raw biogas to the application area, it is first stored in a pressure vessel which has storage capacity of 68m3

Power needed for Compression

The energy required for compression represents a major operating cost of a biogas system. Accordingly, estimating the energy requirement becomes an important component of the system design effort. Estimates are usually based an adiabatic compression process (compression without cooling) since such a calculation estimates the maximum energy required for compression in a frictionless compressor (James L.Waish and others, 1998).

Mathematically, the relationship between the system pressures, the compressor capacity, and the energy required for compression in a frictionless, adiabatic compressor can be stated as:

$$w = C_1 R T_1 \left[\left({}^{P_2}/_{P_1} \right)^{C_2} - 1 \right] \qquad 4.2$$

Where

w = shaft work required for compression (horsepower)

$$C1 = {}^{K}/_{(K-1)}$$

$$C_2 = {}^{(K-1)}/_{K}$$

k = the ratio of specific heats of the biogas (C_p/C_v), 1.3*

R = gas constant for the biogas (Btu/lb/°R), 0.0729*

T_1 = initial temperature **(**°F**)**

P_1**,** = initial pressure (psig)

P_2**,** = final pressure (psig)

* Values for 60% CH_2, 40% CO_2 biogas

Accordingly:

$$C_1 = {}^{1.3}/_{(1.3-1)} = 4.33$$

$$C_2 = {}^{(1.3-1)}/_{1.3} = 0.23$$

$T_1 = {}^{9}/_{5}\,°\mathrm{C} + 32$ = 91.4°F at T = 33°C

$$1pa = 145.04 * 10^{-5} psi$$

$$Psi = psig + 14.7$$

$p_1 = 145.77 psig,$ The maximum pressure inside the digester

$p_2 = 2305.94 psig,$ The pressure developed by selected Compressor (16bar)

$$W = 4.33 * 0.0729 * 91.4 \left[\left({}^{2305.9}/_{145.77} \right)^{0.23} - 1 \right]$$

$$= 25.59 hp$$

$$1kW = 1.36 hp$$

$$w = 18.82 kW$$

The value of "w" represents the amount of energy required to compress biogas of a known composition adiabatically**.** However, compressors are never 100% efficient because of friction and heat transfer that occur during the compression process and therefore the actual energy required will be greater than computed using the preceding equation. It should be noted that manufacturers' literature will indicate different efficiencies for almost every compressor. Confusion can be avoided by asking the manufacturer of the compressor being analyzed for the actual energy consumption of the equipment.

Purification and bottling of biogas

There are different techniques through which carbon dioxide from biogas can be removed to enhance methane content in it. Some of widely used techniques are:

- Absorption in Water (Water scrubbing) ,
- Absorption by Chemicals,
- Pressure swing adsorption,
- Membrane separation & Cryogenic separation can be used under varying conditions.

Table 4: CO_2 & H_2S Removal Processes from Biogas

No	*Method*	*Advantage*	*Disadvantage*
1	*Absorption in Water*	*One of the easy and cheap methods for CO_2 removal.*	*Water pumping load is high.* *CO_2 cannot be recovered*
2	*Absorption by Chemicals*	*The chemical absorbents are more efficient in low pressure and can remove CO_2 to low*	*Regeneration of the solvent requires are relatively high energy input. Disposal of by-product formed due*

		partial pressures in treated gas.	*to chemical reactions is a problem.*
3	*Pressure Swing Adsorption*	*By proper choice of the adsorbent, this process can remove CO_2, H_2S, moisture and other impurities.*	*Adsorption is accomplished at high temperature and pressure. Regeneration is carried out by vacuum. It is a costly process.*
4	*Membrane Separation*	*Modular in nature and separate CO_2 and CH_4 effectively.*	*Suitable to Small capacity, cost is high. Also life of membranes is less.*
5	*Cryogenic Separation*	*Allows recovery of pure component in the form of liquid, which can be transported conveniently*	*High cost involved makes it impractical for Biogas applications.*

However, absorption of CO_2 in water is simple, cost effective, eco-friendly and practical method for CO_2 removal from biogas. It is a continuous process and simultaneously removes H_2S also. This method is most popular in Czech Republic, France, Sweden, New Zealand and USA. High purity biogas (> 95%) methane content can be obtained using this technology (Wellinger,A. & Lindeberg , A.,1999).

A CO_2 scrubbing and bottling technology has been designed and developed at Indian Institute of Technology Delhi and University of Balochistan, Queta, Pakistan based on physical absorption of CO_2 in water at elevated pressure (Syed Zafar Ilyas & Virendra K. Vijay, 2006).

Water Scrubbing

Water scrubbing involves the physical absorption of CO_2 and H_2S in water at high pressures. It is simple method involving use of pressurized water as an absorbent. The raw biogas is compressed and fed into a packed bed absorption column from bottom and pressurized water is sprayed from top. The absorption process is, thus a counter-current direction through packing material (resching rings), so that maximum absorption of carbon dioxide in water takes place. Purified gas is stored in cylinder and the dissolved CO_2 and H_2S in water are collected at bottom of tower (Nonhebel, 1964 and Wellinger & Linderg, 1999).

The design of water scrubbing system depends on the solubility of carbon dioxide in water as solubility is governed by pressure and temperature as given in table 5 (Wellinger A. & Linderg A., 1999). It is clear from table that as the pressure increases solubility of CO_2 in water increases but decreases as temperature increases.

Table 5: Approximate solubility of CO_2 in water (Source: Virendra K.Vijay, 2006).

Pressure (atmospheric)	Solubility, in kg of CO_2 per kg of water at different temperature			
	0℃	10℃	20℃	30℃
1	0.40	0.25	0.15	0.10
20	3.15	2.15	1.30	0.90
50	7.70	6.95	6.00	4.80

System Design

A packed bed scrubber was designed for 95 % removal of carbon dioxide from biogas. Thus, initially 40 % carbon dioxide present in raw biogas would be reduced to 2 % by volume in enriched biogas. To increase solubility of carbon dioxide in water, raw biogas was compressed up to 1.0MPa pressure and pressurized water was used as an absorbent liquid.

A packed bed scrubbing column with 3500 mm packed bed height was designed for absorption of CO_2 at operating pressure of 1.0MPa of biogas inlet. Ceramic Resching rings were used as packing material. The details of various components involved in the system are described below:

Biogas enrichment unit

The unit comprise of a scrubber, a water supply system, a gas supply system, a low capacity compressor, a pressure vessel, pipe fittings and various accessories. Schematic diagram of complete biogas enrichment, further its bottling is shown in appendix V.

Scrubbing Column

The scrubber is 150 mm in diameter and 4500 mm height with 3500 mm packed bed length. The scrubber consists of a packed bed absorption column and a supporting frame as described in following sub-sections: The column has three sections.

1. **Top section** – It has provision for water inlet pipe, water spraying system, gas outlet pipe and a safety valve. Water spraying system is connected with water inlet pipe to provide fine atomized spray of pressurized water inside the absorption column. A safety valve is provided at the upper portion to release the excess pressure as it is a pressurized column.
2. **Middle section** – In this section Resching rings of 16 mm diameter have been filled as packing material. Two sieves are fitted at the top and bottom of the section to hold the packing height of column. A view glass, to see the water level inside the column and a

dry type pressure gauge, to check column pressure; are also mounted at the upper portion of the middle section.

3. **Bottom section** – This section has provision for inlet gas feeding pipe and a view glass at upper side. Lower side has been transformed into truncated cone shape with 50 mm diameter outlet opening. It is fitted with a ball valve to control the outlet water flow. Outlet water is stored in a water collection tank. All the three sections are joined together with flanges, bolts and nuts.

Supporting frame

Supporting frame comprises of three legs. The legs are grouted firmly in ground with cement, sand and stone gravel mixture and fitted with the absorption column in the middle. A staircase has also been attached with the absorption column to climb up to the top of the column to check water level and column pressure.

Water supply system

Screw pump is used to pump water from water storage tank into the scrubber. Screw pump is selected to provide pressurize water at low discharge. 25 mm diameter Galvanized Iron (GI) pipe fitting have been used for water supply. The water flow rate is controlled through a flow regulating valve. A rotameter and a dry type pressure gauge are mounted to measure the water flow rate and pressure of water respectively.

Gas supply system

The gas supply system consists of a biogas plant, a single stage compressor, a pressure vessel, pipe fittings and accessories.

Biogas plant

Raw biogas is fed to the scrubber from a night soil based fixed dome type biogas plant. The raw gas is supplied from the biogas plant, through 25 mm diameter rigid PVC Pipeline to a single stage compressor, after removing water condensed in pipeline using a water remover.

Single stage compressor

A single stage Kirloskar make compressor having 1.1 kW power rating and 10.0 m^3/h suction capacities is utilized for initial compression of raw biogas up to 1.0MPa pressure before sending it to the scrubber.

Pressure vessel

To ensure steady supply of compressed raw biogas to the scrubber, it is first stored in a pressure vessel. It is made from MS sheet and has storage capacity of 1.0 (1.5) m^3.

Pipe fettlings and accessories

12.5 mm diameter G I pipe line is used to supply gas from compressor to the pressure vessel and then to the scrubber. Between the pressure vessel and the scrubber, a rotameter and a dry type pressure gauge are installed to measure the rate of discharge and pressure of the raw biogas respectively. The gas flow rate is controlled through a valve provided near inlet point of the scrubber.

Enriched biogas compression unit

It comprises of a three stage compressor for compression of enriched biogas up to 20 MPa pressures, a set of filters for removal of water vapour, storage cylinders for storing highly pressurized biogas and pipe fittings.

Three stage high pressure compressor

A low suction capacity and high pressure developing compressor is utilized in the present investigation. A three stage compressor is used for bottling. It can compress gas up to 34.5 MPa pressure.

Ultra filters

A set of three filters (Pre filter, Micro filter and Sub Micro filter) are employed in the G I pipeline connected with storage pressure vessel (containing enriched biogas) and three stage compressors. They are designed to remove almost all water vapour from the enriched biogas.

Storage cylinders

High pressure steel cylinders (available in the market for CNG storage) are used for final storage of enriched and compressed biogas. These cylinders are shorter in length and larger in diameter than most gas cylinders and had been specifically built for high pressure gas storage

Pipe fettlings and accessories

12.5 mm diameter G I pipeline is employed to deliver enriched biogas from the scrubber to the storage vessel (0.5 m^3 capacity).From vessel, it is sent to the three stage compressor via ultra filters and rotameter through 12.5 mm diameter G I pipe line. From compressor, compressed & enriched biogas is finally filled in a cylinder. A pressure gauge is mounted in the pipeline near cylinder to check the gas pressure inside the cylinder and provision is made to release the back pressure from the pipeline after cylinder filling.

Comparison Biogas with Natural gas

Natural gas has 75-98 % methane with small percentages of ethane, butane, propane while biogas has about 60 % methane and 40 % carbon dioxide. It is possible to improve the quality of biogas by enriching its methane content up to the natural gas level. After methane enrichment and compression it can be used as vehicle fuel just like CNG. Over and above, it has lower emission than natural gas and diesel as shown in Table 6.

Table 6: Comparison of gaseous emissions for heavy vehicles (source: Report, 2000)

g/km	CO	HC	NO_X	CO_2	Particulates
Diesel	0.20	0.40	9.73	1053	0.100
Natural gas	0.40	0.60	1.10	524	0.022
Biogas	0.08	0.35	5.44	223	0.015

Source: A report on biogas technology and biogas use in Sweden, Traffic and Public Transport Authority, City of Gothenburg, November 2000.

Biogas Production System Design

Calculating the daily gas production (G)

Basic data:

Average number of students in Haramaya University =10,000

Average number of cattle in Haramaya University = 400

Table 7: DM value of fresh discharge and water to be added to make favorable condition (source: At Information, website)

Kinds	**Body weight (kg)**	**Discharge per day (kg)**	**DM (% by wt.)**	**Water to be added 8%**	**%ODM**
Human	50	0.5	20	0.75	15
Cow	200	10	16	10	13
Chicken	1.5	0.1	20	0.15	16
Pig	50	5	20	7.5	14

Total discharge for night soil =10,000 * 0.4kg/day = 4000kg/day

Total discharge for cow manure = 10 * 400 = 4000kg/day

Soil temperature = 35 ^{0}c assumption since Ethiopia found in tropical zone.

The amount of biogas generated each day G [m^3 gas/d], is calculated on the basis of the specific gas yield Gy of the substrate and the daily substrate input Sd. The calculation can be based on (GTZ, 1989):

The volatile solids content VS

$$G = VS \times Gy(solids)\ [\ m^3/d = kg \times m^3/(d\times kg)\ ] \quad 5.1$$

The weight of the moist mass

$$G = kg\ biomass \times Gy(moist\ mass)\ [\ m^3/d = kg \times m^3/(d\times kg)\ ] \ldots\ldots 5.2$$

Standard gas-yield values per livestock unit LSU

$$G = number\ of\ LSU \times Gy(species)\ [\ m^3/d = number \times m^3/(d \times number)\ ] \ldots\ldots 5.3$$

Where

G = daily biogas generated

Gy = specific biogas yield

As a rule, it is advisable to calculate according to several different methods, since the available basic data are usually very imprecise, so that a higher degree of sizing certainty can be achieved by comparing and averaging the results.

For Night Soil:

Based on total solids content (Equation 5.1)

G = Kg TS input * Specific Gy(solids)

$$= 0.2 * 4000 * 0.38$$

$$= 304\, m^3/day$$

Depending on Standard gas yield values per live stock (LSU)(Equation 5.2)

G = number of people * Specific Gy (species)

$$= 10{,}000 * 0.028$$

$$= 280\, m^3/day$$

Based on weight of the moist mass (Equation)

G = Kg biomass * specific Gy(moisture)

$$= 4000 * 0.07$$

$$= 280\, m^3/day$$

☞ ***Averaging the daily biogas yield:***

$$G = \frac{304 + 280 + 280}{3} = 288\, m^3$$

For Cow manure:

Based on total solids content (Equation 5.1)

G = Kg TS input * Specific Gy(solids)

$$= 0.16 * 4000 * 0.34$$

$$= 218\, m^3/day$$

Depending on Standard gas yield values per live stock (LSU)(Equation 5.2)

G = number of cattle * Specific Gy (species)

$$= 400 * 0.66$$

$$= 264\, m^3/day$$

Based on weight of the moist mass (Equation)

$$G = \text{Kg biomass} * \text{specific Gy (moisture)}$$
$$= 4000 * 0.066$$
$$= 264 \, m^3/\text{day}$$

☞ ***Averaging the daily biogas yield:***

$$G = \frac{218 + 264 + 264}{3} = 249\,m^3$$

Therefore the total daily biogas yield is:

$$= 280+249$$
$$=529 \, m^3$$

Estimating the size of biogas plant

The size of the digester, i.e. the digester volume (Vd),is determined on the basis of the chosen retention time RT and daily substrate input quantity Sd.

$$Vd = Sd * RT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.4$$

The retention time, in turn, is determined by the digesting temperature. Practical experience shows that retention times of 60-80 days. For a night soil biogas digester, a longer retention time (70-80 days) is needed so that the pathogens present in human feces are destroyed (Lagrange, 1979). Extra-long retention times can increase the gas yield by as much as 40 %(GTZ, 1989). Therefore

Sizing factors are:

- Daily substrate input, Sd
- Retention time, RT
- Daily gas production,

Total discharge of night soil =10,000* 0.4 = 4000kg/day

Total discharge of cow dung =400* 10 = 4000kg/day

DM(dry matter) of fresh discharge of night soil = 4000kg/day*20% = 800kg/day

For 8% concentration of ODM [to make favorable condition]

$$8\text{kg solid} = 100\text{kg}$$

$$800 \,{}^{\text{kg}}\!/_{\text{day}} = X$$

Water to be added to make the discharge 8% concentration of ODM

$$X = \frac{800*100}{8} = 10{,}000 \,{}^{\text{kg}}\!/_{\text{day}}$$

=10,000 – 4000

= 6000kg/day = 6000L/day water should be added.

Assuming the density of slurry similar to that of water, then the volume of the daily charge of the night soil is:

$$V_s = \frac{m_s}{\rho_s} = \frac{10{,}000}{1000} = 10\,\text{m}^3$$

For cow dung the ratio of water is 1:1. Therefore 4000l/day of water is added. As the result the volume of daily substrate input is: $V_s = 8\text{m}^3$ and totally $Vs = 18\text{m}^3$.

Hence, volume of digester:

$$V_d = Sd * RT$$

$$= 18 * 80 = 1440\text{m}^3$$

Sizing the gasholder

Section 5.1 indicates that the volume of gasholder is ***529m³***. Installing compressor for the system reduces the volume since biogas is stored in pressure vessel, out of digester. As the result the volume of digester becomes ***911m³.***

Inlet and Out let pipe

The size of inlet and outlet pipe is equal to the diameter of the tube that directly connected to the septic tank i.e. (110 – 150) mm. It is mandatory to make some amendment to cause turbulence to avoid scum formation in digester.

Expansion chamber

The size of expansion chamber is equal to the volume of gasholder in fixed dome biogas plant, but biogas stored in pressure vessel out of digester. However the design of expansion chamber is coupled to the system in order to avoid over flow of raw substrate (unfermented substrate) due to different factors.

Compost Tank

Compost tank is an integral part of the biogas plant; no plant is complete without it.Enough earth body must exist, at least 1 meter, between the compost tank and the outlet chamber to avoid cracking of the chamber walls. The volume of the compost tank must be at least equal to the plant volume (Kathmandu, 1994).

Deenbandhu Fixed Dome Plant

The part of the digester below the ground level is subjected to heavy compressive load due to the earth pressure, which increases with depth. In this design, due to hydrostatic pressure, cylindrical digester is selected. In addition to this selection cylindrical shape digester has the advantages such as saving labor and material cost, spreads the pressure evenly and seals easily(AT Information, website).

It prefers Deenbandhu fixed dome plant with a little modification because it is simple design of long operation time, low construction cost and that could be operated and repaired easily. Deenbandhu, the successor of the Janata plant in India, with improved design, is more crack proof and consumed less building material than the Janata plant with a hemisphere digester (FAO/CMS, 1996; Mattocks, 1984 and At-Information website).

Other reasons that support this choice are:

- Constructing the digester underground reduces the negative impacts resulted from atmospheric temperature changes,
- Raw substrate is from the latrine (toilet) it has odour so that it should be beneath under earth.
- Availability of constructing materials such as: - cement sand, small stones etc. with reasonable prices.
- It distributes forces uniformly on surface area
- Deenbandhu fixed dome plant application is well experienced in Ethiopia.

The following section shows the design calculation and dimensional relationship:

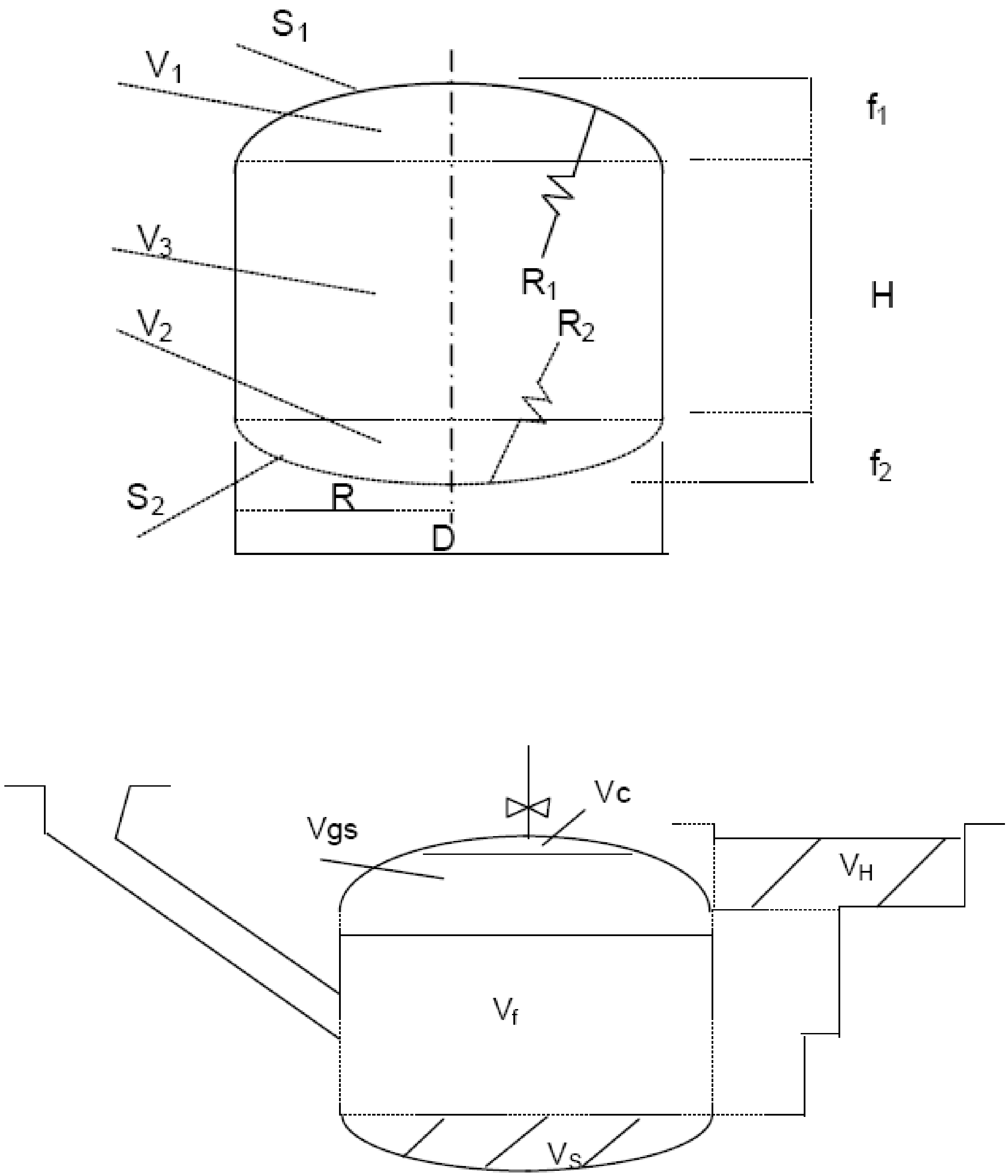

Figure 8: Cross-section of a Digester (Chengdu, 2006)

Where

Vc = Volume of gas collecting chamber

Vgs = Volume of gas storage chamber

V_f = Volume of fermentation chamber

V_H = Volume of hydraulic chamber

Vs = Volume of sludge layer

$V_1(V_c + V_{gs})$ = volume of gasholder

$V_2(V_s)$ = volume of sludge layer

$V_3(V_f)$ = volume of fermentation

V_c = Volume of gas collecting chamber

V_{gs} = Volume of gas storage chamber

V_H = Volume of hydraulic chamber

D = diameter of the cylinder

Total volume of digester $\mathbf{V} = Vc+Vgs+V_f+Vs$

Table 8: Assumptions of Volume and Geometrical dimensions (source: Chendu, 2006)

For volume	For geometrical dimensions
$V_c \leq 5\%\ V$ $V_s \leq 15\%\ V$ $V_{gs} + V_f = 80\%\ V$ $V_{gs} = V_H$ $V_{gs} = 0.5\ (V_{gs} + V_f + V_s)\ K$ Where K = Gas production rate per m^3 digester volume per day. K= 0.4	$D=1.3078 * V^{1/3}$ $V_1=0.0827* D^3$ $V_2 = 0.05011 *D^3$ $V_3 = 0.3142 *D^3$ $R_1= 0.725 *D$ $R_2= 1.0625 *D$ $f_1 = D/5$ $f_2 = D/8$ $S_1 = 0.911\ D^2$ $S_2 = 0.8345\ D^2$

Working volume of digester = $V_{gs} + V_f$ 5.5

$$V_{gs} + V_f = 911m^3$$

From geometrical assumptions:

$$V_{gs} + V_f = 0.8V$$

$$V = \frac{911}{0.8} = 1140m^3$$

$D = 1.308*1140^{1/3} = 14m$

$V_1 = 0.0827*14^{\,3} = 227m^3$

$V_2 = 0.05011*(14^3) = 138m^3$

$V_3 = 0.3142*(14^3) = 862m^3$

From V_3 it can be calculated the value of 'H'

$V_3 = \frac{\pi D^2 H}{4}$ Now we can find from assumption as we know the value of 'D' & 'H'

$f_1 = 14/5 = 2.8$ m

$f_2 = 14/8 = 1.75$m

$R_1 = 0.725*14 = 10.15$m

$R_2 = 1.0625*14 = 14.875$ m

$V_c = 0.05V = 57m^3$

$$H = \frac{4*862}{\pi*14^2} = 5.6m$$

The detail drawing of each component found in Appendix III

Pressure Developed in the Digester

The pressure of a gas mixture is equal to the sum of the pressure each gas would exert if it existed alone at the mixture temperature & volume. Dalton's law

$$p_m = \sum_i^k p_i(T_{m,}V_m) \qquad 5.5$$

The partial pressure of a gas is the pressure exerted by a particular component of a mixture of gases. It is given by(W.Z.Black& J.G. Hartley,1985)

$$p_iV_i = n_iRT \qquad 5.6$$

Where, P_i = Pressure developed by each gas of mixture

V_i = Volume of particular component of gas

T = Temperature of mixture in Kelvin

R =Ideal gas constant

n = number of moles of component

Based on the maximum volume of biogas produced per a day it is possible to find the maximum gas pressure developed in the digester dome. 529m^3 of biogas can be produced per a day (section 5.1). Based on their composition, it is possible to find particular volume & molar number of gas.

Table 9: Biogas composition of different substrate in put (Daisy & Kamaraj, 2011 & different source)

parameter	*Unit by volume*	***Cow dung***	*Pig manure*	*Chick .manure*	***Night soil***
CH_4	%	*67.9*	*40-60*	*70-85*	*65-66*
CO_2	%	*27.2*	*59-94*	*15-30*	*32-34*
CO	%	*4.7*	*10*	*2.5*	*3*
H_2S	%	*0.1*	*0.1*	*0.1*	*1*
NH_3	%	*0.01*	*0.01*	*0.1*	*0.1*

According to their composition the volume of each gas in the mixture can be determined.

Pressured developed due to biogas from Cow dung

The volume of methane:

$$\mathrm{V_{CH_4}} = \%\ \mathrm{CH_4} \times \mathrm{V_{Tb}} = 0.679 \times 249 = 169\,\mathrm{m^3/day}$$

The volume of Carbon dioxide:

$$V_{CO_2} = \% CO_2 \times \mathrm{V_{Tb}} = 0.272 \times 249 = 68\,m^3/day$$

The volume of Carbon monoxide:

$$V_{CO} = \% CO \times \mathrm{V_{Tb}} = 0..047 \times 249 = 12\,m^3/day$$

The volume of Hydrogen Sulphide:

$$V_{H_2S} = \% H_2S \times \mathrm{V_{Tb}} = 0.001 \times 249 = 0.249\,\mathrm{m^3/day}$$

The volume of Ammonia

$$V_{NH_3} = \%\ \mathrm{NH_3} \times \mathrm{V_{Tb}} = 0.0001 \times 249 = 0.0249\,\mathrm{m^3/day}$$

Pressured developed due to biogas from Night Soil

The volume of methane:

$$V_{CH_4} = \%\ CH_4 \times V_{Tb} = 0.655 \times 280 = 183.4\,m^3/day$$

The volume of Carbon dioxide:

$$V_{CO_2} = \% CO_2 \times V_{Tb} = 0.33 \times 280 = 93 m^3/day$$

The volume of Carbon monoxide:

$$V_{CO} = \% CO \times V_{Tb} = 0.03 \times 280 = 8.4 m^3/day$$

The volume of Hydrogen Sulphide:

$$V_{H_2S} = \% H_2S \times V_{Tb} = 0.01 \times 280 = 2.8\,m^3/day$$

The volume of Ammonia

$$V_{NH_3} = \%\ NH_3 \times V_{Tb} = 0.001 \times 280 = 0.28\,m^3/day$$

Table 10: Densities, molecular weight and chemical formulas of some gases at normal Temperature and Pressure (20 ℃ and 1atm) (Source: www.engineeringtoolbox.com)

Gas	**Formula**	**Molecular Weight**	**Density - ρ -** kg/m^3
Air	-	29	1.205
Ammonia	NH_3	17.03	0.717
Carbon dioxide	CO_2	44.01	1.842
Carbon monoxide	CO	28.01	1.165
Hydrogen Sulfide	H_2S	34.076	1.434
Methane	CH_4	16.043	0.668
Water Vapor	-	18.016	0.804

$$Density = \frac{mass}{volume} \qquad 3.12$$

$$mole = \frac{mass}{Molecularweight} \qquad 3.13$$

For cow dung: $\rho_{CH_4} = \frac{m_{CH_4}}{V_{CH_4}}$ $\quad m_{CH_4} = 0.668 \times 169 = 113 kg/day$

$$n_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}} = \frac{113*1000}{16.01} = 7058 mol/day$$

$$m_{CO_2} = \rho_{CO_2} \times V_{CO_2} = 1.842 \times 68 = 125 kg/day$$

$$n_{CO_2} = \frac{m_{CO_2}}{M_{CO_2}} = \frac{125}{44.01} = 2840 mol/day$$

$$m_{CO} = \rho_{CO} \times V_{CO} = 1.165 \times 12 = 14 kg/day$$

$$n_{CO} = \frac{m_{CO}}{M_{CO}} = \frac{14}{28.01} = 500 mol/day$$

$$m_{H_2S} = \rho_{H_2S} \times V_{H_2S} = 1.434 \times 0.249 = 0.357 kg/day$$

$$n_{H_2S} = \frac{m_{H_2S}}{M_{H_2S}} = \frac{0.357}{34.076} = 10.5 mol/day$$

$$\rho_{NH_3} = \frac{m_{NH_3}}{V_{NH_3}} \quad m_{NH_3} = 0.717 \times 0.0249 = 0.018 kg/day$$

$$n_{NH_3} = \frac{m_{NH_3}}{M_{NH_3}} = \frac{0.018*1000}{17.03} = 1.06 mol/day$$

The partial pressure of a methane gas:

$$p_{CH_4} = \frac{n_{CH_4} \times R \times T_m}{V_m} = \frac{7058 \times 8.31 \times 306}{249 \times 10^3} = 72.1 kPa$$

The partial pressure of a carbon dioxide gas:

$$p_{CO_2} = \frac{n_{CO_2} \times R \times T_m}{V_m} = \frac{2840 \times 8.31 \times 306}{249 \times 10^3} = 29 kPa$$

The partial pressure of a carbon monoxide gas:

$$p_{CO} = \frac{n_{CO} \times R \times T_m}{V_m} = \frac{500 \times 8.31 \times 306}{249 \times 10^3} = 5kPa$$

The partial pressure of a hydrogen sulphide gas:

$$p_{H_2S} = \frac{n_{H_2S} \times R \times T_m}{V_m} = \frac{10.5 \times 8.31 \times 306}{249 \times 10^3} = 0.11kPa$$

The partial pressure of Ammonia gas:

$$p_{NH_3} = \frac{n_{NH_3} \times R \times T_m}{V_m} = \frac{1.06 \times 8.31 \times 306}{249 \times 10^3} = 0.011kPa$$

For Night Soil:

$$\rho_{CH_4} = \frac{m_{CH_4}}{V_{CH_4}} \quad m_{CH_4} = 0.668 \times 183.4 = 122.5 kg/day$$

$$n_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}} = \frac{122.5 * 1000}{16.01} = 7652 mol/day$$

$$m_{CO_2} = \rho_{CO_2} \times V_{CO_2} = 1.842 \times 93 = 171.3 kg/day$$

$$n_{CO_2} = \frac{m_{CO_2}}{M_{CO_2}} = \frac{171.3}{44.01} = 3892 mol/day$$

$$m_{CO} = \rho_{CO} \times V_{CO} = 1.165 \times 8.4 = 10 kg/day$$

$$n_{CO} = \frac{m_{CO}}{M_{CO}} = \frac{10}{28.01} = 357 mol/day$$

$$m_{H_2S} = \rho_{H_2S} \times V_{H_2S} = 1.434 \times 2.8 = 4.06 kg/day$$

$$n_{H_2S} = \frac{m_{H_2S}}{M_{H_2S}} = \frac{4.06}{34.076} = 118 mol/day$$

$$\rho_{NH_3} = \frac{m_{NH_3}}{V_{NH_3}} \quad m_{NH_3} = 0.717 \times 0.28 = 0.2 kg/day$$

$$n_{NH_3} = \frac{m_{NH_3}}{M_{NH_3}} = \frac{0.2*1000}{17.03} = 11.7\, mol/day$$

The partial pressure of a methane gas:

$$p_{CH_4} = \frac{n_{CH_4} \times R \times T_m}{V_m} = \frac{7652 \times 8.31 \times 306}{280 \times 10^3} = 69.5 kPa$$

The partial pressure of a carbon dioxide gas:

$$p_{CO_2} = \frac{n_{CO_2} \times R \times T_m}{V_m} = \frac{3892 \times 8.31 \times 306}{280 \times 10^3} = 35 kPa$$

The partial pressure of a carbon monoxide gas:

$$p_{CO} = \frac{n_{CO} \times R \times T_m}{V_m} = \frac{357 \times 8.31 \times 306}{280 \times 10^3} = 3.2 kPa$$

The partial pressure of a hydrogen sulphide gas:

$$p_{H_2S} = \frac{n_{H_2S} \times R \times T_m}{V_m} = \frac{118 \times 8.31 \times 306}{280 \times 10^3} = 1.1 kPa$$

The partial pressure of Ammonia gas:

$$p_{NH_3} = \frac{n_{NH_3} \times R \times T_m}{V_m} = \frac{11.7 \times 8.31 \times 306}{280 \times 10^3} = 0.11 kPa$$

The biogas saturates with water vapor. Therefore, total pressure inside the digester is the sum of two pressures the dry gases and the water vapor.

Table 11: Water vapor pressure at specific temperature (http://hyperphysics.phy-astr.gsu.edu)

Temp (ºC)	**Vapor Pressure (mmHg)**	**Temp (ºC)**	**Vapor Pressure (mmHg)**
-10	2.15	40	55.3
0	4.58	60	149.4
5	6.54	80	355.1
10	9.21	95	634
11	9.84	96	658
12	10.52	97	682
13	11.23	98	707
14	11.99	99	733
15	12.79	100	760
20	17.54	101	788
25	23.76	110	1074.6
30	31.8	120	1489
37	47.07	200	11659

At 33°C temperatures, we can obtain by interpolation:

At $30^{\circ}C$ $p_1 = 31.8mmHg$

At 37°C $p_2 = 47.07mmHg$

$$\Delta T = 7°C, \Delta p = 15.27mmHg$$

$$\Delta T = 3°C, \Delta p = x = 6.54mHg$$

At $33°C$ temperature, $\mathrm{p}_{\mathrm{H_20}} = 31.8 + 6.54 = 5.11\mathrm{kPa}$

Total pressured developed in gasholder:

$$p_{total} = p_{CH_4} + p_{CO_2} + p_{CO} + p_{NH_3} + p_{H_2S} + p_{H_2O}$$

$$= \frac{72.1 + 29 + 5 + 0.11 + 0.011 + 69.5 + 35 + 3.2 + 1.1 + 0.11 + 5.11 + 5.11}{2} = 110.64\mathrm{kPa}$$

Estimation of Soil/Earth Pressure and Hydraulic Forces

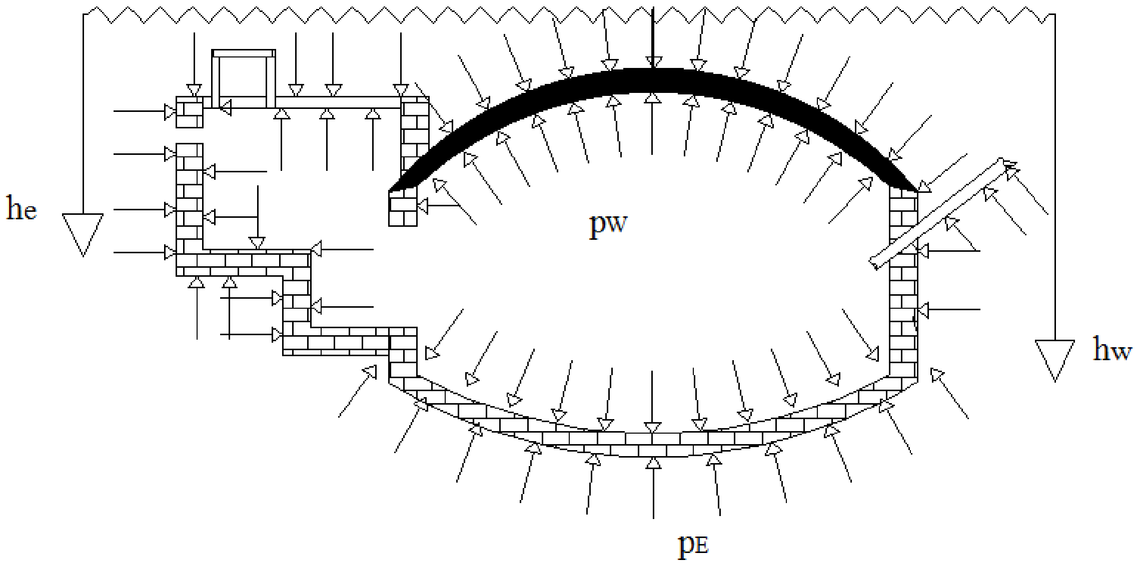

Figure 9: Schematic diagram of Soil Pressure and Hydraulic Pressure Forces

In depth forces, h (e, w):

$$p_W = w_W * h_w \qquad 3.2$$

Where, p_W = Hydrostatic pressure at depth h_w

w_W = Specific weight of water = $1000 kp/m^3$

Active earth pressure is given by:

$$p_E = w_E \times c \times h_e \qquad 3.3$$

Where, p_E = Active soil pressure, i.e. force of pressure of dry, previously loose (not firmly fixed in place) but now compact column of earth on a solid vertical wall

w_E = Specific weight of dry backfill soil= $1800 \ldots 2\,100\ kp/m^3$

h_e = Height of earth column

c = Coefficient of soil pressure for the earth column = 0.3 . . . 0.4

$$p_W = 1000 \times 10.15 = 10150 \frac{kp}{m^2}, 1000N \approx 100kp$$

$$= 101.5kPa$$

$$p_E = 1950 \times 0.4 \times 13.15$$

$$= 102.57kPa$$

Therefore masonry should overcome the 101.5kPa tensile pressure and 102.57kPa compression pressure.

Structural design of Brick masonry Arch

If the total strain energy expressed in terms of the external loads is partially differentiated with respect to one of the loads the result is the defection of the point of application of that load and in the direction of that load.

The general equation for parabolic arch axis is:

$$y = \frac{4h}{L^2}(L - x)x$$

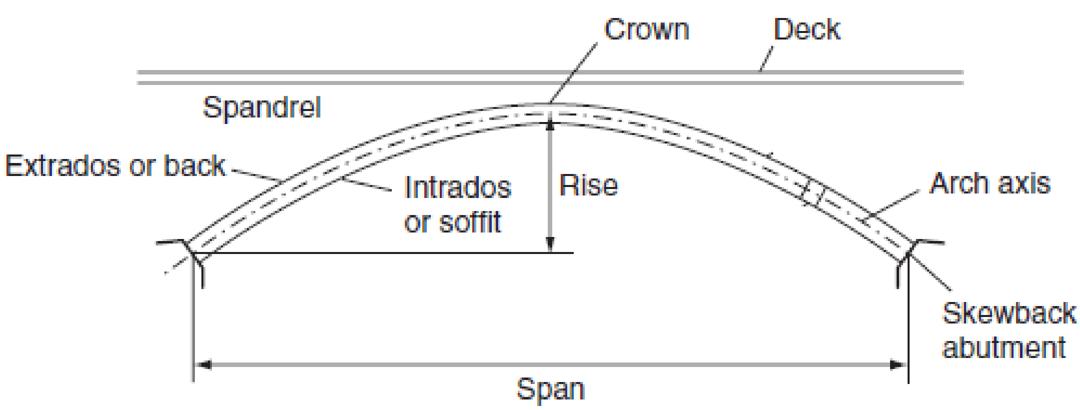

Figure 10: Brick masonry Arch

Arc terms

The strain energy of an arch rib is made up of three components

1. The strain energy due to bending

$$U_B = \int_A^B \frac{M^2 ds}{2EI}$$

2. The strain energy due to axial thrust

$$U_T = \int_A^B \frac{T^2 ds}{2AE}$$

3. The strain energy due to shearing force

$$U_S = \int_A^B \frac{S^2 ds}{2AG}$$

$$U = U_B + U_T + U_S$$

$$\delta_i = \frac{dU}{dF_i}$$

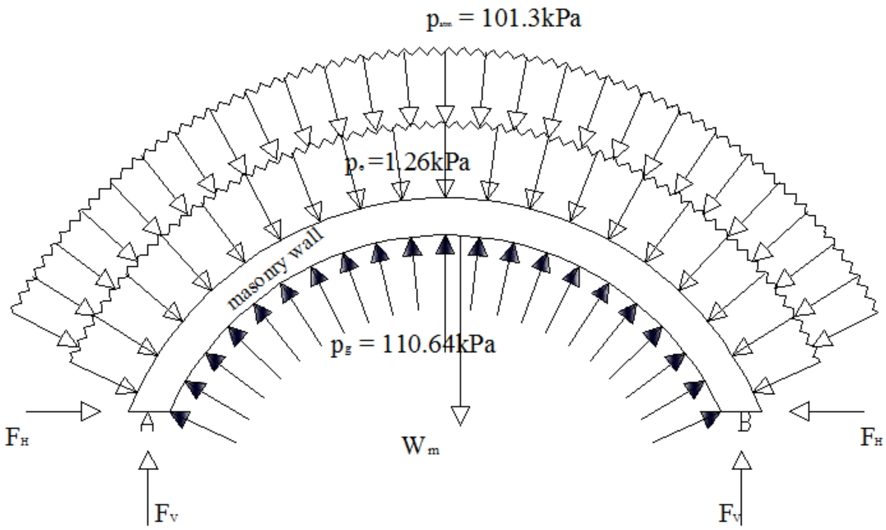

Figure 11: Force Analysis on Gasholder

Where,

$F_{v,A}$= Vertical force at A

$F_{H,A}$ = Horizontal force at A

$F_{V,B}$ = Vertical force at B

$F_{H,B}$ =Horizontal force at B

p_g= Pressure due to biogas

p_e= Active earth pressure

W_m = Weight of masonry

p_{atm}= Atmospheric pressure

The detail calculation is used to determine the thickness of plant.

Financial and Economic Analysis of Biogas Plant

Introduction

Biogas is a non conventional energy and it is a better energy from polluting waste, clean and efficient, eco-friendly, money saver, time saver, minimizes expenditure on the foreign exchanges on the import of fossil fuels. Any decision for or against the installation and operation of a biogas plant depends on various technical criteria as well as on a number of economic and utility factors. Users want to know what the plant will offer in the way of profits (cost benefit analysis) and other. Advantages like reduced work load, more reliable energy supplies or improved health. There are many ways to approach economic analysis, depending on the point of view from which plant is considered. The simplest approach is look at the cash flow position of the organization or households.

Determining Biogas Demand

There are different approaches to estimate gas demand for cooking. The following alternative methods of calculation are useful (GTZ, 1989).

1. **Determining biogas demand on the basis of present consumption**: - This involves measuring the present rate of energy consumption in the form of Fire Wood, Charcoal, Kerosene, Electricity etc.
2. **Calculating biogas demand by means of comparable use data**:- such data may consist of
   - Empirical values from neighboring systems, for example biogas consumption per person & day.
   - Reference data taken from literature, although this approach involves considerable uncertainty, since cooking energy consumption depends on local culture dependent cooking and eating habits and can therefore differ substantially from case to case.
3. **Estimating biogas demand by way of appliance consumption data and assumed periods of use**: - This approach can only work to the extent that the appliances to be used are known in advance.

Equivalence of biogas demand

1 kg of Fire Wood $\cong$ 0.2m^{3}biogas

1 kg of Charcoal $\cong$ 0.5m^3 biogas

0.6liter of kerosene $\cong$ 1m^3 biogas (Source: GTZ, 1989)

Table 12: Some Biogas equivalents (Kristoferson & Bokalders, 1991)

Application	*1 m^3 biogas equivalent*
Lighting	Equal to 60 – 100 watt bulb for 6 hours
Cooking	Can cook 3 meals for a family of 5 – 6
Fuel	0.7kg of petrol
Shaft Power	Can run a one horse power motor for 2 hours
Electricity	Can generate 1.25 kilowatt hours of electricity

Construction Materials and Costs

Table 13: Requirements and costs for constructing the proposed design based on current basis

No	Requirements	Qty	Price /cost in ETB	
			Unit price/cost	Total price/cost
1	Digging operations	1140m^3	35	39,900
2	Cement bags/pieces	1500	180	270,000
3	Rigid plastic pipes	200m	75	15,000
4	Gas pipe	500m length & 1/2" diameter	50	25,000
5	Main gas pipe (galvanized steel)	1" diameter 40m	100	4,000
6	Gas valve and connectors.	500pcs	120	60,000
7	Mold/cast	5m^3	3200	16,000

8	Paint	100gal	420	42,000
9	Sand	50garabage	1500	75,000
10	Brick	50,000	7	350,000
11	Mason (skilled labor)	10 persons 60days	250	150,000
12	Installation work	5person 15 days	250	18,750
13	Biogas Stove	15	1000	15,000
14	Biogas burner	10	500	5000
15	Biogas Compressor	2	20,000	40,000
	Total money in ETB			1,125,650

The construction materials to be used in the plant construction such as cement, sand water, etc, such materials are not good quality; the quality of the plant will be poor even if design and workmanship involved are excellent. In order to select these materials of best quality, their brief description and the specification has been given here under.

i. **Cement:** The cement to be used in the plant construction has to be of high quality with standards sand (of ratio 1:3). It must be fresh without lump and stored in dry place. Bags of cement should never be stacked on the floor or against the walls but wooden planks should be placed on the floor to protect cement from dampness.

ii. **Sand*:*** Sand for construction purpose must be clean. Dirty sand has a very negative effect on the strength of the structure if the sand contains 3% or move impurity, It must be washed. The quality of impurity especially the mud in the sand can be determined by a simple last using bottle. This is called the "*bottle test*" For this test; small quantity of sand is put in the bottle. After this water is poured in and allow the sand to settle down. The particle of sand are heavier than that of mud so it settles down quickly after 20-25 minutes; the layer of mud verses sand inside the bottle is measured. Course and granular can be used for concreting work but fine sand will be better for plastering work.

iii. **Gravel:** Gravel should not big or very small (i.e. it is medium). It should not be bigger than 25% of the thickness of concrete product when it is used in furthermore, the gravel must be clean. If it is dirty, it should be washed with clean water

iv. **Water:** It is mainly used for preparing the mortar for masonry work, concreting work and plastering. It is also used to soak bricks (stones before using them). Beside these, water is also used for washing sand and aggregates. It is advised not to use water from ponds and irrigation channels for these purposes, as it is usually too dirty. Dirty water has an adverse effect the strength of the structure; hence water to be used must clean.

v. **Bricks:** Bricks must be of the best quality locally available. When hitting two bricks, the sound must be clear; they must be well backed and regular in shape. Before use, bricks must be soaked for few minutes in clean water.

vi. **Stones:** If stones are to be used for masonry work, they have to be clean, strong and of good quality. Stones should be washed if they are dirty.

Financial Analysis

Financial analysis is the most commonly used tool that helps to decide whether a user benefits by installing biogas plant or not. The financial analysis show when the cost and benefit increase or how they are distributed over the project period. To make the analysis more comprehensive, costs and benefits should be reflected for each year of the project life. Projects are assumed to be economically feasible if the Net Present Value (NPV) is positive, the internal rate of return (IRR) is $\geq$ 20% and a pay back period of $\leq$ 7years*(Government of Georgia, 2003)*.The major parameters that need to be considered for the financial feasibility, of biogas plants are:

Project life

A fixed dome type plant could last for more than 40 years depending on the quality of construction and the materials used. However, the economic life of a plant is taken as 20 years mainly because any cost or benefit accrued after 20 years will have insignificant value when discounted to the present worth.

Benefits and Cost

All benefits of a biogas plant cannot be readily priced or even compared with the price of similar products or services in the market. For example, it is difficult to put a money value for the benefit of decrease environmental population. This indicates that even if the financial analysis shows zero net benefit of installing a biogas plant, it should be interpreted as having positive net benefits owing to the un priced factors. The biogas plants produce both biogas and organic fertilizer. The biogas could be used mainly instead of firewood, charcoal, kerosene and etc. while organic fertilizer used to improve crops yield, and so could be used instead of manufactured fertilizers. Therefore; the monthly direct economic benefits for biogas plants could be estimated as follows:

$$Monthly\ benefit = (benefit\ from\ biogas + benefit\ from\ organic\ fertilizer) - monthly\ cost.$$

Benefit from Biogas

The proposed biogas system designed to produce biogas quantity could cover the monthly consumption of electricity is *19837.5 kWh*. So the monthly sum saving expected from using biogas is ETB *9,904.86*. The net monthly saving is ETB 9679.34(section 6.5.2.3).

Organic Fertilizer

The amount of organic matter gets out from the digester into the compost tank is:

$$= Load\ amount - converted\ amount\ in\ to\ biogas$$

= (0.2*8000kg/day*30) per month – (0.15*8000kg/day*30) per month

= 48,000-36,000

= 12,000kg per month

The manufactured fertilizer of the lowest price available in the local markets is Urea fertilizer which sale to farmer by about ${}^{888Birr}/_{100kg}$. By selling the organic matter gets out of the digester by 5% Urea price, and then the price of 12,000kg will be:

= 0.05*888*120

= ETB 5328per month

= ETB 63,936 per year

Monthly cost

The monthly cost for operating the biogas plant may come from replacing some of using the used equipments (mainly gas valve, gas transporting pipe and etc), i.e. is maintenance cost & operational cost. The main operational cost is the cost of compressor power for the system. The estimated power required for compressor is around 18.82kW (section 4.3). If this compressor is operates for 24 hour, it will come 451.68kWh. This amount of energy has reduced from total energy production. As 1m^3 biogas can generate 1.25kilowatt hours of electricity (table 6.2). Currently EELPA charges as follows:

1. For less than 50 kWh it charges 0.273 birr per kWh
2. 50 to 100 kWh it charges 0.354 birr per kWh
3. For greater than 100 kWh it charges 0.4993 birr per kWh

As the result, the monthly income:

$$= 9{,}904.86\,ETB + 5{,}328\,(organic\ fertilizer) - 225.52ETB\,(monthl$$

$$= 15{,}007\,ETB$$

Cash Flow Analysis

The basic procedure of a cash flow analysis is to enter all the year-by-year income to be received over the estimated life of the project as *inflows.* Similarly, yearly expenditures are entered in the analysis as *outflow*. Finally, for each year, expenditure is deducted from the income. The result thus arrived at is the net cash flow or net benefit. Generally, in the initial year(s) of the project, the net cash flow or net benefit tends to be negative, because of the expenditures incurred to meet the establishment costs *(Gittinger. 1982).*

Time Value of Money and Discount Ratio

The real value of money changes over time. The reasons for such changes are:

- Money of today can be invested to earn a return in the future; and
- People have time preference, i.e. they prefer now to the future.

a) Net Present Value

As the costs and benefits *of* a project are spread over the useful years of project life, they need to be expressed in terms of one common denominator to make the comparison possible. Once the annual cash flow of a project is derived, it needs to be discounted so that all values could be compared to the value of a single year. This discounted net cash flow will provide a widely used criterion for measuring the profitability of a project. For this purpose, all future values are discounted to make them equivalent to the present value and is expressed as Net Present Value (NPV).

The NPV technique measures the worthiness of a project by converting the annual cash flow to a single present value. A positive NPV indicates that the benefits are higher than the costs that accrue over the project life. The process of relating future amount to the present value is known as discounting and is expressed by the following equation:

$$P = \frac{F}{(1+r)^n} \quad \text{...6.1}$$

Where

P = present sum of money

F = future sum of money

r = rate of interest

n = number of years

The commonly used discount rate is the rate of interest that a bank charges on loans and the opportunity cost of capital in situations where private capital is being committed.Series present worth is given by:

$$P = A\left[\frac{((1+r)^{n}\_1)}{[r(r+1)^{n}]}\right] \quad \text{...6.2}$$

Where

A = annual worth (value)

a) Benefit Cost Ratio

The benefit-cost ratio (BCR) is another tool for assessing the profitability of a project. If the ratio is greater than unity (i.e. B/C > 1.0) the project is profitably.

b) Simple Payback Period

The time period required to recover the original investigated for the construction of the plant. It represents the number of years in which the investment is expected to pay for itself. It is given by:

$$SPP = \ Initial\ cost / \ annual\ savin \qquad 6.3$$

Economic Analysis

Some of the benefits and costs of biogas plants are not limited to the users. If a large number of biogas plants are installed in a community, the non-users will also be benefited by avoidance of environmental pollution and conservation of forest in the area. Such benefits and costs that increase even outside of the user household is a subject matter of economic analysis and not of financial analysis. A single biogas plant does not significantly affect the economy as a whole. Economic analysis measures the effect of biogas programme on the fundamental objectives of the whole economy (van der Tak, 1975).

Calculation

20% down payment and a 15 years system life, 12% discount rate & 35 % marginal abatement tax rate were taken from bank rate for lone (NBE, 2003/4)

Present worth cost = Initial investment + present value of annual maintenance & operational cost.

Present benefit: $Pc = I + A(P/A, r, n)$

$$= 1{,}125{,}650 + 2{,}706\left[\frac{\left((1+0.12)^{20} - 1\right)}{0.12(0.12+1)^{20}}\right], at\ r = 12\% \quad P = A\left[\frac{((1+r)^{n}\_1)}{[r(r+1)^{n}]}\right]$$

$$= 1{,}145{,}852\,ETB$$

$$= 180{,}084\left[\frac{((1+.12)^{20}\_1)}{[0.12(0.12+1)^{20}]}\right]$$

$= 1{,}344507\ \ ETB$

$\boldsymbol{Net\ Present\ Value\ (NPV)}$

$= Present\ benefit - present\ cost$

$$= (1{,}344{,}507 - 1{,}145{,}852)$$

$= 198{,}654 ETB$

$\boldsymbol{Simple\ Payback\ Period} \quad = \frac{Initial\ cost}{Annual\ saving}$

$Annual\ saving$
$= an\ energy\ saving\ of\ birr\ 180{,}084\ per\ year - total\ cost\ birr\ 2{,}706\ per\ year$

$= \ 177{,}378\ ETB$

$$SPP = \frac{1{,}125{,}650}{177{,}378}$$

$6.34\ years$

This indicates the organization will get back the capital of constructing biogas plant with in a time of 6 years and four months. It is a reasonable period.

Conclusion and Recommendation

Conclusion

The research was conducted on biogas system design and its feasibility. In this study, it was observed that the proper working of biogas digester can be achieved if the operating & process parameters are kept at optimum condition for the designed $1140m^3$ biogas digester. It is necessary to feed with $18\,m^3/day$ for 80 days of retention time to avoid pathogenic effect on the environment. At optimum condition $529\,m^3/\mathrm{day}$ of biogas is obtained from 8000kg biomass substrate collected. The $529m^3$ volume of biogas produced per day can substitute 19,837.5kWh of electricity.

Compressing biogas reduces storage requirements, concentrates energy content and increases pressure to the level needed to overcome resistance to gas flow. As a result of installing compressor for this system, $529m^3$ of biogas volume is stored in $68m^3$ of pressure vessel and the pressure increased to 1600kpa from 110.64kpa to overcome the problem of mismatch of pressure requirements of gas utilization equipment. In this study, it was possible to see that the Biogas System Design for the campus is financially as well as economically feasible as the NPV is positive and benefit cost ratio is greater than one. Financial study has shown that net present value of the plant is Birr 198,654 and the simple payback period is 6 years and four months.

Recommendation

The following recommendations are made to make the implementation of the project. To be sure about the loading substrate content, the actual flow of substrate should be measured and checked. If the composition of the dry organic matter in the efluent is not between 7 to 10% the following measure has to be taken.

a) Water from shower and bath room completely divert from the drainage of toilet
b) To increase the biogas production pretreated kitchen waste should be added to the digester
c) Night soil and pretreated kitchen waste should be fed with the feed rate $18\,m^3/day$ having 8% total solid organic matter
d) The necessity of a pump has to be checked

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www.teriin.org/renew/tech/biogas

Appendix - I

Compressor Specification

BV8900										
Model	**Code**	**Pump**	**Tank Lt**	**Air displace l/min**	**Power**		**Max press**		**Size mm**	**Weight kg**
					HP	**kW**	**bar**	**Psi**		
BV800/1000 FT15	7PV9X5*	BV8900	1000	2016	15	11	11	160	2430x930x1770	584
BV800/1000 FT20	7PVB9Y5*	BV8900	1000	2400	20	15	11	160	2430x930x1770	584
BV800/1000 FT25	7PVB9W5*	BV8900	1000	2770	25	18.5	11	160	2430x930x1770	584

Technical data - 60Hz, GA30-90C (source: http://www.atlascopco.com)

Compressor type 60Hz	**Max .Compressor working press.**		**Compressor capacity m^3 /hr**	**Motor power**		**Dimension Mm**			**Weight kg**
	Bar(g)	Psi(g)		kW	Hp				
GA30-100	7.4	107	335	30	40	1713	903	1670	830
GA30-125	9.1	132	306	30	40	1713	903	1670	830
GA30-150	10.8	157	259	30	40	1713	903	1670	830
GA30-175	12.5	181	238	30	40	1713	903	1670	830
GA37-100	7.4	107	421	37	50	1713	903	1670	970
GA37-125	9.1	132	374	37	50	1713	903	1670	970
GA37-150	10.8	157	335	37	50	1713	903	1670	970
GA37-175	12.5	181	299	37	50	1713	903	1670	970
GA45-100	7.4	107	504	45	60	1713	903	1670	970
GA45-125	9.1	132	454	45	60	1713	903	1670	970
GA45-150	10.8	157	410	45	60	1713	903	1670	970
GA45-175	12.5	181	364	45	60	1713	903	1670	1035
GA55C-100	7.4	107	569	55	75	1713	903	1670	1035
GA55C-125	9.1	132	518	55	75	1713	903	1670	1035
GA55C-150	10.8	157	475	55	75	1713	903	1670	1035

GA55C-175	12.5	181	450	55	75	1713	903	1670	1400
GA55-100	7.4	107	630	55	75	2055	1028	1949	1400
GA55-125	9.1	132	562	55	75	2055	1028	1949	1400
GA75-100	7.4	107	864	75	100	2055	1028	1949	1500
GA75-125	9.1	132	763	75	100	2055	1028	1949	1500
GA75-150	10.8	157	695	75	100	2055	1028	1949	1500
GA75-175	12.5	181	630	75	100	2055	1028	1949	1600
GA90C-100	7.4	107	947	90	125	2055	1028	1949	1600
GA90C-125	9.1	132	871	90	125	2055	1028	1949	1600
GA90C-150	10.8	157	799	90	125	2055	1028	1949	1600
GA90C-175	12.5	181	731	90	125	2055	1028	1949	1600

Appendix - II Discharge per day, TS value of fresh discharge and water to be added to make favorable TS condition (Source: At Information, website*)*

Kinds	**Body weight (kg)**	**Discharge per day (kg)**	**TS value of fresh discharge % by wt**	**Water to be added with fresh discharge to make the TS value 8%(kg)**
Human	50	0.5	20	0.75
Cow	200	10	16	10
Chicken	1.5	0.1	20	0.15
Pig	50	5	20	7.5

Appendix – III Assembly drawing and Schematic of biogas purification drawing

Physico-Chemical Properties of Three Amaranth Grain Species (*Amaranth Caudatus, Amaranthus Hypochondriacus, and Amaranthus Cruentus)* Collected From Ganji, Jarte and Harar, Ethiopia

By

Geremew Bultossa (PhD) and Ayalew Temesgen (PhD student)

Abstract: *The main aim of this research was to investigate the physical characteristic and nutritional contents of three different varieties of amaranth species (amaranth caudatus, amaranthus hypochondriacus, and amaranthus cruentus), which were collected from different parts of Ethiopia. Proximate analysis of the nutritional contents of amaranths varieties was carried out using standard analytical techniques. The results obtained showed that the percentage (%) Moisture contents as 10.36, 11.20 and 11.31; % ash as 2.06, 2.41 and 3.35; % Crude fiber as 4.75, 5.00 and 5.75; % Crude protein as 15.05, 14.83 and 13.00; % Crude fat as 7.01, 7.09 and 7.51; % total carbohydrate as 58.47, 57.35 and 57.28 in amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus respectively. The findings also reveal the energy contents of these different species were* 357.2862 Kcal, 352.6175kcal and 348.8287kcal *for amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus, respectively.*

Key words: *proximate analysis, amaranth, analytical*

Introduction

Amaranthus are an herb spread in all continents and are characterized by good adaptability. It was cultivated by Aztecs since 5 to 7 thousand years ago (Svirskis, 2003). Amaranth growing area extended from the south-west of the present USA, Africa, India, and China through Central America to Argentina (Dhellot *et al.*, 2006).

Many researchers noted that amaranth can grow on infertile soil. It can well withstand drought and heat and is hardly attacked by any pests (Arowhed, 1993; Meyers, 1996). The leaves of young amaranth plants are used as lettuce in many countries. The most widely grown amaranth species are *Amaranthus cruentus* L. and *Amaranthus caudatus* L. Their seeds differ in color depending on the variety. The seed has the taste of nuts. It is eaten boiled, roasted, crushed, or ground. It is used for porridge production, as well as in confectionery, pasta and candy production. Amaranth is especially suited for mixing with other plants flour (Meyers, 1996; Svirskis, 2003). Amaranth oil is used for the treatment of ontological diseases, sclerosis, malfunctions of the brain and periferic blood circulation system, immune deficient states, gynecological, skin, stomach and liver diseases, wounds, bruises, bedsores, ulcers, vitamin deficiency, and for disease preventive purposes (Smith, 2000; Martirosyan *et al*., 2005; Pablo *et al.*, 2011).

Chemical composition of most amaranth species was tested at the Novosibirsk Institute of Genetics and Cytology. Their seeds contained on average of 21% crude protein and over 9% of crude fat. Very high protein heterogeneity was determined (Svirskis, 2003). The leaves also contain much protein, carotene, vitamins, and other valuable substances. The most valuable property of amaranth seeds and dry leaves is that they contain high quality protein (Svirskis, 2003; Berghofer and Schoenlechner, 2006). The content of lysine, the chief amino acid, in amaranth is 3 - 3.5 times higher than in maize, and 2 - 2.5 times higher than in wheat. Amaranth is especially suitable for people allergic to the proteins (glutenine) of other plant species. Amaranth seed contains about 7% fat, which is used as raw material for the production of steroid preparations. Amaranth oil contains as much as 8% of squalene, which takes oxygen from the environment, and saturates tissues and organs. Squalene is used for cancer treatment (Rao, 1998; Gregory and Kelly, 1999). Furthermore, it easily penetrates the skin and acts as immune stimulator. It was also reported that this compound has important beneficial effects on cancers and reduce cholesterol level in the blood. Amaranth seed has been suggested as an alternative to marine animals as a natural source of squalene (He *et al*., 2002).

Introducing amaranthus as a food crop will help provide to fight malnutrition and diseases in developing countries like Ethiopia. Despite the importance of the crop, there is no evidence exists in the use and type of amaranth; as source of nutrients, as food, and no chemical investigations was done in Ethiopia. So, the aim of this paper is to identify common amaranthus species grown in Ethiopia; to determine the grain physical character of amaranth (grain size, thousand kernel mass); to investigate the proximate chemical composition (moisture content, crude protein, crude fat, crude fiber, ash, total carbohydrate), and nutritional value of common seed amaranth species grown in Ethiopia.

Research methods

Description of the Study Area

Seeds samples of three amaranth species (*Amaranthus cruentus* L., *Amaranthus hypochondriacus* L. and *Amaranthus caudatus* L.) were collected from different localities of Ethiopia based on the availability of the plant and knowledge of the society regarding the use of amaranth. Accordingly, three areas were selected: Namely, East Wollega area (Jarte), West Wollega (Ganji), and Harar area (Harar city), Ethiopia. These amaranth species were labeled, transported and authenticated at Haramaya University herbariums and transported to different laboratory for analysis. The chemical analysis was conducted at Haramaya University; Research Laboratory of Chemistry Department, Soil Science Laboratory, Animal Nutrition Laboratory, and Food Science and Post Harvesting Technology Laboratory.

Apparatus and Instruments

Polyethylene plastic bags, air-circulating oven (Genlab Limited, UK), blender (K-M20, IKA-WERKE, Germany), ceramic mortar and pestle (Haldenwanger, Germany), digital analytical balance (Mettler Tolendo, Model AG 204, Switzerland), digestion tubes, Volumetric flasks (Pyrex, USA), Desicattor, measuring cylinders, pipettes and micropipettes, burettes (Pyrex, USA), Soxhlet, Kjeldhal Nitrogen distiller, fume hood, and UV-Vis spectrophotometer were employed for chemical analysis.

Sample preparations

The three species of amaranth seeds were washed with running water inorder to remove the dirty particles and rinsed with deionized water. Then, the samples were dried for seven days at room temprature (25^{o}C) and pulverized into fine powder using a sterile electric grinder.

Reagents

All the reagents and standard used in this work were of analytical grade. Deionized water (chemically pure: 1.5 µs/cm) were used for sample preparation, dilution, and rinsing apparatus. The methods used in this work for the various determinations of the samples are the standard methods.

Cleaning apparatuses

Apparatus such as glassware, plastic containers and polyethylene bags were washed with the tap water using detergent and rinsed by deionized water. The apparatuses were soaked with about 10% (v/v) nitric acid for 24 hr followed by rinsing with deionized water several times. Then, the apparatus were dried in oven and kept in dust free place until analysis begun.

Chemical analysis

Thousand kernel weight

Thousand kernel weights were determined by counting number of kernels followed (Jideani and Akingbala, 1993) work. The thousand kernel weights were calculated from the equation.

$$1000 \text{ kernel wt.} = \frac{\text{wt. of sample}}{\text{no. of kernels}} \times 100$$

Kernel size

The kernel sizes were determined by counting number of kernels and measured with digital caliper (model CD-6'P, Japan) in triplicate. Then, the size of the kernel was divided for number of kernels and the result expressed in millimeter.

Hectoliter weight

The hectoliter weight of the three amaranthus species were determined by filling 100ml of pre weighed volumetric flask with kernels and weighed on digital balance in triplicate.

Moisture Content

Moisture contents of the plant and soil samples were determined according to AOAC method (AOAC, 1999). Based on the method, empty evaporating dishes and lids were oven dried at 105^{o}C for 3 h and transferred to a desiccator and cooled. Then, the empty evaporating dish and lid were weighed. About 3.0 g of samples were weighed and transferred to the evaporating dishes and spread uniformly on the dishes. The dishes were placed in an oven with the samples and dried for 3 h at 105^{o} C. After dried, the dishes were transferred with partially covered lid to desiccator and cooled. Then, the dishes and their dried samples were weighed.

The moisture contents of seed samples were calculated based on the equation given below from the initial weight of air dried samples and the final oven dried samples.

$$\text{Moisture }\% = \frac{(W_1 \ - W_2)}{W_1} * 100$$

Where: W_1 = Weight (g) of sample before drying and W_2 = Weight (g) of sample after drying

Ash contents

To determine ash content of amaranth seeds, 3gm of powdered seed was placed in weighed silica dish and then it was incinerated over burner or in the muffle. Then it was kept in a muffle furnace at about at 550 - 600°C until light grey ash results or to a constant weight and cooled in a desiccator and weighed. The total ash was expressed in percentage of dry weight.

$$\%\text{ Ash} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Where,W_1 = Wt. of silica dish, W_2 = Wt. of silica dish + sample, W_3 = Wt. of silica dish + ash

Crude fiber

The crude fiber content was analyzed as described in AACC (2000) Method No 32-10. About 2g of sample was transferred to 600 mL beaker. After digestion with 1.25% sulfuric acid it was washed with distilled water and then digested by 1.25% sodium hydroxide. It was then filtered in coarse porosity 75-76 /lm crucible in apparatus at a vacuum of about 25 mm. The residue left after refluxing was washed again with 1.25% sulfuric acid near boiling point. This residue was then dried at 110°C for one hour, cooled in desiccators and then it was weighed (M_1). After carbonization was ashed at 550°C, it was the cooled in desiccators and weighed again (M_2). The total crude fiber was expressed in percentage as:

$$\%\text{CF} = \frac{(M1 - M_2)}{M_3} * 100$$

Where: M_3 is the weight of sample, M_l is the dried sample and M_2 is the dried ashed sample.

Crude fat analysis

About 2 g of sample was measured and transferred to extractor and was extracted with diethyl ether for 4 hr at condensation rate of 5-6 drops/sec to 16 hr at 2-3 drops/sec rate (AACC Method, 2000). The ether from sample was removed by drying on steam bath at low temperature before oven drying. The fat remaing in previously dried and tarred fat beaker was dried in oven at 100°C for 30 min. Then it was desiccated and cooled. And finally the sample measured. Then the crude fat was calculated as follows:

$$\text{crude fat ether extract } (\%) = \frac{\text{weitht of extract(F)} - \text{blank (S)}}{\text{sample weight (g)}} \times 100$$

Where: where F = weight of cup + fat residue, g; T = weight of empty cup, g; S = test portion weight, g.

Determination of crude protein

Total nitrogen of the sample was determined by micro-Kjeldahi method according to AOAC (1995) method No. 925-09 using Automatic digestion and distillation systems (Model UDK-142, Europe). Protein nitrogen was transformed to ammonium sulfate by hot digestion of the dry sample was takes place with concentrated sulfuric acid in the presence of a catalyst. Ammonia was liberated from the sulfate by distillation in the presence of sodium hydroxide and driven into a known volume of boric acid solution. From the ammonium borate formed the amount of ammonium ion attached to borate was titrated with standardized about 0.1 M HCI. The % of protein was estimated from %of nitrogen as follows:

$$\%\ \text{N} = \frac{((V_{\text{HCl}} - V_{\text{blank}}) \times N_{\text{HCl}})x14}{\text{Weight(g) of sample}} \times 100$$

$$\%\,\text{Protein} = \%\,\text{N} \times 5.7$$

Where: V is volume of HCI in L consumed to the end point of titration, N is the normality of HCl used (0.lN) and 14.00 is the molecular weight of nitrogen. The percent of nitrogen is converted to % of protein by using appropriate conversion factor (% Protein = % N x 6.25).

Determination of carbohydrate

The total carbohydrate content was determined according to Sarkiyayi S. and Agar T.M., (2010) by difference method. The sum of the percentages of moisture, ash, crude lipid, crude protein and crude fiber were subtracted from 100% as follows:
Carbohydrate = 100 - (% moisture + % ash + % protein + % lipids + % fiber).

Estimation of the energy value

Energy was calculated as described by Osborne and voogt (1978) using the Atwater factors: 1gm of carbohydrates (C) provides (4Kcalories), 1gm of protein (P) provides (4Kcalories) and 1 gm of fat (F) provides (9Kcalories).

E = [9* Fat (%) + 4* Protein (%) + 4*Carbohydrates (%)]

Data Analysis

All analysis such as drawing of calibration curve, calculating mean, and percentage were performed using Microsoft excel.

Result and discussions

The nutritional content of the amaranth varieties (*Amaranthus hypochondriacus, Amaranthus caudatus and Amaranthus cruentus)* were investigated and the results of the proximate analysis of these species are shown in Table 1. The results showed that the Moisture content of *Amaranthus hypochondriacus (white seed)* 10.36419%, *Amaranthus caudatus,(red seed)* 11.20694*% and Amaranthus cruentus (black seed)* 11.31171%, respectively. When we compare each other the moisture content of *Amaranthus cruentus, (black seed)* 11.31171% was higher than the other while, the moisture contents of *Amaranthus hypochondriacus, (white seed) was least.* The ash content of amaranth ranges from 2.06897 % - 3.359934%. The high values of ash content (3.359934%) in the *Amaranthus cruentus* indicate a high mineral content in it, than the other variety, which contains low ash (2.06897%) in *Amaranthus hypochondriacus,* and 2.413012% in *Amaranthus caudatus*). This result is also similar with John H. Muyonga, et al (2008) report.

Table 1: Proximate composition of grain amaranth varieties commonly grown in Ethiopia

Nutrient	*Percentage composition (%)*		
	Amaranthus hypochondriacus, (white seed)	*Amaranthus caudatus,(red seed)*	*Amaranthus cruentus, (black seed)*
Moisture	10.36419	11.20694	11.31171
Ash	2.06897	2.413012	3.359934
Protein	15.05417	14.83125	13.00833
Crude fiber	4.75	5.00	5.75
carbohydrate	58.475047	57.354191	57.289461
Crude fat	7.018812	7.097304	7.515283

Based on dray matter basis (Db)

There was a significant increase in crude fibre content (4.75%) in the *Amaranthus hypochondriacus;* 5.00% *in Amaranthus caudatus* and 5.75% in *Amaranthus cruentus.* This was as a result of high cellulose that it contains than the *Amaranthus hypochondriacus* and *Amaranthus caudatus* with decrease contents as seen in table 3.2 above. The results were within the normal range with that presented by (John H. Muyonga, *et al.,* 2008; and Ricardo Bressani, *et al*., 1992). Crude protein content of *Amaranthus hypochondriacus* (15.05417%) was higher compared to *Amaranthus cruentus* (13.00833%), and *Amaranthus caudatus* 14.83125% variety. This result indicates that amaranths variety contain more nitrogenous substances. Some literatures also addressed that amaranth species are good sources of high quality proteins compared to the other cereal crops. Amaranth grain has high protein content, ranging from 12.5% to 17.6% in selected light-seeded varieties (Becker et al., 1981; Correa et al., 1986; Lorenz and Gross, 1984; Pedersen et al., 1987; Sanchez-Marroquin et al., 1986; Teutonico and Knorr, 1985), a particularly high nutritive value with high digestibility, and an amino acid composition close to optimal for human requirements.

According to Pearson (1976), as cited in Akubugwo, I. E. et al (2007,) plant food that provides more than 12% of its calorific value from protein is considered good source of protein. Therefore, *Amaranthus species* meet this requirement. Furthermore, adults, children, pregnant and lactating mothers require 34 - 56, 13 - 19 and 17 and 71g of protein daily, respectively (FND, 2002). Similarly, the crude fat content of *Amaranthus hypochondriacus* (7.018812%), *Amaranthus caudatus* (7.097304%) and in *Amaranthus cruentus* (7.515283%). These results are also similar with other studies conducted on amaranthus species. Amaranth grain contains 6% to 10% fat, which is found mostly within the germ (John H. Muyonga, *et al.,* 2008; Betschart et al., 1981; Garcia, Alfaro, and Bressani, 1987a; Lorenz and Hwang, 1985). It is predominantly an unsaturated fat (76%) and is high in linoleic acid, which is essential for human nutrition. Total carbohydrate content is significantly lower (57.354191%) in *Amaranthus caudatus* and 57.289461% in *Amaranthus cruentus* compared to *Amaranthus hypochondriacus* having higher value (58.475047%) as given in Table 3.1.

Table 2. The grain physical character of amaranth species

Species	Grain size in thousand kernel mass(TKW)	Hectoliter weight (HLW) in gm/100ml	kernel size in mm
Amaranthus hypochondriacus	0.3888	90.8286	0.9664
Amaranthus caudatus	0.4887	91.1354	1.1143
Amaranthus cruentus	0.42	87.981267	0.9144

As seen from table 2 above, the thousand kernel weight (TKW) of Amaranth seed species used in this study were 0.3888 TKW for *Amaranthus hypochondriacus*, 0.4887 TKW for *Amaranthus caudatus and* 0.42 TKW for *Amaranthus cruentus.* The Hectoliter weights (HLW) of amaranth species were 90.8286 gm/100ml**,** 91.1354 gm/100ml**,** 87.981267 for *Amaranthus hypochondriacus, Amaranthus caudatus and Amaranthus cruentus* respectively. *Similarly* the Kernel size (KS) of the amaranth species also measured in mm and the results are 0.9664, 1.1143 and 0.9144 for *Amaranthus hypochondriacus, Amaranthus caudatus and Amaranthus cruentus* respectively.

Table 3: Energies in kilo calories

Species	Energy in kilo calories
Amaranthus hypochondriacus	357.2862kcal
Amaranthus caudatus	352.6175kcal
Amaranthus cruentus	348.8287kcal

The energy contents of different amaranthus species also indicated from table 3 above 357.2862kcal, 352.6175kcal and 348.8287kcal amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus respectively. Compared to the other two species amaranthus *hypochondriacus* is high in energy content.

CONCLUSION

A proximate analysis of the nutritional contents of amaranths varieties was carried out using standard analytical techniques and the results obtained showed that the percentage (%) Moisture contents as 10.36, 11.20 and 11.31; ash as 2.06, 2.41 and 3.35; Crude fiber as 4.75, 5.00 and 5.75; Crude protein as 15.05, 14.83 and 13.00; Crude fat as 7.01, 7.09 and 7.51; total carbohydrate as 58.47, 57.35 and 57.28 for, amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus respectively. The findings also reveal the energy contents of these different species were 357.2862 Kcal, 352.6175kcal and 348.8287kcal for amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus respectively.

A comparative assessment of the results however, showed that amaranthus cruentus (black seed) has higher values of Moisture, Ash, crude fat, crude fiber, and amylase/amylopectine ratio than the other two species (amaranthus hypochondriacus and amaranthus caudatus); while amaranthus hypochondriacus (white seed) has higher in protein, energy and carbohydrate contents. Generally our results show that the seed of amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus contain appreciable amount of proteins, fat, fibre, carbohydrate and energy. Thus, it can be concluded that amaranthus hypochondriacus, amaranthus caudatus, and amaranthus cruentus *seed* can contribute significantly to the nutrient requirements of human being and should be used as a source of nutrients to supplement other major sources.

Recommendation

The quantity of various nutrients found in amaranth, which both human and animals consume varies among the species (amaranthus hypochondriacus, amaranthus caudatus and amaranthus cruentus). Each day we require enough energy, for daily activities and amaranthus species are good source of carbohydrate, protein and energy, it is recommended that it should be used as alternative source of nutrient for different industrial purpose and others, after being properly processed. Only chemical analysis, however, should not be the sole criterion for judging the nutritional value of this plant. It is necessary to consider other aspects such as the mineral nutrients and anti-nutrient contents of the plant in order to determine the bioavailability of the nutrients and also the effects of processing on the chemical and nutritive value of the plant. **Study on the nutritive minerals and anti-nutrients chemical values of the plant seed is in progress by the same authors (the student can be asked for additional information if the data is already generated)**.

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Appendix

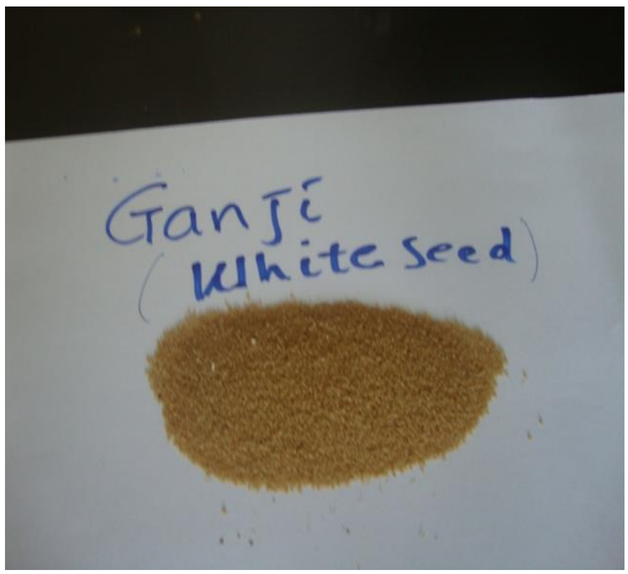
Picture of different Amaranthus spsecies

Amaranthus caudutus plant

Amaranthus cruentus plant

Amaranthus hypochondriacus

Amaranthus caudutus seed



Amaranthus hypochondriacus

Amaranthus cruentus

5. College of Law

6. College of Natural and Computational Sciences

Heavy Metals in Selected Vegetables Produced Through Wastewater Irrigation and Their Toxicological Implications in Eastern Ethiopia

By

Meseret Amde, Deribachew Bekana, Abi Taddesse, and Nigussie Dechassa

Funded by HrU Government Grant

Abstract: *Extensively consumed vegetables (cabbage and potato) and the narcotic plant khat are cultivated through irrigation with wastewater in some areas of Eastern Ethiopia. This research was initiated to analyse selected toxic heavy metal (Cr, Co, Cd and Pb) contents of the vegetables, effluent and respective soil samples with flame atomic spectrometry. Wet digestion procedures were employed to solubilize the metals from the samples. The metal contents (mg kg^{-1}) in the cabbage were in the ranges of less than method detection limit (<MDL)-17, 5.7-9.7, 1.2-2.5 and 5.5-12 for Cr, Co, Cd and Pb, respectively. The metal contents (mg kg^{-1}) in the potato were in the range of 12-14, 5.2-8.7, 1.2-1.5 and 5.4-7.8 for Cr, Co, Cd and Pb, respectively. The metal contents (mg kg^{-1}) in the khat were in the range of 9-15, <MDL-8.8, 0.4-3.2 and 4.5-11 for Cr, Co, Cd and Pb, respectively. The metal contents (mg kg^{-1}) in the effluent samples were 0.2-0.3, 0.6-1, 0.01-0.1 and 0.8-2.5 for Cr, Co, Cd and Pb, respectively. Similarly, the metal contents (mg kg^{-1}) in the soil samples were in the range of 26-41, 18-24, 0.8-2.6 and 26-47 for Cr, Co, Cd and Pb, respectively. The amounts of all metals in the vegetables, except Co, were found to be above the safe limits set by different international organizations. Vegetables collected from the study areas are contaminated with abnormal levels of metals capable of causing health hazards to the consumers. Therefore, regular monitoring of these metals from effluents, soils, and vegetables is essential to prevent excessive build-up of these metals in the food chain.*

Keywords: *Ethiopia; Vegetables; Heavy metals; Wastewater irrigation; Wet digestion*

Introduction

Vegetables are important ingredients in the human diet and contain essential nutrients and trace elements that have potential health benefits (Abdullah and Chmielnicka, 1990) Environmental pollution has caused the contamination of soil; on the other hand waste water irrigation resulted in significant infusion of heavy metalsinto agricultural lands (Mapanda et al., 2005). The chief cause is the waterways through which heavy metals are leached out of the soil and taken by the vegetation. If plants decay, these toxic metals are redistributed and as a consequence their enrichment in the agricultural soil occurs. Bioaccumulation, geoaccumulation and biomagnifications may result because of entrance of heavy metals to the ecosystem. Thus, long term waste water irrigation leads to a build up of heavy metals in soils and food crops (Khan et al., 2008).

Accumulation of toxic heavy metals in vegetables irrigated with wastewater was studied and it was found that heavy metal concentrations in vegetables grown with wastewater was many-fold higher than the concentrations of heavy metals in vegetables grown in controlled area (Cheraghi et al., 2009).

Municipal wastewater had higher amount of heavy metals such as Mn, Fe and Cr compared to well water Soil, irrigation water, and leaves were analyzed and found to be severely contaminated with these heavy metals (Tabari et al., 2008). Eslami et al., (2007) investigated heavy metal concentration in roots and leaves of radish, leek, sweet basil and parsley. In the study, some of them were found to contain high levels of the heavy metals beyond the levels given by FAO and WHO for human consumption. Concentration of Cu, Pb and Zn were investigated in five leafy vegetables species. Both unwashed and washed leaves of vegetables originating from urban areas showed the highest amount of the heavy metal concentrations.

Exposure of vegetables or plant products to various metal containing components have varying health implications (Soomro et al., 2007). Furthermore, consumption food and vegetation contaminated with heavy metals can seriously deplete some essential nutrients in the body causing a decrease in immunological defenceses, intrauterine growth retardation, impaired psycho-social behavior, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer. Based on the effect of heavy metals on consumers, different organizations set the maximum permissible limits of the metals in edible vegetations, waste water, and soils as shown in Table 1.

Table 19. Guideline for safe limits of heavy metals in soil, water, and edible plants

Sample	Standards	Metals			
		Cr	Co	Cd	Pb
Soil (mg/kg)	Indian Standard (Awashthi, 2000)	-	-	3-6	250-500
	WHO/FAO (2007)	-	-	-	-
	European Union Standards (EU 2002)	150	-	3.0	300
	Ewers, 1991	100	50	3	100
Water (mg/L)	Indian Standard (Awashthi, 2000)	0.05	-	0.01	0.10
	WHO/FAO (2007)	0.10	-	0.01	5.0
	European Union Standards (EU 2002)	-	-	-	-
	Ayers and Westcott, 1985	0.55	0.05	0.01	0.065
Plant (mg/kg)	Indian Standard (Awashthi, 2000)	20.0	-	1.5	2.5
	WHO/FAO (2007)	-	-	0.2	5.0
	European standard (EU 2006)	-	-	0.2	0.30
	FAO/WHO, 2001		50.00	0.10	0.30

It has been reported that sewage effluents contain significant amounts of major plant nutrients and thus fertility levels of soil are increased under sewage irrigation of crops like cabbage, radish, cauliflower, spinach, etc (Jolocam et al., 2010). However, studies of untreated sewage irrigated crops (cabbage, radish, chandaliya, etc) revealed the presence of toxic metals like Pb, Cr, Cd, Ni, Fe, Co, Zn, Co, etc. and as a result reduce soil fertility and agricultural outputs. In our country, farmers are cultivating vegetables with water effluents coming from different towns. Similar exists in Aweday, Harar (Figure 1), Haramaya town and areas around the main campus of Haramaya University (HU) in vegetable production.

Figure 4. a. Farm of cabbage irrigated with effluent at Harar town; b. effluent diversion to farm land from the main canal.

Therefore, the present study was undertaken to assess the extent of toxic trace heavy metal contamination in selected vegetables grown under irrigation with sewage waterin various fields of Harari region near Harar town, Aweday and Haramaya towns of the Oromia national regional state as well as the vegetable producing areas in the vicinity of the main campus of Haramaya University (HU). The municipal wastewaters of Harar, Aweday and Haramaya towns and Haramaya University (HU) flow to farm fields of smallholder farmers in the vicinities. Various vegetables such as cabbage and potato and the narcotic plant khat (*Catha edulis* forsk.) are grown on the farms lying beside these drains by farmers using the untreated wastewaters. This study was conducted to investigate accumulation of heavy metals in vegetables grown in the areas. The study was necessary as a large number of people consume the produces and no research had been conducted to elucidate the extent of the problem in the region. This paper presents the results of the investigation.

Materials and Methods

Experimental Sites

Vegetable, soil, and effluent water samples were collected from different areas of East Hararghe zone of the Oromia Regional Stae *viz.,* Harar town (9°18'16.54"N, 42°07'57.55"E), Aweday town (9°21'36.75"N, 42°02'44.01"E), Haramaya town (9°23'30.33"N, 42°00'40.82"E), and the vicinity of Haramaya University (HU) (9°25'05.69"N; 42°02'45.65"E), where toilet and laundry sewage from student dormitories flow downhill into farmlands. The analysis for the heavy metals was conducted in the Chemistry and Soil Science Laboratories of Haramaya University.

Equipment, Chemicals, and Reagents

Equipment

Air circulating oven (Genlab Limited, UK), electronic blending device (K-M20, IKA-WERKE, Germany), ceramic mortar and pestle (Haldenwanger, Germany), a digital analytical balance (Mettler Tolendo, Switzerland), stainless steel Auger, Kjeldahl block digester (Gallenkamp, England) were used. Flame atomic absorption spectrophotometer (Buck Scientific Model 210VGP AAS, East Norwalk, USA) with air-acetylene flame was used for the analysis of the target metals.

Chemicals and Reagents

All chemicals and reagents used were of analytical grade. HNO_3 (69−72%, Fine-Chem Mumbai-391780, India) and 70% $HClO_4$ (A.C.S. reagent, Aldrich, UK) were used for the digestion of the vegetable samples (cabbage, potato and khat). HNO_3 (69−72%, Fine-Chem Mumbai-391780, India), 70% $HClO_4$ (A.C.S. reagent, Aldrich, UK) and H_2SO_4 (Fine-Chem Mumbai - 400 02 India) were employed during digestion of the soil samples. HNO_3 (69−72%, Fine-Chem Mumbai-391780, India) and 36-37% HCl (A.C.S. reagent, Aldrich, UK) were used in digestion of the effluent samples. Stock standard solutions 1000 mg/L, containing 2% HNO_3, of the metals Pb, Co, Cd and Cr (Buck Scientific Puro-GraphicTM, USA) were used for preparation of the working solutions (which were immediately prepared before analysis) for calibration and in spiking experiments. The glassware and polyethylene containers used for analysis were washed with tap water, then soaked in 4 M HNO_3 solution and rinsed several times with deionized water. Deionized water was used throughout the experiment for preparation and dilution of the sample solutions.

Sample collection and preparation

The effluent, soil, and vegetable samples were collected in from January to April, 2012. About 2 kg of each of the vegetable materials were collected, packed, labeled and transported to the laboratory. The samples were washed with tap water to eliminate dirt and possible parasites; the edible parts were separated from the other portions, rinsed with distilled deionized water, shredded for cabbage and khat leaves and minced for potato tubers. The samples were then air dried. The air-dried samples were ground, sieved, homogenized, and heated in an oven at 105 ^{o}C to constant weights. The contents were cooled and placed in clean paper bags and stored in a desiccator until digestion.

Soil samples (about 1 kg) were collected from 0-15 cm depth in triplicate from the plant origins with an auger into clean polyethylene bags. The collected soil samples were mixed thoroughly and composited samples were obtained for the four sites. Then, the composited soil samples were air-dried in a dry and dust-free place below 25 ºC for 5 days followed by oven drying to constant weights. The samples were then ground with a mortar and pestle to pass through 2 mm sieve and were homogenized. The dried sieved and homogenized soil samples were stored in clean and dry containers till digestion.

Effluent samples were collected from the four areas *viz*. Harar, Aweday, Haramaya town and the vicinity of Haramaya University from surfaces where effluents are being directed to vegetable farms. The effluents were filled in to plastic bottles (250 mL) after being rinsed with the effluent water several times. The collected effluent water samples were transported to the laboratory and acidified with conc. HNO_3 (5 ml L^{-1}) and stored in a clean area for further treatment.

Digestion of the Samples

Digestion of the plant samples

To obtain a clear sample solution that is suitable for the analysis using flame atomic absorption spectrometry (FAAS), different digestion procedures for the plant samples (cabbage, potato and khat) were assessed using conc. HNO_3 and $HClO_4$ acid mixtures by varying the volume of the acid mixture, digestion time, and digestion temperature. Optimized procedure was selected based on usage of lesser reagent volume, shorter digestion time, and reasonably mild temperature for obtaining clear solutions of the resulting digests. Among the different digestion procedures tested, digestion of 0.5 g plant materials with 5 mL of 3:2 (v/v) mixture of concentrated HNO_3 and concentrated $HClO_4$ heated at 250 °C for 55 minutes gave a clear colourless solution and this procedure was chosen for the digestion of the plant samples (cabbage, potato and khat).

Accordingly, 0.5 g of cabbage, potato and khat samples were quantitatively transferred into a 100 mL digestion tubes. Accurately measured 5 mL of freshly prepared 3:2 (*v/v*) mixture of concentrated HNO_3 and concentrated $HClO_4$ was added to the samples. The samples were swirled gently and digested continuously for 55 min at 250 °C on a Kjeldahl digestion block. After the digestion was completed, the digest was cooled and filtered into 50 mL volumetric flask using Whatman no. 41 filter paper to remove any suspended and turbid matters. After subsequent rinsing, the solutions were diluted to the mark with deionized water. Digestion was made in triplicates for each of the vegetable samples collected from the four sampling sites. Digestion of a reagent blank was performed in parallel with the vegetable samples keeping all digestion parameters the same. All the digested and diluted samples were stored in a refrigerator at 4 ºC until analysis of the metals was done by the FAAS.

Digestion of the soil samples

A digestion method reported by Allen et al. (1986) was used for the digestion of the soil samples after making slight modification on the procedure to obtain clear solutions of the digest. Accordingly, 1g of soil samples were digested on Kjeldahl digestion block by adding 7 mL of tri-acid mixture (HNO_3, H_2SO_4, and $HClO_4$ in 5:1:1 (*v/v/v*) ratio) at 100 ºC for 40 min and then 160 ºC for 50 min to obtain transparent solution of the digest. After cooling the digested sample, it was filtered using Whatman no. 41 filter paper and the filtrate was finally made up to 100 mL with deionized water. Concentrations of heavy metals in the filtrate of the digested soil samples were estimated by using FAAS.

Digesting the effluent samples

EPA 3005A method was used for digesting the effluent water samples used for irrigating the vegetables. *ca*. 50 mL aliquot of well mixed effluent samples were digested in a beaker covered with watch glass by adding 1 mL of concentrated HNO_3 and 2.5 mL of concentrated HCl and heated on a hot plate at 90 ºC until the volume was reduced to about 15 mL. Then the beaker was removed and cooled and the solution was filtered and finally diluted to 100 mL with distilled-deionized water. The level of heavy metals in the filtrate was determined by FAAS.

Quality Assurance

Calibration procedure for the determination of metals

Calibration curves were prepared to determine the concentration of the heavy metals in the sample solutions. Calibration curves for each of the analysed metals were made from diluted solutions prepared from stock standard solutions containing 1000 mg L^{-1} of the metals Co, Cd, Cr and Pb. The correlation coefficients of the calibration curve for the entire analytes were higher than 0.998 which assured a linearity of responses for the individual analyte. Analytical wavelengths, colour of the flame and slit width were adjusted according to the instrument operation manual to attain its better sensitivity. Potassium chloride solution was added as an ionization suppressor for determining the concentration of Cr. For each of the vegetable, soil and effluent samples, three replicate measurements were performed.

Method of Detection Limit

Nine replicate blank samples were digested following the same procedures that have been utilized for digesting the vegetable, soil, and effluent samples. Each of the blank samples was assayed for its metal contents, *viz.* Cr, Co, Cd and Pb by FAAS. The standard deviations (SD) of the nine replicate blanks were calculated to determine the method detection limit (MDL) and limit of quantification (LOQ). MDL was calculated as three times the standard deviations (MDL = 3SD) and LOQ was calculated as ten times the standard deviation (LOQ = 10SD) (David and Terry, 2008). The MDL values obtained were compared with the instrument detection limit (IDL) and found to have greater values in all cases (Table 2).

Table 20: MDL and LOQ for the assayed samples

Sample	Metal	MDL	LOQ	IDL
Effluent	Chromium	0.175	0.584	0.050
	Cadmium	0.028	0.094	0.005
	Cobalt	0.146	0.487	0.050
	Lead	0.304	1.014	0.100
Soil	Chromium	0.277	0.922	0.050
	Cadmium	0.037	0.123	0.005
	Cobalt	0.137	0.457	0.050
	Lead	0.513	0.712	0.100
Vegetables	Chromium	0.175	0.584	0.050
	Cadmium	0.032	0.107	0.005
	Cobalt	0.139	0.463	0.050
	Lead	0.362	1.207	0.100

Recovery of the analytical method

Efficiency of the optimized procedure used for digesting the vegetable samples and the methods used for soil and effluent samples were checked by spiking the pre-treated vegetable, soil and effluent water samples with standard solutions of each metal having a known concentration. The spiked vegetables, soil, and effluent samples were digested following the same procedure employed in the digestion of the respective samples.

Accordingly, a 0.5 g of cabbage sample was spiked with 5 mg kg^{-1} Cr and Pb, and 1 mg kg^{-1} Cd and Co. The same amounts (0.5 g) of potato and khat leaf samples were spiked with 5 mg kg^{-1} Cr, Co and Pb, and 1 mg kg^{-1} Cd. For a soil sample, 1 g was spiked with 10 mg kg^{-1} Cr and Pb, 5 mg kg^{-1} Co and 1 mg kg^{-1} Cd. However, the effluent water sample (50 mL) was spiked with 0.5 mg kg^{-1} Cr and Cd, and 1 mg kg^{-1} Co and Pb. For the vegetables, effluent, and soil samples, the recovery was performed in triplicates.

Transfer Factor (TF)

Transfer factor (TF) was calculated to understand the extent of risk and associated hazard due to waste water irrigation and consequent heavy metal accumulation in the edible portions of test vegetables following the procedure of Cui et al. (2004).

$$TF = \frac{\text{concentration of metal in edible part}}{\text{concentration of metal in soil}}$$

Statistical Analysis

Analysis of variance (ANOVA) was used to test the level of significance at $\alpha = 0.05$ (Miller and Miller, 2010) using Microsoft Excel. Means were separated using the least significant difference test at 5% level of significance.

Correlation test was carried out between the investigated metals for the vegetable materials and among metals of soil and vegetables to associate the distribution of metals in the soil samples and their availability and accumulation in the vegetables at $\alpha = 0.05$. Thus, Pearson product moment correlation coefficient was used and the value was computed using Microsoft Excel.

Results and discussion

Levels of Metals in the Effluent, Soil, and Vegetable Samples

Levels of metals in the effluent samples

Mean concentration values (mg kg^{-1}) of the toxic heavy metals in the effluent collected from the four sampling sites are given in Figure 2.

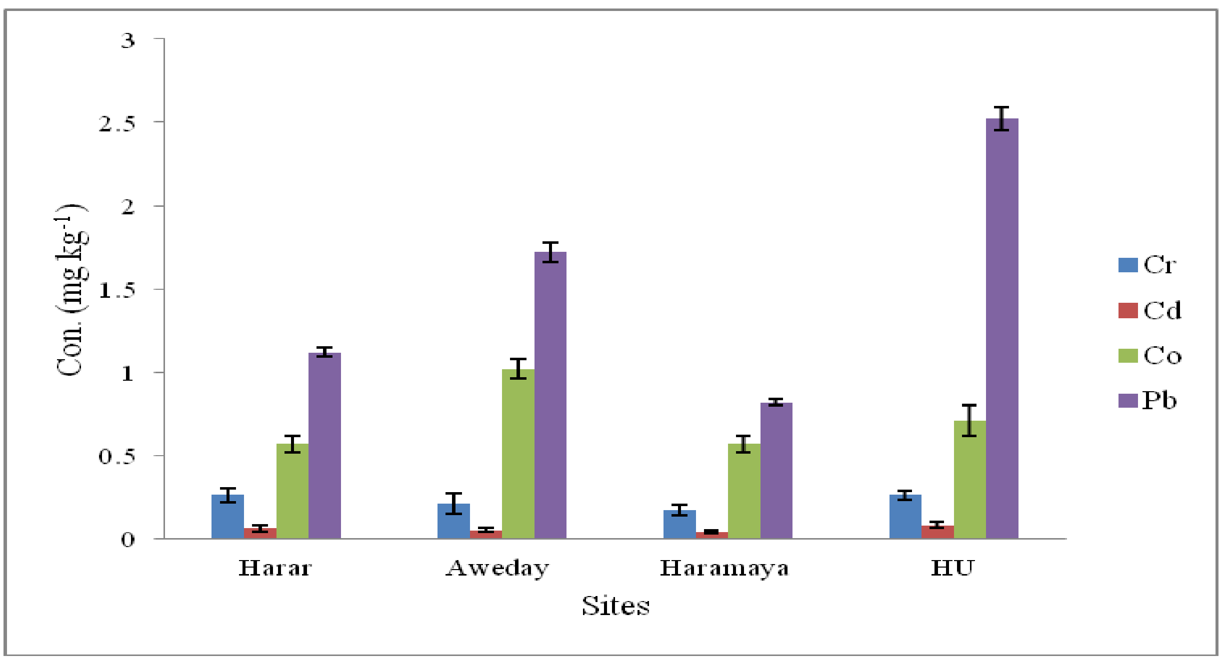


Figure 5. Concentrations of metals in the effluent samples

The effluent analysis revealed significant differences in the concentrations of heavy metals in the samples collected from the various sampling areas. The differences may be attributed to the fact that the contaminating analytes depended on sources of the wastewater discharged to the irrigation water. Heavy metals in the sewage water are associated with small scale industries such as colouring, electroplating, metal surface treatments, fabric printing, battery, and paints releasing Cd, Co, Cr, Pb, Zn, Ni and other heavy metals into water channels, which are accessed for irrigation.

The concentration of Cr in the effluent was found to be the lowest (0.2 mg kg^{-1}) in the samples collected from Haramaya town and the highest (0.3 mg kg^{-1}) in the samples collected from both Harar and Hramaya University (HU). The concentration of the same metal was found to be 0.2 mg kg^{-1} in the effluent collected from Aweday site. The concentration of Cd in the effluents varied from 0.04 mg kg^{-1} for the sample collected from Haramaya site to 0.05 mg kg^{-1} from Aweday, 0.06 mg kg^{-1} from Harar. The highest concentration of the metal (0.1 mg kg^{-1}) was observed in the effluent from HU site.

The concentration of Co in the effluent ranged from 0.6 mg kg^{-1} from Harar and Haramaya towns to 0.7 mg kg^{-1} from HU and 1 mg kg^{-1} from Aweday. Among the four heavy metals analysed in the current study, Pb was found to be the highest constituent in the effluent samples which ranged from 0.8 mg kg^{-1} in the sample from Haramaya town to 1.1 mg kg^{-1} from Harar town and1.7 mg kg^{-1} from Aweday town. The highest concentration (2.5 mg kg^{-1}) of this heavy metal was detected in the effluent collected from the vicinity of Haramaya University. Among the investigated metals, Pb was found to have the highest concentration followed by Co and Cr in the effluent waters. The concentration of Cd was found to be the lowest in the effluent waters collected from all sites.

The concentrations of Cd and Co detected in the effluent waters exceeded the safe limits set by international organizations *viz*., WHO/FAO (2007), Indian standard (Awashthi, 2000) and FAO (Ayers and Westcott, 1985). The concentration of Pb in all the effluent samples was found to be under the safe limit set by WHO/FAO (2007), but above the limit when compared with Indian standard (Awashthi, 2000) and FAO (Ayers and Westcott, 1985). However, Cr exceeded the safe limit according to WHO/FAO (2007), but was below the limit according to Indian standards (Awashthi, 2000) and FAO (Ayers and Westcott, 1985). The results obtained show that the effluent samples are profoundly contaminated with heavy metals.

Levels of metals in the soil samples

The level of metals in the soil samples collected from the four sampling areas of the plant origins is presented in Figure 3.

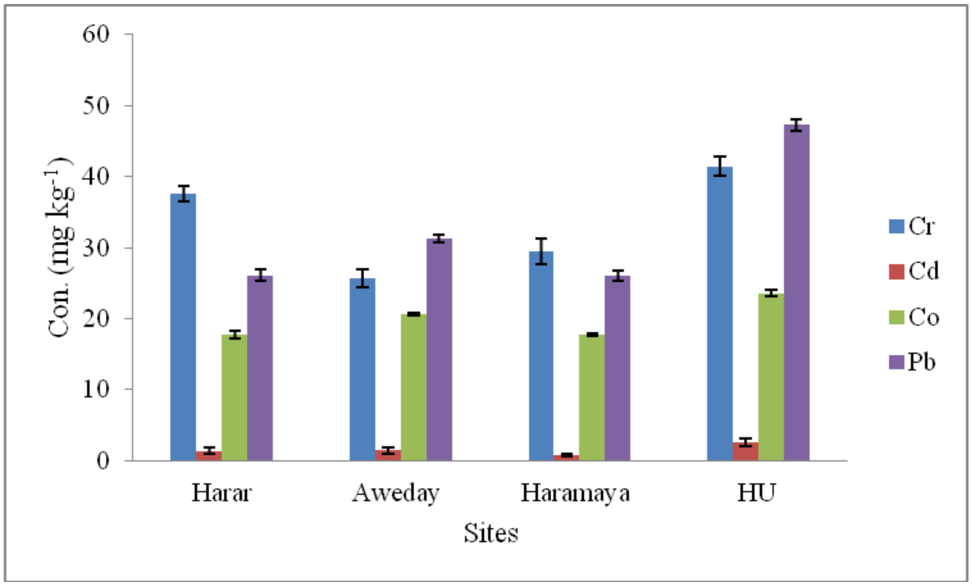


Figure 6. Concentrations of the metals in the soil samples of the plant origins

For the soil samples, high Cr concentration (41 mg kg^{-1}) was observed at HU site and the least concentration (26 mg kg^{-1}) was recorded in Aweday site. However, Cr concentration in soils of Haramaya and Harar sites were 30 mg kg^{-1} and 38 mg kg^{-1}, respectively. The concentration of Cd in the soil samples was found to be 0.8, 1.4, 1.4 and 2.6 mg kg^{-1} for Haramya, Harar, Aweday and HU sites, respectively. Similarly, the soil from which the vegetables originated revealed high Co concentration (24 mg kg^{-1}) from HU site. This was closely followed by the Co concentration collected from Harar and Aweday sites, which amounted to 18 mg kg^{-1} and 21 mg kg^{-1}, respectively. The lowest concentration (18 mg kg^{-1}) was observed for the Haramaya site. The soil sample from HU site contained high Pb concentration (47 mg kg^{-1}) followed by soil from Aweday site (31 mg kg^{-1}). The lowest and comparable Pb (26 mg kg^{-1}) was recorded in soil samples of Haramaya and Harar towns. Among the targeted heavy metal analytes, Cr was found to be the highest in concentration followed by Pb and Co. The concentration of Cd was found to be the lowest in the soil samples from all the sampling sites.

The amounts of heavy metals in the soil samples considered in the current study *viz*., Cd, Cr, Co and Pb were found to be below the safe limits set by different organizations (European Union Standards (EU, 2002), Indian Standards (Awashthi, 2000), and (Ewers, 1991). The critical level of Cd in the soil for plant growth is 3 mg Cd/kg soil (Mengel and Kirkby, 2001). For the soil samples collected from HU site, the concentration of Cd was found to be high and approaching the safe limits according to Ewers (1991), Awashthi (2000) and EU (2002). The concentration of Cd in the soil may be increased due to the application of sludge (Vlamis et al 1985). Cd is also added to the soil in small amounts in phosphate fertilizers ((Baize. 1997). The relatively higher concentration Cd in soils sampled from the vicinity of Haramaya University may be attributed to the higher sewage sludge emanating from the residences of staff and students as well as the higher use of phosphate fertilizers in the research and nearby farms in the area. This indicates that the level of cadmium in the soil needs to be managed.

Levels of metals in the vegetables

The concentrations of the metals in the vegetables (cabbage, khat, and potato samples) are given in Figures 4a-4d for Cr, Co, Cd and Pb, respectively.

Chromium

The concentration of Cr was observed to be the highest (17 mg kg^{-1}) in cabbage samples collected from HU site and it was below method detection limit in cabbage samples from Haramaya site (Figure 4). As presented in the Figure, the range of Cr concentration (mg kg^{-1}) was found to be <MDL – 17, 12–14 and 9-15 for cabbage, potato and khat samples, respectively. Except in cabbage from the Haramaya site (<MDL), the concentrations of Cr detected in all of the vegetables analysed in this study were higher than the stipulated permissible levels in food by FAO/WHO guidelines (Kihampa et al., 2011). However, the amounts in all samples were below the permissible limit set by Indian standards (Awashthi, 2000). Among the investigated vegetables, cabbage was found to be Cr-loaded than potato and khat samples. Higher concentration of this heavy metal was obtained in vegetables from HU site which might be due to sewage sludge discharged to the environment from laboratories as well as toilets and laundries of student dormitories and staff residences of the University.

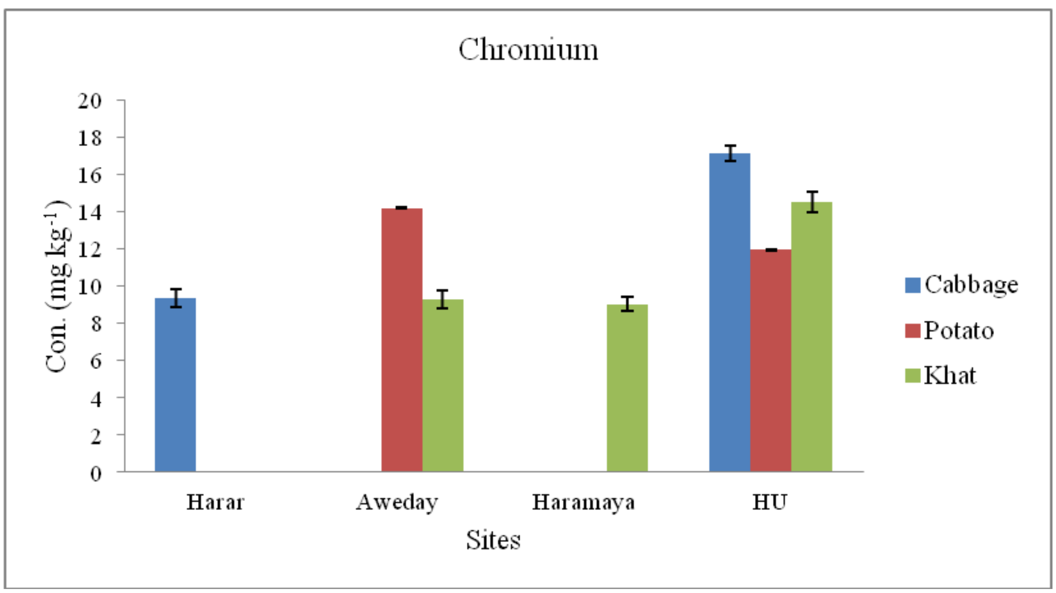


Figure 7. Concentration of chromium in the vegetables

Cobalt

The concentration of Co (mg kg^{-1}) ranged 5.7 – 9.7, 5.2 – 8.7 and <MDL – 8.9 for cabbage, potato and khat samples, respectively (Figure 5). The concentrations of Co detected in all of the vegetables analysed, in this study, were far lower than the stipulated permissible levels in food by FAO/WHO guidelines (FAO/WHO, 2001). Based on these results, it can be said that the vegetables are safe to consumers, which might arise due to the toxic effect of Co. From among the investigated vegetables,

cabbage was found to be more Co-loaded than potato and khat, and high concentration of the heavy metal was obtained from vegetable samples collected from the vicinity of Haramaya University.

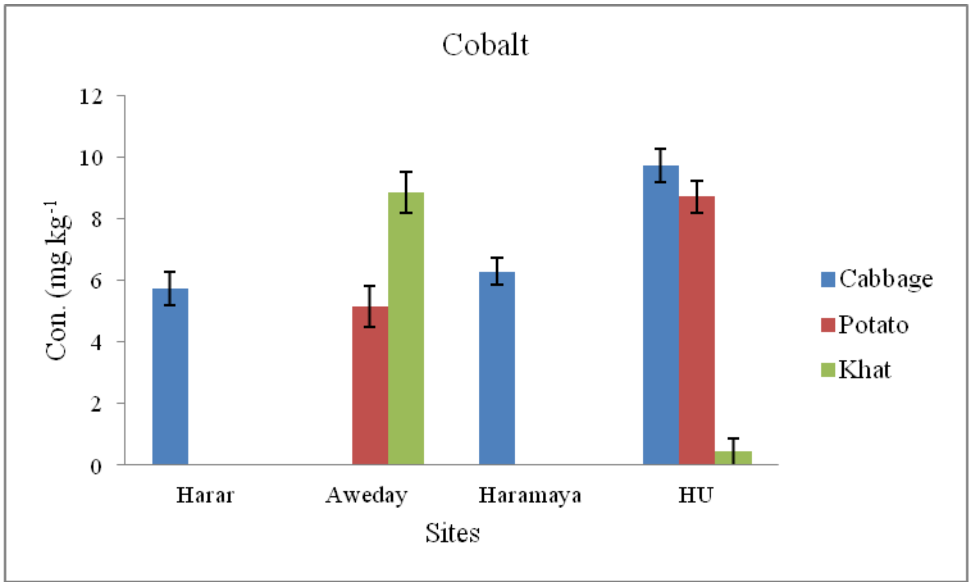


Figure 8. Concentration of cobalt in the vegetables

Cadmium

Cd is a toxic metal and can cause serious health problems. Recently, attention has been focused on its availability in water, soil, milk, dietary products, medicinal plants, herbal drugs, etc. (Khan et al., 2007). The most common sources for Cd in soil and plants are phosphate fertilizers, non-ferrous smelters, lead and zinc mines, sewage sludge application and combustion of fossil fuels (Davies, 1990).

Data in Figure 4c show that Cd concentration (mg kg^{-1}) in the investigated vegetables ranged 1.2 – 2.5, 1.2 – 1.5 and 0.4 – 3.2 in cabbage, potato and khat samples, respectively. All samples of the current study contained Cd concentration above the maximum permissible limit set by different organization, which is 0.1 mg kg^{-1} (FAO/WHO, 2001) and 0.2 mg kg^{-1} (EU, 2006; WHO/FAO, 2007). Among the sampling sites, samples from HU site contained higher Cd concentration which might be attributed to the sewage sludge discharge from the University's laboratories, student dormitories, garage and cafeterias. Hence, the University and agricultural officers of the surrounding areas should take immediate action against this development.

As presented in Figure 6, leafy vegetables (khat and cabbage) contained the highest levels of Cd c which shows higher accumulation of this metal in the aerial parts of the plants than the roots. It has been reported that Cd is a highly mobile metal, easily absorbed by the plants through root surface and moves to wood tissue and transfers to upper parts of plants (Fazeli, 1998; Sanita di Toppi and Gabbrielli, 1999, Mohsen and Mohsen, 2008).

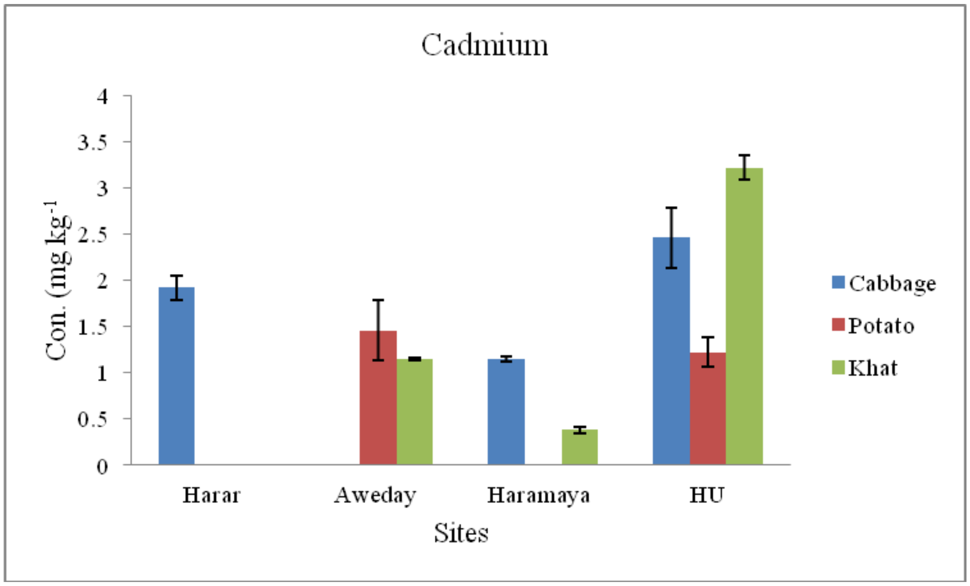


Figure 9. Concentration of cadmium in the vegetables

Lead

The concentration range (mg kg^{-1}) of Pb in the assayed vegetable samples was; 5.4–12, 5.4–7.8 and 4.5–11 in cabbage, potato and khat samples, respectively (Figure 7). The samples contained Pb above the maximum permissible limit set by China (Chinese Department of Preventive Medicine, 1994), India (Awashthi, 2000), (FAO/WHO, 2001), European regulation (EU, 2006) and (WHO/FAO, 2007). Hence, the vegetables collected from the four sampling sites (Aweday, Harar, Haramaya, and HU) are not safe to consume based on their Pb contents. Cabbage accumulated the highest amount of Pb c followed by khat and potato samples. The three samples collected from HU site accumulated higher Pb than samples from the other sites which might be due to the effluents from laboratories and toilets from the University.

Pb is a toxic element that can be harmful to plants, although plants usually show the ability to accumulate large amounts of Pb without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several hundred times than the threshold of maximum level permissible for humans (Wierzbicka, 1995). On the whole, all vegetables that were studied in this study were contaminated by Pb and are bound to be unsafe for human consumption. .

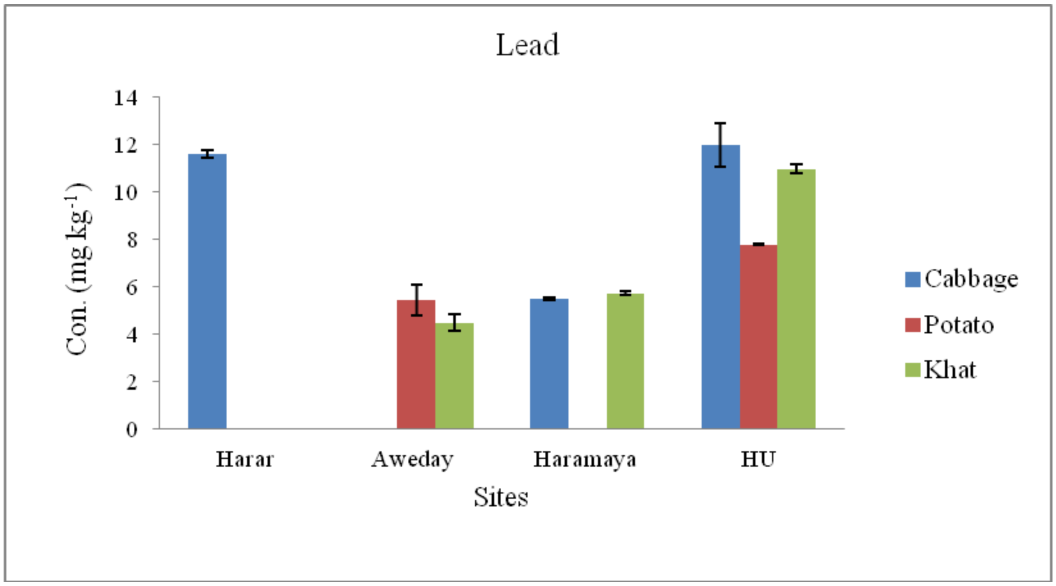


Figure 10. Concentration of lead in the vegetables

Transfer Factor (TF)

Among the different metals, Cd showed the maximum transfer factor value, which ranged from 0.48 (khat from Haramaya) to 1.46 (cabbage from Haramaya) and it was minimum for Co, ranging from 0.02 (khat from HU) to 0.43 (khat from Aweday). The transfer factor for Cr and Pb ranged from 0.25 (cabbage from Harar) to 0.55 (potato from Aweday) and 0.14 (khat from Aweday) to 0.45 (cabbage from Harar) (Table 3). Variations in transfer factor among the different vegetables may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables (Cui et al. 2004; Zheng et al. 2007; Singh et al. 2010). Among all the vegetables, transfer factor of Cd was highest except for assayed vegetables from the four sampling sites, which showed that Cd is more mobile than the other metals. Consistent with this suggestion, Lokeshwari & Chandrappa (2006) reported that Cd was retained less strongly by the soil and hence it is more mobile than other metals.

Table 21. Transfer Factor of the metals

Metals	Vegetables	Sites			
		Harar	Aweday	Haramaya	HU
Chromium	Cabbage	0.25	-	-	0.41
	Potato	-	0.55	-	0.29
	Khat	-	0.36	0.31	0.35
Cobalt	Cabbage	0.32	-	0.36	0.41
	Potato	-	0.25	-	0.37
	Khat	-	0.43	-	0.02
Cadmium	Cabbage	1.39	-	1.46	0.96
	Potato	-	1.02	-	1.26
	Khat	-	0.8	0.48	1.26
Lead	Cabbage	0.45	-	0.21	0.25
	Potato	-	0.17	-	0.16
	Khat	-	0.14	0.22	0.23

Transfer factor of 0.1 indicates that the plant is excluding the element from its tissues. The greater the transfer coefficient value than 0.50, the greater will be the chances of vegetables for metal contamination by anthropogenic activities (Sajjad et al., 2009). Hence, most of the metals might be affected by anthropogenic activities based on the transfer factor calculated in the current study (Table 3). The transfer factor does not present the risk associated with the metals in any form. The degree of toxicity of heavy metals to human beings depends upon their daily intake (Anita et al., 2010).

Quality Assurance

Evaluation of the analytical method

In this study, the method validation was made by a spiking experiment in which known quantities of the metals standard solution were added to three replicate samples of the soil samples, the effluent water samples and the vegetable materials (cabbage, potato and khat). The same digestion procedures employed for the samples were applied to the spiked samples and the per cent recoveries were calculated. The percentage recovery values of the metals for soil, effluent, and vegetable samples were found to be within 91.0–98.3%, 92.0–102% and 89.0–101% ranges, respectively. These ranges are within the acceptable range (USEPA, 2007) which confirmed the validity of the method utilized in the current study. Percentage recovery values for individual analytes for soil, effluent, and vegetable samples are presented in Table 4.

Table 22: Percentage recovery values (Erroı, n =3) of vegetables, effluent water, and soil samples

Samples		Metals			
		Cr	Cd	Co	Pb
cabbage	CIS[a]	9.4	1.9	5.7	12
	AA[b]	5	1	1	5
	AR[c]	4. 8±0.23	0.96±0.04	1.1±0.11	4.9±0.08
	R[d](%)	95.6	96.0	106	98.2
potato	CIS[a]	14	1.5	8.7	7.8
	AA[b]	5	1	5	5
	AR[c]	5.1±0.06	0.89±0.05	4.9±0.21	4.8±0.12
	R[d](%)	101	89.0	97.2	96.6
khat	CIS[a]	9	3.2	8.9	11
	AA[b]	5	1	5	5
	AR[c]	4.7±0.1	0.9±0.07	4.7±0.06	4.9±0.02
	R[d](%)	94.6	94.0	94.2	99.4
effluent	CIS[a]	0.3	0.06	1.0	2.5
	AA[b]	0.5	0.5	1	1
	AR[c]	0.5±0.03	0.5±0.01	0.97±0.02	0.9±0.05
	R[d](%)	92.0	102	97.0	93.0
soil	CIS[a]	37.6	1.4	18	26
	AA[b]	10	1	5	10
	AR[c]	9.8±0.13	0.9±0.09	4.9±0.03	9.2±0.07
	R[d](%)	98.3	91.0	97.6	92.1

$\bar{x}$ = mean, SD = standard deviation, n = number of replicates, [a]concentration in sample, [b]concentration added, [c]concentration recovered, [d]recovery.

Comparison of metal content in the vegetables with other edible and medicinal plants

The levels of metal contents in the investigated vegetables (cabbage, potato and khat) were compared with other edible and medicinal plants reported in various parts of the world as summarized in Table 5. Based on the comparison, the results of the present study are agreement with most of the reported values.

Table 23: Comparison of metal concentration (mg/kg) in the vegetables with other edible and medicinal plants from the literature

Scientific name of the plant	Concentration (mg/kg) of metals in plants				Reference
	Cd	Pb	Cr	Co	
Artemisia vulgaris	UDL[a]	UDL[a]	4.65	-	Shad *et al.*, 2008
Galium aparine	UDL[a]	UDL[a]	5.89	-	
Mucuna pruriens	UDL[a]	UDL[a]	0.27	-	
Bryophyllum pinnatum	2.22	3.00	7.20	0.14	Lokhande *et al.*, 2010
Withania somnifera	5.40	UDL[a]	12.64	3.91	
Artemisia scoparia	0.95	3.20	10.25	0.40	Muhammad *et al.*, 2010
Artemisia incise	0.65	09.55	3.30	0.28	
Artemisia dubia	1.20	11.03	8.15	1.38	
Artemisia annua	0.98	3.95	6.225	0.78	
Artemisia japonica	0.35	1.75	7.38	0.75	
Senna siamea	UDL[a]	0.34	-	-	Alli Smith, 2009
Amaranthus dubius	0.21	0.07	-	0.32	Opaluwa *et al.*, 2012
Hibiscus sabdarifa	0.22	0.02	-	0.33	
Azadirachta indica	0.041	12.35	1.704	1.126	Mahwash *et al.*, 2011
Brassica rapa	0.495	21.36	3.219	0.866	
Murraya koenigii	0.263	24.02	UDL[a]	1.634	
Brassica oleracea	0.160	14.22	1.506	0.738	
Artemisia afra	-	UDL[a]	-	-	Mtunzi *et al.*, 2012
Berkheya setifera	-	UDL[a]	-	-	
Cucurbit maxima	0.92-1.16	UDL[a]-7.64	8.33-25.69	-	Amde *et al.*, 2013a
Embelia Abyssinia	0.91	6.16	18.69	-	
Hagenia Abyssinia	0.52-1.07	6.12 - 7.04	6.23 - 15.57	-	
Rosa abyssinica	0.77-1.23	UDL[a]-13.33	UDL[a] - 13.51	-	
Rhamnus prinoides leaf	<MDL[b]	<MDL[b]	<MDL[b]	<MDL[b]	Amde *et al.*, 2013b
Rhamnus prinoides stem	<MDL[b]	<MDL[b]	<MDL[b]	<MDL[b]	
Rhamnus prinoides fruit	<MDL[b]	<MDL[b]	<MDL[b]	<MDL[b]	
Cabbage	1.2-2.5	5.5-12	<MDL[b] -17	5.7-9.7	Present study
Potato	1.2-1.5	5.4-7.8	12-14	5.2-8.7	
Khat	0.4-3.2	4.5-11	9.0-15	<MDL[b]-8.9	

[a]under detection limit, [b]less than method detection limit

Statistical Analysis of Data

Analysis of variance (ANOVA)

Pair-wise statistical analyses of the results were made to verify whether there was a significant difference in metal contents in the effluent water, soil, and vegetable samples assayed with the sampling sites. For the present study, the significance of variation within sample and between samples has been studied using one-way ANOVA and calculations were made using Microsoft Excel (Amde et al., 2013a).

At 95% confidence level, for the effluent samples, no significant difference ($P > 0.05$) was observed for Cr (except for those from Harar/Haramaya and Haramaya/HU), Cd (except for the samples from Haramaya/ HU) and Co (except for the samples from Harar/Aweday and Aweday/HU). However, significant differences ($P < 0.05$) were observed for Pb between the samples from the various sampling areas.

For the case of soil samples, significant differences ($P < 0.05$) were observed for most of the investigated metals except Cd (for the samples from Harar/Aweday, Harar/Haramaya and Aweday/Haramaya), and Co and Pb (for those from Harar/Haramaya).

For the cabbage samples, significant differences ($P < 0.05$) were observed for Cr, Cd (except for the samples from Harar/HU) and Co (except for the samples from Harar/Haramaya) and Pb (except for those from Harar/HU). In the case of potato samples, significant differences ($P < 0.05$) were observed for Cr, Cd, Co and Pb for different sampling sites. Similarly, all metals had significant variations ($P < 0.05$) for khat with the sampling sites except for Cr which varied insignificantly ($P > 0.05$) (for the samples from Aweday/Haramaya).

The absence of significant differences in the concentrations of the heavy metals in the different vegetables may indicate the presence of similarities in certain factors or variables such as climatic conditions, soil type, age of the collected plant materials, etc. Similarly, the presence of significant differences in the concentrations of the heavy metals indicates variations in agricultural activities, for example, application of fertilizers, pesticides, irrigation, etc.

Correlation of metals in the samples

Correlation of Metals in the vegetables

The Pearson correlation matrices using correlation coefficient (r) for the vegetable sample materials, namely, cabbage, potato and khat are shown in Table 6. As presented in this Table, all metals in cabbage, potato, and khat samples have strong and positive correlations except Co with Cr and Cd with

Co which had weak and positive correlations and Pb with Co which had weak and negative correlations for the khat samples.

Table 24. Pearson Correlation matrix among the investigated metals in the vegetable samples

Vegetable		Correlation of Metals			
		Cr	Co	Cd	Pb
	Cr	1			
Cabbage	Co	0.76067283	1		
	Cd	0.88645431	0.93697133	1	
	Pb	0.85847075	0.863538	0.9814747	1
		Cr	Co	Cd	Pb
	Cr	1			
Potato	Co	0.89152705	1		
	Cd	0.9999876	0.88926005	1	
	Pb	0.93324203	0.99473829	0.9314413	1
		Cr	Co	Cd	Pb
	Cr	1			
Khat	Co	0.16111252	1		
	Cd	0.84090355	0.02874893	1	
	Pb	0.96403472	-0.0793893	0.899303	1

Strong and moderate positive correlations may arisefrom common anthropogenic or natural sources as well as from similarity in chemical properties. The negative correlations between the heavy metals may indicate that absorption of one may hinder that of the other in the vegetables. The weak negative or positive correlation may indicate that the presence or concentration of one metal may not affect that of the other or it affects the other to a lesser extent.

For the case of effluent samples, the correlation among the metals is shown in Table 7. As revealed from the correlation matrix, strong and positively significant correlations ($r > 0.5$) were observed between Cr and Co, Cr and Pb, and Co and Pb. Weak and positive correlations were observed between Cd and Pb, but weak and negative correlations were observed between Cr and Cd, and Co and Cd. The variation in association among the metals might be due to the points affirmed earlier.

Table 25. Pearson correlation matrix among the metals in the effluent sample

	Cr	Co	Cd	Pb
Cr	1			
Co	0.873159	1		
Cd	-0.06667	-0.020696219	1	
Pb	0.576088	0.839274063	0.450852	1

According to Table 8 for association among metals in soil samples of the sampling sites, all metals showed strong and positive correlations (r > 0.5) except Cd with Cr which had positive but weak associations.

Table 26. Pearson correlation matrix among the metals in the soil sample

	Cr	Co	Cd	Pb
Cr	1			
Co	0.704292	1		
Cd	0.380487	0.909346061	1	
Pb	0.579329	0.945402217	0.964013	1

Correlation among metals in the various samples

A correlation test was carried out among metals in the various samples (effluent, soil and vegetables) to evaluate the distribution of metals in the effluent and soil samples and to evaluate their availability and accumulation in the vegetables. Thus, Pearson product moment correlation coefficients were calculated and are presented in Table 9. Based on the results of R-value, the metal contents of the studied soils are found to correlate differently with the corresponding metal contents of the investigated vegetables (Table 9).

Table 27. Correlation of the investigated metals between the effluent, soil and vegetable samples

Vegetable	Correlated with	**Cr**	**Co**	**Cd**	**Pd**
cabbage		0.962615	-0.71902	0.565885	0.36123099
potato	soil	-0.10653	0.550243	0.626452	0.89505323
khat		0.031685	0.963811	0.901177	0.85362148
cabbage		0.856623	0.270504	0.732174	0.21513144
potato	effluent	0.206447	0.9959	0.412971	0.96476239
khat		-0.16309	0.220438	0.776592	0.72114038

The metal content of the effluent, soil, and vegetable samples were found to correlate strongly. The high association between the heavy metals, evidenced by high positive correlation coefficient, can arise from common anthropogenic or natural sources as well as from similarity in chemical properties. The correlation of the level of the metals in cabbage and soil samples were found to be strong and positive ($r>0.5$) for Cr and Cd, weak and positive for Pb and strong and negative for Co. All metals had positive correlations in cabbage and effluent (strong for Cr and Cd, and weak for Co and Pb). The associations of the metals in potato and soil samples were found to be strong and positive ($r>0.5$) for all metals except for Cr in which the association was weak and negative. For Cr and Cd, the associations were weak but positive, and for Co and Pb, the associations were positive and strong in potato and effluent samples. The correlations of the level of the metals in khat and soil samples were found to be strong and positive ($r>0.5$) for all metals except for Cr in which the association was weak and positive. In the case of khat and effluent samples, the correlations were strong and positive for Cd and Pb, weak and positive for Co and weak and negative for Cr.

The high correlation between metals in vegetables (cabbage, potato and khat samples) and metals in effluent and soil samples might verify that the main source of the plant nutrient is soil. The poor relationship between metals may be due to different size of the samples, environmental conditions, ability of the plants to uptake these metals, etc.

Conclusions

The concentrations of non-essential toxic metals *viz*., Cr, Cd, Co and Pb in edible vegetables (cabbage, potato and khat) cultivated through irrigation with wastewater were investigated. In addition, respective effluent and soil samples were analysed for their metal contents so that the uptake of metals by the vegetables and the correlation of metals in the vegetables, effluent, and soil samples were documented. Based on the results, Cr was found to have the highest concentration in the vegetables among the investigated toxic heavy metals. The range of metals in the vegetables were ranged in <MDL-17.13, 1.22-14.21 and <MDL-14.54 in cabbage, potato and khat, respectively.

The respective soil samples contained higher concentrations of all assayed metals than the corresponding plant materials except for the case of Cd in some samples (cabbage from Harar and Haramaya, potato from Aweday and khat from Haramaya University) in which higher Cd concentrations were detected in the plant samples than in the corresponding soil samples.

In general, the results revealed high concentrations of toxic heavy metals in the vegetable samples and most of the contents were found to be above the international safe limits set by different organizations. This indicates that consuming the vegetables produced in these areas poses health risks associated with the heavy metals. Therefore, the concerned bodies, local and regional agricultural officers should work on the development (usage) of waste water treatment technologies to remove the contaminants from the effluent waters discharged to the environment. In additions, the University should educate farmers against using sludge water for crop production.

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Investigation of Pesticide Residues in Marketed Khat (*Catha edulis* Forsk) Leaves Collected From Eastern and Southern Ethiopian Markets

By

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Funded by HrU Government Grant

Abstract: *Khat samples were collected from some selected markets in the Southern and Eastern parts of Ethiopia between August and September, 2012. The levels of pesticide residues of three selected pesticides viz., 2, 4-D, malathion, and DDT metabolites (o,p-DDE, o,p'-DDD, p,p'-DDD, o,p-DDT and p,p-DDT) were determined on all khat samples collected from the selected locations. The hexane extracts of the respective khat samples were prepared and analyzed by gas chromatography-mass spectrometry (GC-MS). Results of these analyses indicated that 2, 4-D and Malathion were below the quantifiable limit in all the analyzed khat samples. The khat samples from Hawassa, Wondogenet, and Dilla contain o,p-DDE (0.633 µg/kg), o,p'-DDD (0.506 µg/kg), p,p'-DDD (33.204 µg/kg), o,p-DDT (6.403 µg/kg), and p,p-DDT (41.375 µg/kg). However, the residue levels of all the DDT metabolites in the Aweday and Harar khat samples were below the quantifiable limits. The Dire Dawa and Haramaya khat samples, on the other hand, contained 0.633 µg/kg and 7.603 µg/kg of p,p-DDT, respectively. Residues of p,p-DDT were also detected in the Chiro and Hirna khat samples. Hawassa, Wondogenet, and Dilla khat samples were marked as the most contaminated with respect to the total DDT residue (82.121 µg/kg), which is an amount much greater than the maximum residue level (MRL) set by the European Union (EU). Accordingly, consumers of khat collected from Hawassa, Wondogenet, and Dilla areas might be exposed to acute toxicity of DDT.*

Keywords: *Ethiopia, Pesticide residue, Khat, Quantification limit, Maximum Residue Level*

Introduction

Pesticides are substances consisting large group of chemicals intended for preventing, destroying, attracting, repelling, or controlling any pest including unwanted species of plants or animals during production, storage, transport, distribution, and processing. The term includes substances proposed for use as a plant growth regulator, defoliant, desiccant, fruit thinning agent, or sprouting inhibitor and substances applied to crops either before or post harvest to protect the commodity from deterioration during storage and transport (FAO/WHO, 2001). The term normally excludes fertilizers and plant nutrients (WHO, 2007). Pesticide residue refers to pesticides, their poisonous metabolic and degradation products and impurities that may remain on or in the organism, agricultural product, and the environment, after they are applied (Bais and Chandewar, 2011).

Use of agrochemicals at various stages of cultivation and during post-harvest storage, plays an important role in food protection and quality preservation (Carla, *et al*., 2005). But, using them in agricultural and plant protection practices could cause extensive pollution of the environment and constitutes a potential risk for human health (Fernandez, *et al.*, 2001). Among the used pesticides, some are persistent, their residues accumulating in soils, water and plant products (Florica and Bloj, 2011). Sometimes pesticide residue is unavoidable and if the residue exceeds the maximum limit of a tolerance, it will pose significant risk to human and animal in the ecological system through food chain (Bais and Chandewar, 2011).

Recently, Ethiopia has been considered as having the largest accumulations of obsolete pesticides in Africa. It was estimated that there were 402 stores at 250 sites containing 1, 500 tones of obsolete pesticides. Pesticides of various kinds have been widely used on farms in Ethiopia for the last four decades. These pesticides are usually organophosphates, carbamates and to some extent organochlorides. While pesticides have increased agricultural production and improved public health, evidences in the last few decades have shown that they could also be detrimental to human health and the ecosystem. The real impacts of pesticides are not easily mapped in most circumstances. Acute effects are easier to observe, but they could also be confused with common illnesses. Pesticides may also cause chronic diseases such as cancer, reproductive disorders, birth defects, and immune system disorders. The impacts of pesticides in Ethiopia are likely to be aggravated by the limited knowledge among users on toxicological and chemical properties of these substances. Little is known about the long term and indirect effects of pesticides on rural and urban communities as well as on local and national food production systems (Tadesse and Asferachew, 2008).

Khat (*Catha edulis Forsk*) is an evergreen perennial shrub plant that belongs to the *Celastraceae* family. The plant is known with different vernacular names: Khat in English and in Arabic, *Jimaa* in Afaan Oromo and *chat* in Amharic. It is widely cultivated in Yemen and East Africa, where its fresh leaves are habitually chewed for their amphetamine like effects. This many centuries old habit is practiced by millions of people and has been introduced to the western countries by immigrants (Elmi *et al*., 1987; Abdulsalam *et al.*, 2002). Its cultivation extending from Southern Africa to the Arabian Peninsula more specifically in Yemen, Ethiopia, Kenya, Madagascar, Somalia, Tanzania and others as well (Elmi *et al*., 1987; Dechassa, 2001; Abdulsalam *et al*., 2002; Al-Motarreb *et al*., 2002).

The most favored part of the khat is its leaves, particularly the young shoots near the top of the plant. However, leaves and stems at the middle and lower sections are also consumed. Khat is chewed for its stimulating property due to the presence of the phenylalkylamines in the plant (Al-Motarreb *et al*., 2002). In Ethiopia, khat is grown in most parts of the country. It is the second biggest export after coffee (Eden, 2009). The total area of land under khat cultivation in Ethiopia in the year 1997/98 was estimated at 78,570 hectare (Central Statistics Authority, 1997/98). There is an ever growing demand both for domestic consumption and for the export market. Ethiopia is exporting khat to the neighboring and the Middle East countries and in recent years the market for khat has grown to Europe and America (Dechassa, 2001; Karlsson, 2006; Andrew *et al*., 2011). Now a day, chewing khat is a common practice among many individuals of all age levels of the country and its use is socially sanctioned and even prestigious (Belew *et al*., 2000).

Khat is subjected to a wide range of insect pests, diseases, weeds, and animals that damage its leaves, newly growing shoots, stems, and roots. At worst, the result could be a total destruction of the plant but mostly the damage is to the quality of the harvested material, which affects the economic gains from the crop. In most cases, traditional pest control practices like hand picking, spraying a solution of hyena faeces (against deer and antelopes), botanical or plant origin solutions such as an infusion of crushed garlic, tobacco, and soap are commonly used (Dechassa, 2001). Nevertheless, the occurrence and severity of pest damage has increased and now a day khat farmers are practicing use of pest control chemicals and fertilizers to protect the plant from pests and to increase the yield of their product in addition to traditional pest control mechanisms (Dechassa, 2001).

Extensive researches have been done qualitatively and quantitatively on many agricultural products and foodstuffs. However, there is still paucity of information on the extent of pesticide residues on khat samples where the plant is cultivated as well as their toxicological implication. This study is, therefore, initiated to investigate prevalence and extent of pesticide residues on some selected khat samples, as this was not analyzed properly till date by giving special emphasis on the toxicological implications in the major khat growing areas i.e., by correlating the pesticide residues identified in khat samples with the areas where pesticide applications for cultivating khat plant are more prevalent.

The study was conducted in two phases: Phase One of the study exclusively involved Sample Survey of the selected study areas with respect to their khat cultivation and pest management practices; the types, dosages and frequencies of pesticide applications commonly made in these areas for purpose of pest control; as well as health related complaints received from people because of consumption of pesticide contaminated khat leaves and the implied sources of the alleged contaminants etc. Whereas, Phase Two of the project was fully devoted to chemical investigation of samples of khat leaves collected from the study areas for the presence as well as extent of pesticide residue levels in the samples by using GC-MS technique.

Materials and Methods

Description of the Study Area

Survey and analytical samples were collected from some *woreda's* of East and West Hararghe Zones of the Oromia Regional State which includes Harar, Awaday, Haramaya, Dire Dawa, Hirna, and Chiro and some areas of South Nations Nationalities and People Regional Sate, which includes Wondo Genet, Hawasa, and Dilla. Though difficult to investigate more khat growing areas across the different ecosystems in Ethiopia, these areas were purposely selected for their extensive khat production and marketing, huge dependence of the people on the crop and their well-developed khat cultivation culture due to the development of basic infrastructure, mainly roads and the proximity to market centers which vital for marketing the commodity.

Survey study

Sample size

A total of 100 respondents were selected for each Eastern and Southern Ethiopia study sites. Additionally, a total of 100 respondents were interviewed from each study area to collect the opinion of the society.

Sampling procedure and data collectors

The respondents were selected by stratified sampling method for questionnaire and interview survey. Those farmers who can read and write properly were selected randomly. From agricultural bureaus, those employees working on farm management were selected. Concerned NGOs workers were also included as respondents. Among khat consumers, those who are educated were selected which includes teachers, instructors, students, brokers, drivers and traders.

Data collection tools

A semi-structured questionnaire and interview questions were developed by referring to literature and modifying sample questionnaires to meet the objectives of this study. The questionnaire was prepared in order to collect information with particular emphasis on khat production, consumption as well as the pest management practices and more specifically on the; types of pesticides used, application system and frequency of application of each pesticides. Furthermore, various participatory rural appraisal (PRA) techniques including field and market visits, pictures, transect walks, and observations were used during the study.

Analytical Investigation

Reagents and standards

Analytical grade reagents of the following types: 96% sulfuric acid (Merk, Stockholm), anhydrous sodium sulfate (99%) (Technopharmchem: Bahaduragarh, India), and n-hexane (Sigma Aldrich, Germany); and reference standards: l,1,1-trichloro-2,2-bis (*p*-chlorophenyl)ethane (*p,p'*-DDT) (99.6%); 1,1,1-trichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethane (*o, p'*-DDT) (99.6b%); l,l-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (*p,p'* DDE) (99%); Malation (99%); 2,4-D (99b%); and internal standard triphenyl phosphate (99.5%) all products of Sigma Aldrich, Germany, were used.

Apparatus and Instruments

Centrifuge (Gemmy industrial corp., Taiwan), rotary evaporator (Ika® Labortechnik, Germany), glass chromatograph column (40×3 cm^2) (Sinta Glass, England), gas chromatograph-mass spectrometer (GCMS-4000, Shimazdu, Japan), fitted with an Auto sampler (AOC-20i+s) automatic injector and fussed silica capillary column: DB-5MS (95 % dimethyl-5 % diphenyl polysilphenylene) 30 m x 0.25 mm ID with 0.25 μm film thickness (J and W scientific) were used in the analysis. GC-MS solution release 2.30 version software was used to process the result.

Sample preparation

The khat leaf samples were collected from Eastern Ethiopia (Aweday, Chiro, Dire Dawa, Haramaya, Harar, and Hirna markets) and from Southern Ethiopia (Hawassa, Wondo Genet and Dilla markets) based on the outcome of phase one study (sample survey). Samples were collected from each site in triplicate and composited and the composited samples of each site were mixed to get a total of 4 composite khat samples (3 from Eastern and 1 sample from Southern) for analysis as appended in Table 1. The sample preparation was conducted at Haramaya University, Chemistry research laboratory and the processed samples (extracted and treated samples) were analyzed for their pesticide residue content by GC-MS at Indian International testing center. The collected samples are coded and the coding system was presented in Table 1.

Table 28: **Sample coding system**

Sample code	Sample 1	Sample 2	Sample 3	Sample 4
Khat market	Harar Awaday	Dire Dawa Haramaya	Hawassa Wondo Genet Dilla	Chiro Hirna

Sample preparation and clean up of the extract

Pesticide extraction and clean up from the khat samples was performed following the procedure described by Huang *et al*. (2007) with slight modifications. The collected khat samples were dried under shade and powdered. 15 g portion of homogenized khat sample were weighed into a 250 mL Teflon centrifuge bottle and then homogenized with 30 mL hexane for 30s. 60 mL of dichloromethane-petroleum ether (50+50) were added and the mixture were homogenized for 1 min, after centrifuging at 4000 rpm for 5 min. The organic phase was decanted into a graduated flask, and the volume of extract was measured (about 85 mL). An aliquot of extract (10 mL) were concentrated to dryness in a rotary evaporator with a bath water at 35º C. The residues were dissolved in 2 mL of internal standard solution. Then, 10 µL of this solution was injected into the GC-MS analysis.

Spiking procedure

A representative 50 g portion of khat previously homogenized was weighted and transferred to a glass mortar, where it was fortified homogenously with 5 mL of the working standard solution. The mixture was then gently blended in the mortar for 1 h, to assess the homogeneity of the sample. The sample was then allowed to stand at room temperature for one hour, before it was kept at -18 ºC, until analysis.

Gas chromatography–mass spectrometry conditions

The chromatographic conditions were: helium gas was used as the carrier gas at a flow rate of 1 mL/min. A volume of 1 µL mixture of standard or sample extract was injected in a split less mode. The injection port temperature was 250 ºC and the oven temperature was initially held at 50 ºC for 2 min and then ramped to 60 ºC at a rate of 10 ºC/min, and finally at 10 ºC/min to 270 ºC (held for 10 min). The mass spectrometer was operated with an (EI) source in the selected ion monitoring (SIM) mode, and target TIC, 10000 counts and emission current, 20 uAmps. The electron energy was 70 eV and the ion source and the interface temperature was maintained at 230 ºC.

Results and Discussion

Survey study

Background data obtained from the respondents

All of the intended 200 (100%) respondents participated in the survey. The respondents were selected from Eastern and Southern Ethiopia study sites and the composition of the respondents were 25% agricultural officials, 5% NGO workers, 40% khat consumers (10% teachers, 10% students, and 20% khat brokers), and 30% khat traders.

Pesticide use by farmers

Regarding usage of chemical pesticide, the majority, 144 (72%) of the farmers said that they use chemicals (pesticides) at different stage during khat cultivation (regularly or occasionally) and 56 (28%) said that they don't use chemicals (pesticides) for khat production.

As identified from the outcome of this survey, the types of chemicals commonly used by farmers for cultivating khat are; 2, 4-D, DDT and Malathion. While conducting the interview, some farmer respondents also revealed that they are using chemicals which they did not know the name and type. The chemicals used by farmers and the percentage of the respondents using the respective pesticide are summarized in Table 2.

Table 2: List of pesticides used and their frequency of use by farmers in the study sites

No	Pesticides used by farmers	Frequency	Percent
1	Malathion	39	19.5
2	2,4-D	58	29.0
3	DDT	47	23.5

Purposes of pesticide application

The farmers who are using the chemical pesticides indicated that they use the pesticides for weed, insect pest, fungi/moulds/rust, and rodent control. Regarding the benefits of the pesticides they were using, the farmers indicated that the pesticides they used completely solved the pest problems and increased khat production in quality and quantity. The farmers also said that pesticides sprayed khat leaves do have good looking, so it attracts the khat consumers.

Analytical Investigation

Identification and quantification of pesticide residue by GC-MS

The selected pesticides analysed by GC–MS were: malathion, 2, 4-D and DDT metabolites (*o,p*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p*-DDT and p,p-DDT). These pesticides were targeted based on the outcome of survey work. Summary of the levels of pesticide residues found in the investigated khat samples is shown in Table 3 and their corresponding total ion chromatogram (TIC) are presented in Figures 1-5.

Table 3: **Levels (%) of the pesticides residues in the four khat samples**

RT[a] of pesticide in sample (min)	Pesticide tested	Pesticide residue level (µg/kg)			
		Sample 1	Sample 2	Sample 3	Sample 4
-	Malation	ND[b]	ND[b]	ND[b]	ND[b]
-	2,4-D	ND[b]	ND[b]	ND[b]	ND[b]
34.484	*o,p*-DDE	ND[b]	ND[b]	0.633	ND[b]
34.841	*o,p'*-DDD	ND[b]	ND[b]	0.506	ND[b]
36.357	*p,p'*-DDD	ND[b]	ND[b]	33.204	ND[b]
36.472	*o,p*-DDT	ND[b]	ND[b]	6.403	ND[b]

38.008	*p,p*-DDT	ND[b]	9.065	41.375	7.603
	Total DDT	ND[b]	9.065	82.121	7.603

[a]Retention Time; [b]Not Detected

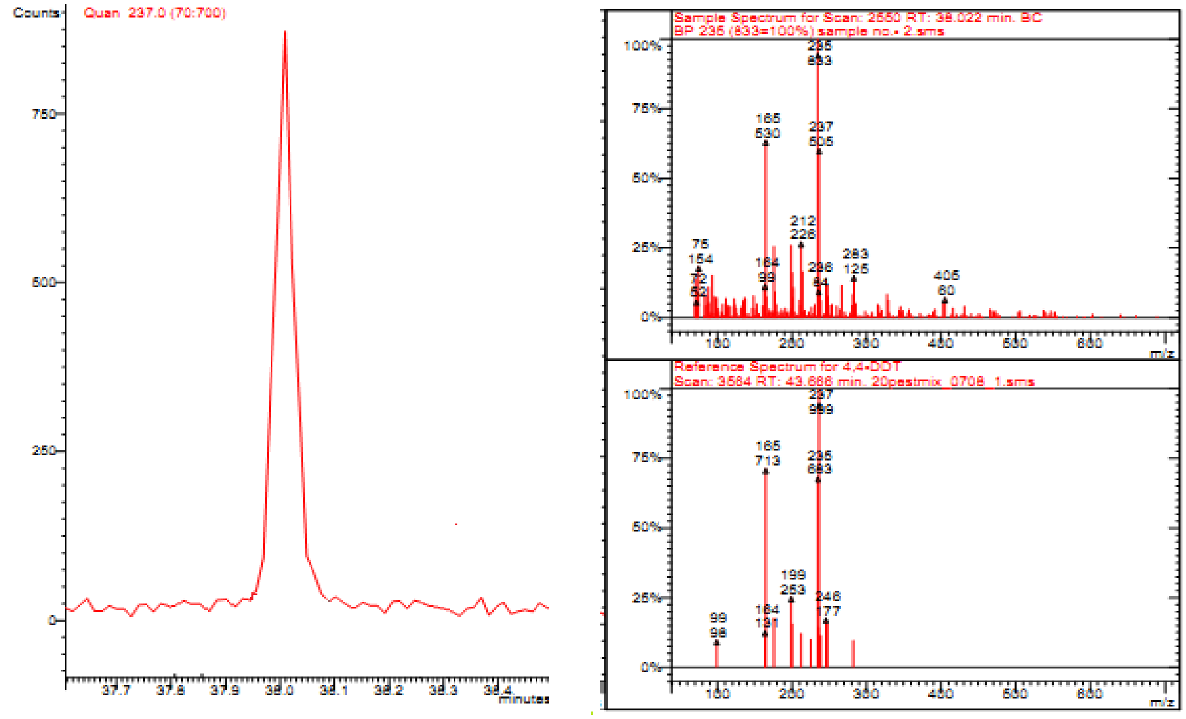

Figure 1. TIC and mass spectra of *p,p*-DDT in a khat sample 2

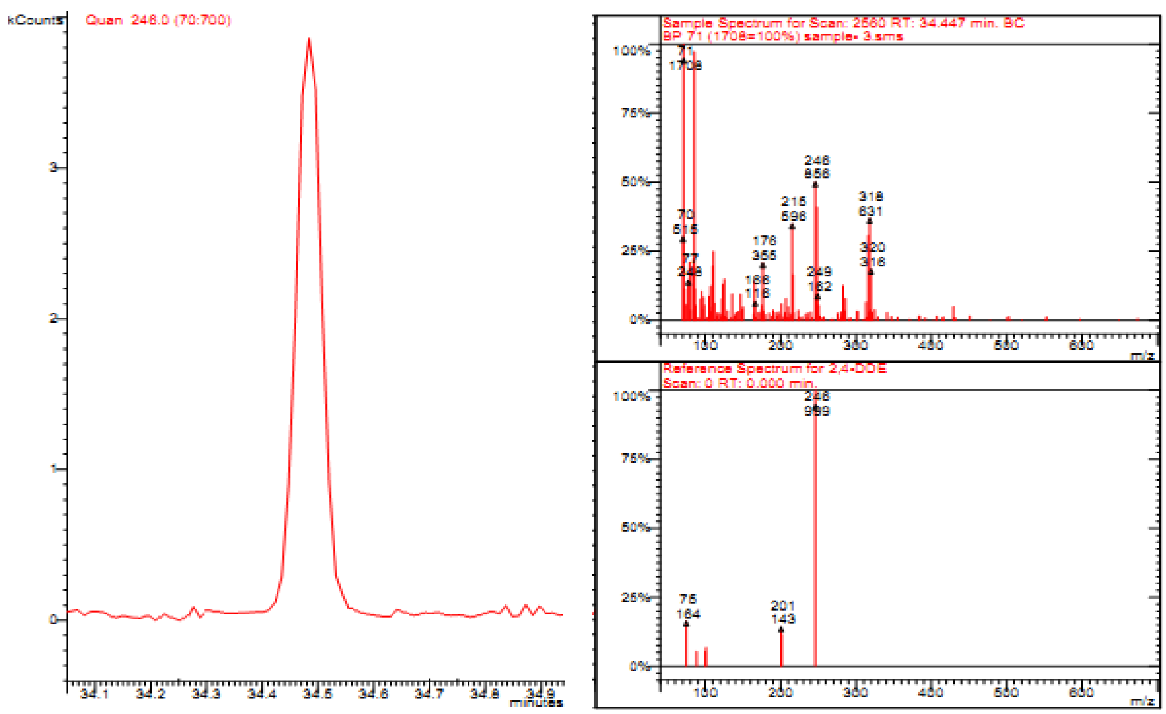

Figure 2. TIC and mass spectra of *o,p*-DDE in a khat sample 3

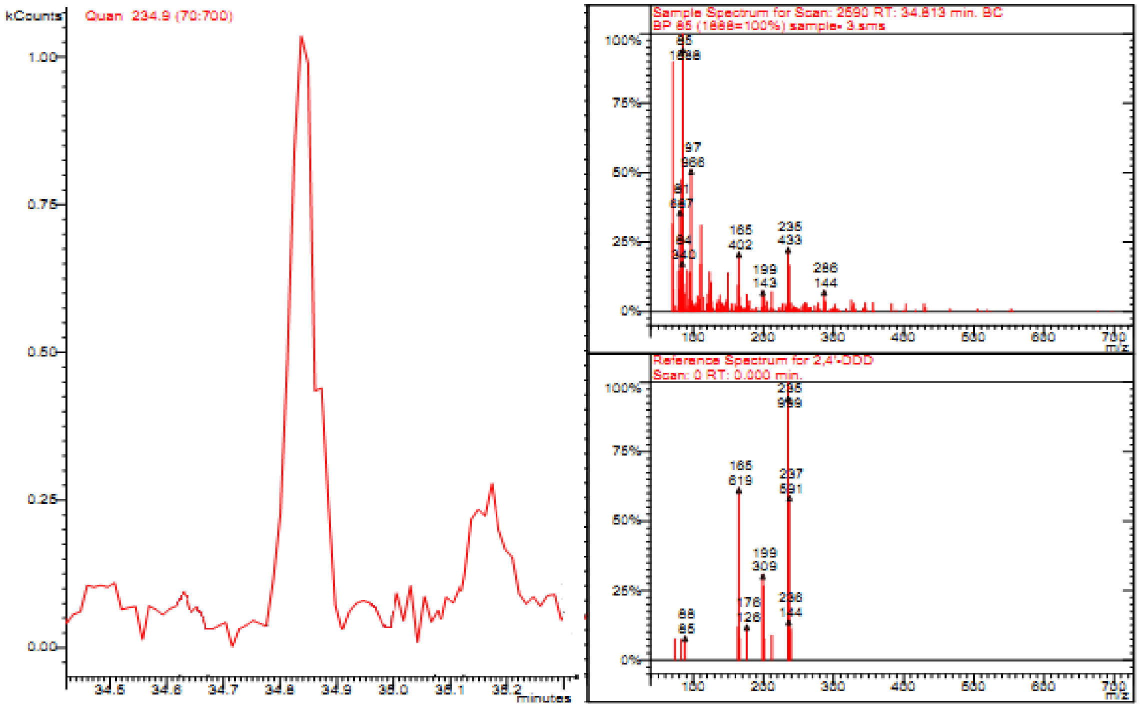

Figure 3. TIC and mass spectra of *o,p'*-DDD in a khat sample 3

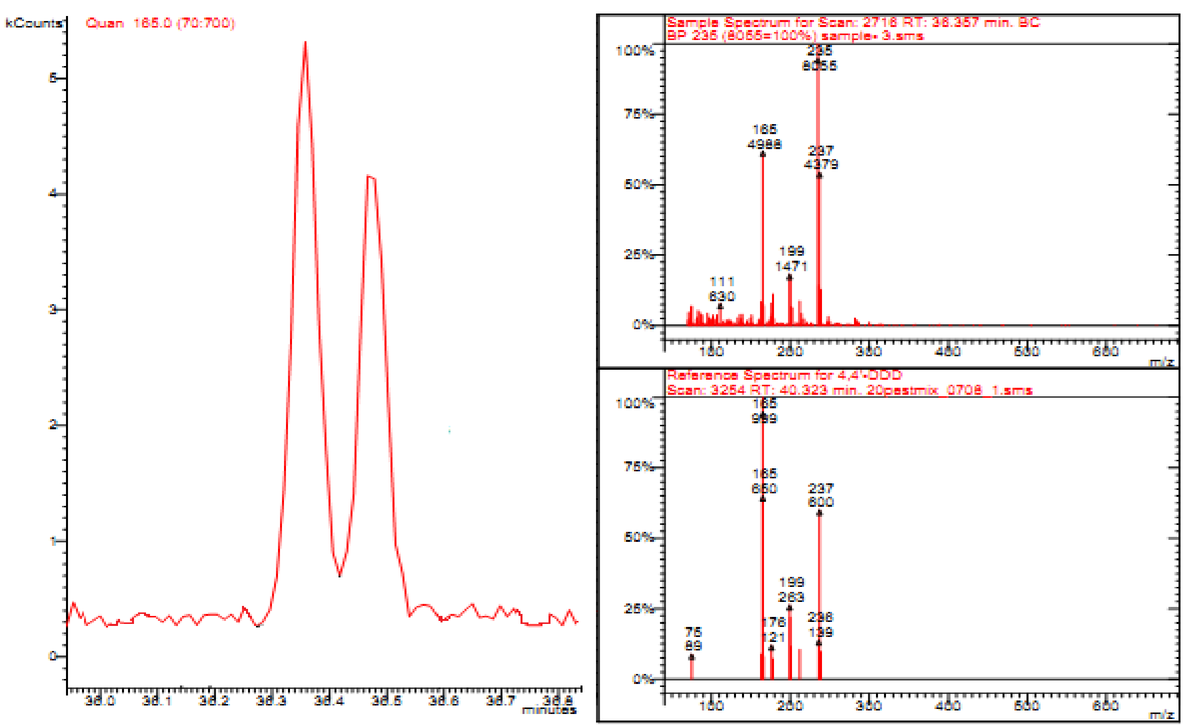

Figure 4. TIC and mass spectra of *p,p'*-DDD in a khat sample 3

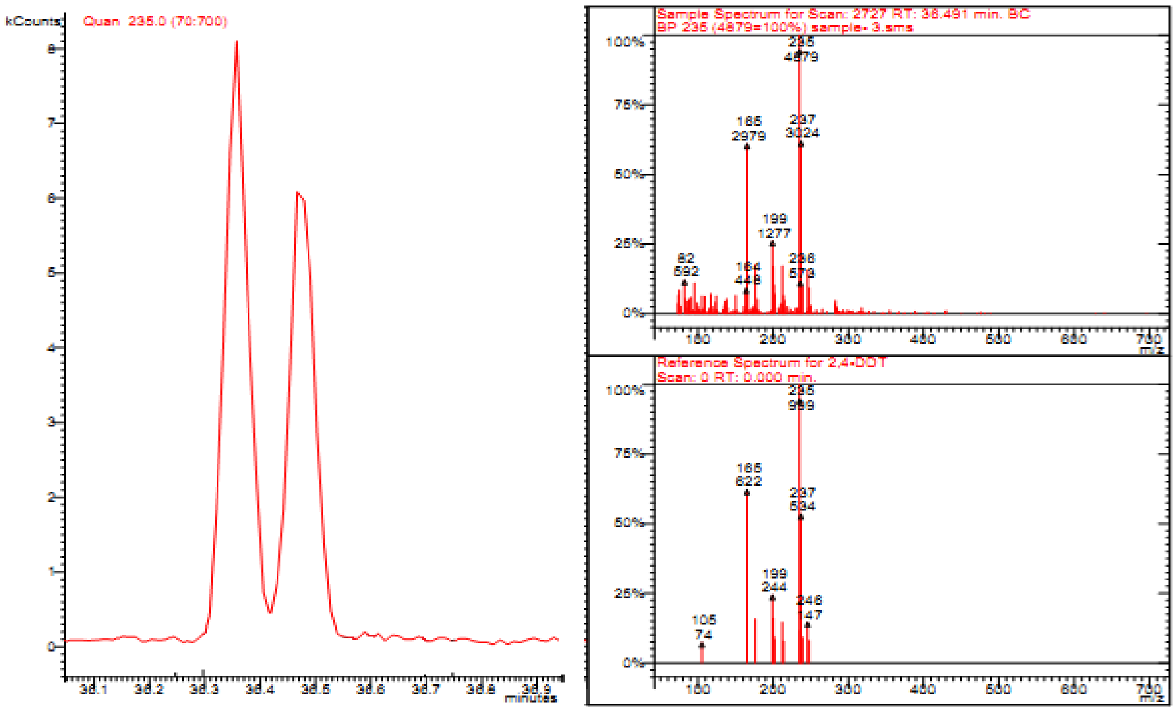

Figure 5. TIC and mass spectra of *o,p*-DDT in a khat sample 3

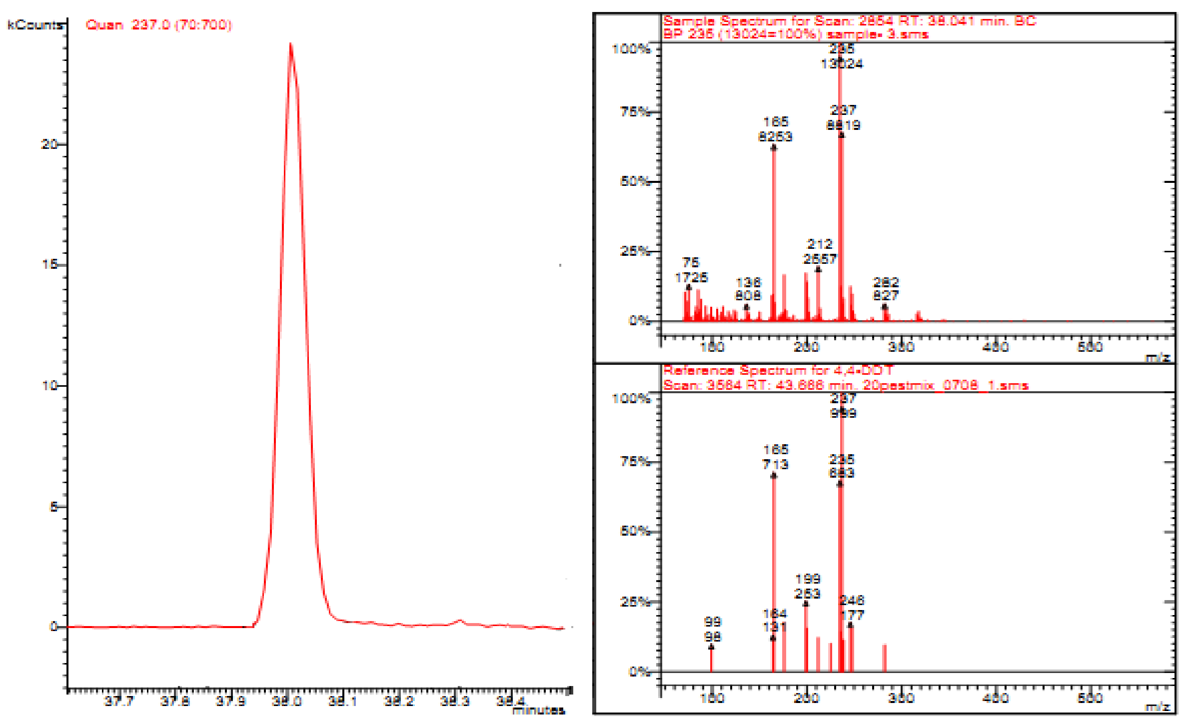

Figure 6. TIC and mass spectra of *p,p*-DDT in a khat sample 3

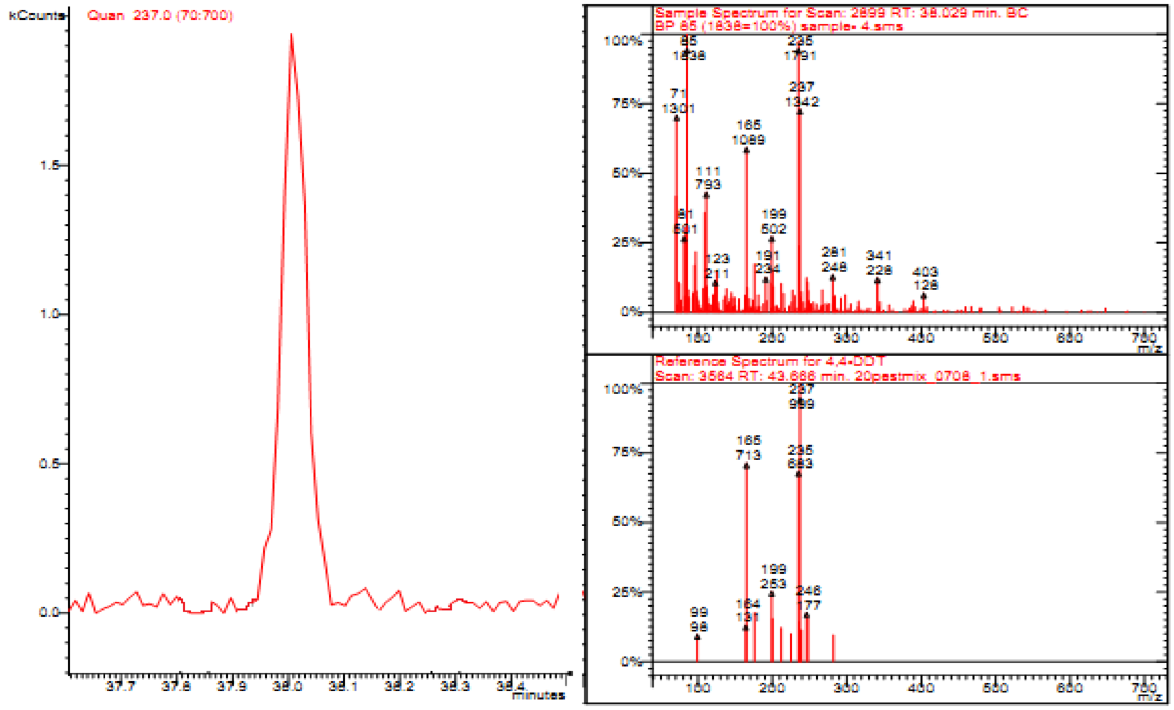

Figure 7. TIC and mass spectra of *p,p*-DDT in a khat sample 4

Malathion and 2, 4-D were not detected in all khat samples considered in the current study (Table 3). 2, 4-D is a herbicide containing three kinds of active ingredients: most common is the dimethylammonium salt of 2, 4-D-dichlorophenoxyacetic acid, but the ethylhexyl and other esters are also possible. The major use of 2, 4-D is as a general purpose of herbicide for weed control. Regarding their impact on human health, prolonged exposure to 2, 4-D causes liver, kidney, and nervous system disfunction (Tadesse and Abate, 2008). McCall *et al*., (1981) reported that 2, 4-D has short half-lives ranging from a few days to several months but detectable residues can persist for up to a year. 2, 4-D residues taken up by plants remain intact in the foliage until it is lost as litter and degraded in soils (Newton *et al.*, 1990). Plants absorb 2, 4-D through their roots and leaves within 4-6 rain free hours after application. If rain occurs, 2,4-D will dissolve in the rain water and runoff of plants and soil before sufficient amounts are absorbed by the plant (Munro *et al*., 1992). Malathion is an organophosphate insecticide used to control mosquitoes and a variety of insects that attack fruits, vegetables, landscaping plants, and shrubs. Malathion persistence in water, sand, soil, and plant matrices showed that Malathion degrades to malaoxon less quickly in soils with greater amounts of organic matter affecting pesticide fixation in soils (Neal *et al.*, 1993). The half-life of Malathion on foliage of various fruits, vegetables, alfalfa, and grass ranged from less than 1 to nearly 9 days (Bradman *et al*., 1994). In this study the residue level of 2, 4-D and Malathion was found to be below quantification limit which might be due to the reason that farmers apply these pesticides 4-5 hours before rain occurs which may dissolves them in the rain water and runoff of plants and soil before sufficient amounts are absorbed by the plant and due to their short half-life.

DDT and its metabolites were detected in khat samples collected from some areas of the sampling sites (Table 3). The average total DDT (*o,p*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p*-DDT and *p,p*-DDT) in Hawassa, Wondogenet and Dilla khat (Sample 3) were 0.633, 0.506, 33.204, 6.403 and 41.375 µg/kg, respectively. *p,p*-DDT was the only metabolite of DDT detected in khat samples from Dire Dawa and Haramaya (Sample 2) and Chiro and Hirna (Sample 4) with residue levels of 0.633 and 7.603 µg/kg, respectively. The residue levels in Aweday and Harar khat was below quantifiable limit. The total DDT residue level in Hawassa, Wondogenet, and Dilla khat sample (82.121 µg/kg) was much higher than the European union (EU) set maximum residue level (MRLs) for total DDT in edible foodstuffs such as cereals (50 µg/kg), citrus fruits, vegetables and sugar plants (10 µg/kg). Daniel *et al.* (2011) and his worker conducted similar study on Gelemso and Aseno khat and reported that the total DDT residue detected were about 240–1,200 times the EU MRL for foodstuff (Daniel *et al.*, 2011).

Dichlorodiphenyltrichloroethane (DDT) and other chlorinated hydrocarbons are persistent broad spectrum insecticides. Even though DDT use are banned in most countries, FAO state that the build-up of pesticides in developing countries like Ethiopia is partly due to excessive donations made with good intentions for malarial control. But, due to its easy accessibility to the farmers from the depots, it is illegally used on khat farms. Its residue persists in the environment for long periods, ranging from a few months to years. The half-life of DDT is estimated to be 7 to 30 years, depending on the environment. Environmental persistence of this group of chemicals is due to the fact that they are not readily degraded by the action of water, heat, sunlight, or microorganisms (Ming, 2005).

The acute toxicity of DDT ranges from highly toxic (many arthropods and some fish) to moderately toxic (many birds, amphibians) to slightly toxic (mammals). Chronic exposure which is critical problem regarding DDT is its persistence and its tendency to bioconcentrate and bioaccumulate, particularly in adipose (fatty) tissue. Exposure to DDT over long periods has potential risks of reproductive effects, mutagenicity, teratogenicity and carcinogenicity. Women exposed to DDT can accumulate residues in breast milk, so leading to exposure of sucking infants (Tadesse and Asferachew, 2008).

In the current study, the high level of the residue observed in the khat sample from Hawassa, Wondogenet, and Dilla indicate its excessive use in those areas. Given that the daily consumption of khat is estimated to be in the range of 100–300 g (Al-Habori, 2005), khat chewers in Hawassa, Wondogenet and Dilla areas are exposed to acute toxicity of DDT according to the MRL under EU-regulation set for vegetables and fruits which is 10 µg/kg.

Due to lipophilic nature of organochlorine compounds, foodstuffs having less water and greater lipid contents have greater potential to accumulate the organochlorine pesticides. Because khat has high water and low lipid contents, the obtained results indicate that very high levels of DDT have been used (Daniel *et al*., 2011). Due to its very low vapor pressure, extremely low solubility in water and high solubility in oils, DDT can be readily absorbed through the skin into the fatty tissues of living organisms and can bio-magnify as it passes through the food chain (Colin, 1971).

The high level of DDT in the khat samples instead of its metabolites DDE and DDD suggest that DDT is currently in use for control of pests in the study areas. As the result obtained showed, the accumulation was not due to historical use, if so the level of DDE and DDD would have been much higher than DDT as DDT gets metabolized to DDE and DDD over time. As depicted in Table 3, there is wide range of total DDT residue level (*ND* to 82.121 μg/kg) in the four samples which is attributed to the difference in the level of DDT usage by farmers within each region and suggests that there is lack of regulation or information on the use of these pesticides. This also shows that DDT is still in use as pesticides in Ethiopia.

Extensive researches have been done on Khat socio-economic, chemistry, impact of chewing, and other related issues so far. But, very little research has been conducted on pesticide residue level in khat and their negative health impact. Organochlorines have been shown to cause abnormalities in the reproduction and immune systems of birds and marine mammals. Several abnormalities caused by organophosphorous have been reported in many organisms (Bonilla *et al.,* 2008). According to the report of the International Agency for Research on Cancer (IARC) and American Environmental protection agency (EPA) pesticide residues of DDT, DDE, and DDD are possibly carcinogenic in humans (ATSDR, 1994). Colin (1971) reported that DDT, DDE, and a number of other chlorinated hydrocarbons affect the endocrine system (Colin, 1971).

Griffiths *et al.* (2010) reported that khat contamination with pesticide and the negative health impact is a problem in khat growing countries (Arabian Peninsula) and several European and Australasian countries. The current study showed as similar problem is facing in many farm practices in Ethiopia (Griffiths *et al.,* 2010). Therefore such adverse effects could be extended to khat users in these communities. In this study, the residue level of two isomers of DDT (*o,p*-DDT and *p,p*-DDT) were detected and residue level of *p,p*-isomer (*p,p*-DDT) was found to be higher than the *o,p*-isomer (*o,p*-DDT). As Caroline (1991) reported the *p,p*-isomer is more toxic to invertebrates than the *o,p*-isomer (Caroline, 1991).

Conclusion

The results from the present study underline that pesticide residues are present in khat samples collected from the various sampling regions of Ethiopia. *p,p'*-DDD and *p,p* -DDT in khat samples collected from southern Ethiopia was above the MRL set for vegetables by EU.

Generally, the level of pesticide residue observed in the khat sample from southern Ethiopia is of a high magnitude that calls for a special attention to regulate the use and circulation of such chemicals. Routine monitoring of pesticides residue in different food items is necessary for the prevention, control, and reduction of environmental pollution, as well as for legal decisions to minimize health risks. Therefore, there should be an integrated effort from governmental and non-governmental organizations on the awareness creation among farmers regarding misuse of DDT in agriculture, which has adverse health effect human and animal.

Acknowledgements

The authors are grateful to Research and Extension Office of Haramaya University for providing the financial support for the study and for facilitating transport for conduct of the surveys. We would also like to thank the Department of Chemistry and Laboratory Management Office of the University; Department of Chemistry of Indian Institute of Technology for facilitating analysis of the Khat samples that led to the finalization of this report.

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ASSESSMENT OF THE MICROBIOLOGICAL QUALITY OF GROUND WATER USED IN AND AROUND HARAMAYA UNIVERSITY

By

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Funded by HrU Government Grant

Abstract: *A cross-sectional survey was conducted to determine the quality of ground water used in and around Haramaya University. A total of 32 water samples were collected from eight sampling points (four wells, one reservoir and three distribution points). The parameters studied were enumeration of bacterial indicators such as fecal coliform bacteria, total coliform bacteria , fecal streptococci, hetrotrophic bacteria, selected pathogenic microorganisms including S. aureus, P.aeruginosa; yeasts, and moulds; detection of Salmonella/ Shigella spp.; Biological Oxygen demand and Chemical Oxygen demand of the water samples. Membrane filtration, spread plate method and Most Probable Number method were used for bacterial, yeast and mould counts as well as for the detection of selected pathogenic bacterias. Thermoreactor and BOD Trak method were used to determine COD and BOD, respectively. The data from wells were compared pair-wise. Similarly, the results of water samples from each of the three zones were compared with water samples from the reservoir. All data obtained for microbial counts, BOD and COD levels of water samples from the different wells, reservoir and distribution points of the campus were statistically analyzed using one way ANOVA. The results indicated that the mean values of FC, TC and FS for wells, reservoir and distribution points were 0.58 cfu/100ml, 1.5 cfu/100ml, 0.93cfu/100ml; 1.1 cfu/100ml, 0.7 cfu/100ml, 0.6cfu/100ml and 6.92 MPN/100ml, 4.7 MPN/100ml, 3.86MPN/100ml, respectively. Except for fecal coliforms in well$_4$, HPC (22^0C) in well$_{1,}$ COD in well$_2$, total coliforms at all zones, HPC(37^0C) at zone3, and BOD for the three zones, all the recorded values exceeded the recommended values set by WHO and or EU. Two wells (W_2 & W_3) showed significant differences from W_1 & W_4 ; and Reservoir and Z_1 also showed significant difference from Zone$_2$ and Zone $_3$ in most of the parameters at $p<0.05$. Generally, the findings of this study suggested the presence of a serious problem in the microbiological quality of the drinking water used in and around Haramaya University. Thus, treatment of the water before use is essential to make the water safe for drinking.*

Key words: Biofilm, BOD, COD, Microbial indicators, Water quality

Introduction

An adequate supply of safe drinking water is one of the major prerequisites for a healthy life. Groundwater constitutes 97% of global freshwater and is an important source of drinking-water in many regions of the world, up to 80% in Europe and Russia, and even more in North Africa and the Middle

East (Struckmeier *et al.*, 2005). It is the single most important supply for the production of drinking-water, particularly in areas with limited or polluted surface water sources. For many communities, it may be the only economically viable option (WHO, 2006).

This is in part because groundwater is typically more stable and of better microbial quality in its natural state than surface water. It is generally assumed that ground water is safe (free from pathogenic bacteria). It does not contain harmful constituentsand it is free from suspended matter because the rainwater which is the primary source of ground water has moved through soil and unsaturated zone before meeting the ground water. It gets cleaned and purified due to number of physical, chemical, and biological activities and processes such as oxidation and reduction, adsorption, precipitation, etc (Jain and Sharma, 2011).

Nevertheless, it is readily contaminated and outbreaks of disease from contaminated ground water sources are reported from countries at all levels of economic development (WHO, 2006). The belief that groundwater is safe is not true under all circumstances. The unscientific disposal of human and animal wastes is found to be the main anthropogenic activity that has led to the contamination of ground water with microorganisms, nitrates, potassium etc (Moeini *et al.*, 2008; Jain and Sharma, 2011). Pathogenic bacteria such as *Escherichia coli*, *Vibrio cholerae*, *Aeromonas hydrophila*, *Shigella dysenteria*, *Salmonella tyhimurium*, *Pseudomonas* spp. and *Klebsiella* spp. have been reported in groundwater sources (Momba and Notshe, 2003).

Threats to the quality of drinking water come from a variety of sources: bacteria, turbidity (caused by suspended matter in the water), overflowing storm sewers, defective storage tanks, pesticides, fertilizers, and other agricultural run-off, run-off from oil-slicked or salt-treated highways, and underground injection of waste (Devlin, 2012) and from introduction of chemical compounds into the water supply system through leaks and cross connection. Rainfall is also one of the factors affecting water quality as it can wash dissolved nutrients into the watershed and increase organic carbon level, and can also depress alkalinity levels and stimulate corrosion (Napacho *et al.*, 2010).

The most common and deadly pollutants in drinking waters of developing countries are of biological origin (OECD/WHO, 2003). The most communicable wide-spread health risk associated with drinking water is microbial contamination (WHO, 1993). Some pathogens contaminate the water at the source, but contamination may also occur during transportation, distribution, or handling of the water in households or other working places (WHO, 2004b).

Potable water released into the distribution system becomes altered during its passage through pipes, open reservoirs, standpipes and storage tanks. Water that is bacteriologically pure when it enters the distribution system may undergo deterioration before it reaches the consumers' taps (LeChevallier *et al.*, 2003). Contamination by micro-organisms can occur through air valves, hydrants, booster pumps, service reservoirs, cross-connections, and back syphonage or through unsatisfactory repairs to plumbing installations. Among the major genera found in distribution systems are *Acinetobacter*, *Aeromonas*, *Listeria*, *Flavobacterium*, *Mycobacterium*, *Pseudomonas* and *Plesiomonas* (LeChevallier *et al.*, 2003).

It is estimated that 1.1 billion of the world's population does not have access to clean drinking water (WHO/UNICEF, 2000; WHO, 2003). Approximately, three out of five persons in developing countries do not have access to safe drinking water (WHO, 2006). As a result, water-related diseases continue to be one of the major health problems globally (WHO, 2004). Diseases contracted through drinking water kill about 5 million children annually and make 1/6th of the world's population sick. An estimated 4 billion cases of diarrhea annually represented 5.7% of the global disease burden in the year 2000 (WHO, 2002).

In Ethiopia, over 60% of the communicable diseases are due to poor environmental health conditions arising from unsafe and inadequate drinking water supply (Abebe, 1986). About 80% of the rural and 20% of urban population have no access to safe drinking water (Mengesha *et al.*, 2004). Furthermore, increasing population density, and scarcity and pollution of surface and ground water pose a serious problem on drinking water supplies of the country (Reimann *et al.*, 2003).

Eventhough, groundwater is generally a preferred source for water supply compared to other sources, it, however, requires appropriate physical, chemical and biological treatment depending on the nature of existing pollutants before being supplied for domestic uses (Zinabu Tebeje, 2012). In an effort to sustain the water supply for Harar, Aweday and Haramaya towns, the Harari and Oromia National Regional States investigated and developed a large number of groundwater wells in the vicinity of Haramaya University. Currently, these wells supply domestic water for the three towns. In addition, Haramaya University and the surrounding community have been exploiting the ground water source in the area as well by developing ground water wells in the University compound.

However, the current exploitation of the ground water in the surrounding area is not being carried out scientifically. The quality of the water is unknown and the current groundwater balance of the area has not been deeply studied (Zinabu Tebeje, 2012). Besides, in the area, there is no regulation for the abstraction of water and predetermined prioritization between different water uses and water users. All these practices expose the ground water resources of the area to mismanagement and risk (Nata *et al*., 2010). Moreover, from the Environmental point of view, the University has been disposing its liquid waste close to lake-bed ever since it has been established. The liquid waste consists of not only organic wastes but also wash out of chemicals from laboratories. Even if the soil can filter most of these contaminants on their way to ground water, there is still a chance for some, if not all, of the contaminants to dissolve in water and reach the ground water (Moeini *et al.,* 2008).

This pollution issue, particularly of the microbiological quality of the water obtained from these wells has not been scientifically tested so far and it needs to be given due attention before it reaches a point of no return (i.e. a point where the ground water is contaminated to the extent of compromising the health of the community).

The contamination by sewage or human excrement presents the greatest danger to public health associated with drinking water; and as a result, bacteriological testing continues to provide the most sensitive means for the detection of such contaminants i.e. pathogenic microorganisms (Hrudey *et al*., 2003).

This study was, therefore, carried out to determine current levels of pollution indicator bacteria such as Fecal coliforms, Total coliforms, *Eenterococci* (Enterococcus fecalis) and Hetrotrophic plate count as well as some human pathogens(*Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Salmonella*/ *Shigella*, Yeasts, and Moulds). COD and BOD level of the water samples were also determined. Comparisons were first made among wells and also among reservoir and distribution points. The results were compared with the safe level of WHO and or EU standard.

Materials and Methods

Description of the Study Area: The study was conducted at Haramaya University which is located at 510 Km east of Addis Ababa. The site is located at an altitude of 1980 m above sea level with geographical coordinates of 9^{o}N and 4^{o}E latitude and longitude, respectively. The mean annual maximum and minimum temperatures are 23.4^{o}C and 8.25^{o}C, respectively (Mishra et *al*., 2004).

Table 29. Location coordinates of the sampled wells and reservoir

		GPS location		
Sampling sites	Name	Altitude (m)	Northing	Easting
W1	Lake bed	2016	09^{o}24' 60.5″	042^{o} 01 ' 64.4″
W2	Research station	2024	09^{o} 24' 88.6″	042^{o} 02' 17.4″
W3	Motor pool	2020	09^{o}25' 32.0″	042^{o} 01' 77.4″
W4	Well serving Harar	2023	09^{o}24' 04.0″	042^{o}01' 76.4″
R	Reservoir	2087	09^{o} 25' 60.3″	042^{o} 02' 22.6″

Study Design: A laboratory based cross-sectional survey was conducted at Haramaya University from June to August, 2012. [In this study, a total of eight sampling points were selected to collect water samples. Four water wells, one reservoir (R) and taps (distribution points) from three distribution zones.

Water Sample Collection and Preparation: Water sample collection was done according to the WHO drinking water guidelines (WHO, 2006), and American Public Health Association guideline (APHA, 1998). The water samples were collected once every week for a period of one month from each sampling point. A total of thirty two (32) water samples were collected from the eight sampling sources. Thousand mililiter of water samples from each sampling points were collected in bottles for different bacteriological, fungi and BOD and COD tests.

After sampling, bottles were kept in ice box and transported to the pathology laboratory, College of Agriculture, Haramaya University. The bacteriological tests were undertaken within 6 hours after collection to avoid the growth or death of microorganisms in the sample (WHO, 2006). For BOD and COD analysis, water samples were collected in 1000 ml glass bottles, labeled and transported to the microbiology laboratory of Harar Brewery Share Company, Harar, in an ice box.

Microbiological Analysis

Bacterial counts

For TC, FC, and *Pseudomonas auroginosa* counts, 100 ml of water samples were filtered using 47mm diameter, 0.45 µm pore size membrane filters (Gelman Sciences sterilized membrane) as specified in standard methods (APHA,1998). After filtration, the membrane filters were placed in pre-sterilized Petri dishes containing Lauryl Sulfate Broth (mLSB) medium (ELE International) and incubated at 37^{o}C and 44.5^{o}C for 24hrs and yellow colonies were counted as TC and FC, respectively. On the other hand, the membrane filters that were placed on *Pseudomonas* agar base (Don Whitley Scientific Eqp, PVT Ltd, India) were incubated at 42^{0}C for 24-48 hours (APHA, 1992) and blue to green colonies were counted as *Pseudomonas aeruginosa.*

For enumeration of streptococci, most probable number (MPN) technique was used (APHA, 1998; Collins *et al.*, 1989). Three tubes containing 10 ml double strength Azide Dextrose Broth (Don Whitley Scientific Eqp, PVT Ltd, India) was inoculated with 10 ml of water samples, while two other sets, each of 3 tubes containing 10 ml single strength broth were inoculated with 1ml and 0.1ml water samples, respectively. Well mixed tubes were incubated at 35±0.5°C for 24-48 hours. The tubes showing growth were considered positive for faecal streptococci. Turbidity was noted and interpreted from MPN table (Collins *et al*., 1989; UNEP/WHO, 1996). For further confirmation, Bile Esculine Azide Agar (Hi-Media) was streaked with 1ml turbid culture, and incubated at 35±0.5°C for 48 hours. Pink to dark black colonies were examined.

For counts of *S. aureus*, and Hetrotrophic plate count (HPC), 0.1ml aliquots of original sample were spread- plated in duplicates on pre dried surface of Manitol Salt Agar (MSA), (HIMEDIA) and Plate Count Agar (PCA), (HIMEDIA) respectively. Plates were incubated at 37^{o}C for 24-72 hrs and 37^{o}C for 24-48 hr, respectively. Colonies with golden yellow zones were counted as *Staphylococci*. For HPC, all plates with colony ranging from 30-300 were considered. Similarly, for *Salmonella* and *Shigella*, 0.1ml of water samples were spread plated in duplicates on pre-dried surface of *Salmonella-Shigella* Agar and Deoxycholate Citrate Lactose Sucrose Agar(DCLS) and incubated at 37^{0}C (Wahab *et al.*, 2012). Orange to red colonies were considered as *Salmonella/ Shigella.*

Yeast and mould counts

For yeast and moulds counts, water sample (100ml) was filtered with a sterile membrane filter of 0.45µm pore size (Kanzler *et al*., 2008). The membrane filter was then placed aseptically on Potato Dextrose Agar (PDA) (Hi-Media) and incubated at 22 ^{0}C for 48-72 hrs (APHA, 1992). Yeast grown as creamy to white colonies where as the other colonies on the plate were counted as moulds.

Determination of Biological Oxygen Demand and Chemical Oxygen Demand

Determination of biological oxygen demand was done by the BODTrak method Hach *et al*. (1997) using Thermostat cabinets (Model TS606/2-i, Germany) whereas the level of COD in the water samples was determined by Thermoreactor CR 22 00 (Photolab 56, Germany). The COD reactor was preheated at 150^{o}C. Two mililiter of the sample was taken and added to a vial which contains chemicals (potassium dichoromate, silver sulphate as catalyst and sulphric acid) and closed tightly. A blank was prepared with deionized water in another vial. The two vials were gently mixed and placed in the reactor for two hours. Then the vials were taken from the reactor and cooled. The vial with deionized water was inserted to a colorimeter and set to zero reading. Then the vial with the sample was placed in the colorimeter and the reading was taken in mg/L (APHA, 1999).

Data Analysis

Results of water analyses were compared against standards set by WHO and or EU and evaluated as acceptable or unacceptable. Analysis of variance (ANOVA) at 5% level of significance was used to compare the quality of water among all wells. Comparison among reservoir and the three distribution points were also made in a similar manner. Pair comparision test were made to compare each well with one another and also reservoir and distribution points with one another. The results were analyzed using statistical software SAS version 9.1.

RESULTS AND DISCUSSION

Analysis of Samples from Ground Water

Bacteriological analysis

The results of the microbiological analysis of water samples from wells are presented in Table 2. Of the four wells, fecal coliform bacteria were not detected in W_4. The others contained FC ranging from 0.1$\pm$0.17cfu/ 100ml (W_2) to 1.83$\pm$0.76 cfu/100ml (W_3). These wells were not free from FC and hence did not conform to the recommendation of WHO (0/100ml). On the other hand, TC and FS were detected in all the wells which represent 100% of the ground water samples. With regards to TC and FS counts, all the wells did not fulfill the requirement (0cfu/100ml) set by WHO. W_3 was significantly different from others with respect to FC count at $P<0.0027$. Similar results were recorded in the study of desta (2009) from Debrezeit, Mengestayew (2007) from Akaki kality subcity of Addis Ababa, Getnet(2008) from Bahir-Dar city and Atnaf (2006) from South Wello.

With regards to HPC, the present study revealed counts at 37^0C ranging from 130$\pm$45.8 cfu/ml in W_4 to 176.7$\pm$25.2 cfu/ml in W_1 (Table 2). The counts obtained from water samples of all wells (100%) were higher than the acceptable limit (10^2cfu/ml) of WHO (1996) guideline (Table 2). The difference between samples from wells were not significant at $p<0.3596$. Similarly, HPC analyzed at 22^0C showed the mean values ranging from 79±12.5 cfu/ml at W_1 to 206.7±63.3 at W_4 (Table 2). With respect to HPC (22^0C), the results indicated that W_4 is significantly different from W_1 and W_3 at $p<0.0472$. The higher count (206.7±63.3) in W_4 may be due to runoff from the environment as the well (W_4) is close to the main road to Harmaya town. Moreover, there was stagnant water in the well surrounding and this was serving for washing purposes for the public at the site. This might have infilterated down to the ground water.

Table 30: Mean FC, TC, FS, HPC, *S. aureus, P. aeuroginosa*, yeast, and moulds counts from wells (n=3 for each)

Parameters	**Units**	**Sample sources**				**Standard**	
		W1	W2	W3	W4	WHO	EU
FC	cfu/100ml	0.40 ± 0.36^b	0.10 ± 0.17^b	1.83 ± 0.76^a	0 ± 0^b	0	0
TC	cfu/100ml	1.2±2.02	0.5±0.86	2.4±1.10	0.3±0.58	0	0
FS	MPN/100ml	3.6±0.96	10.2±7.9	7.7±7.3	6.2±1.95	0	0
HPC(37^0C)	cfu/ml	176.7±25	170±30	151±25.5	130±45.8	100	20
HPC(22^0C)	cfu/ml	79 ± 12.5^b	145.7 ± 56^{ab}	115 ± 32.78^b	206.7 ± 63^a	100	20
S.aureus	cfu/ml	2.8 ± 1.26^b	8.3 ± 3.3^a	4.0 ± 2.3^b	0.7 ± 0.58^b	0	nil
Salmonella/Shigella	P/A	-	-	+	-	nil	NA
P. aeuroginosa	cfu/100ml	9.2 ± 2.7^b	2.5 ± 2.3^c	5.8 ± 4.1^{bc}	16.7 ± 3.1^a	1	0
Yeast	cfu/100ml	10.3 ± 4.5^b	45.7 ± 8.1^a	52.3 ± 6.6^a	10 ± 2.6^b	nil	NA

Mould	cfu/100ml	$2.5±1.32^{ab}$	$3.6±1.8^{a}$	$4.1±1.2^{a}$	$1.2±0.29^{b}$	nil	NA

Means with the same letter across the row are not significantly different.

Key: FC, Fecal Coliforms; TC, Total Coliforms; FS, Fecal streptococci; HPC, Heterotrophic Plate Count; W1=Well 1; W2=Well 2; W3=well 3; W4=well 4; WHO standards (1989, 1993, 1996, and 2004) and EU standards (1998), P/A= present or absent; NA, not available

Related study Oludare *et al*. (2012) indicated that the rise in the colony counts was due to surface runoff and seepage or discharge from septic tanks. According to Shittu *et al*. (2008), the higher HPC values were indication of the presence of organic and dissolved salts in the water. Their study attributed the high count of HPC to animal and human wastes. Comparable results were recorded by Prasai *et al*. (2007) from drinking water of Kathmadu Valley, Anyanwu and Okoli (2012) from Nsukka, southeast Nigeria, Abila *et al.* (2012) from Kenya.

In the present study, the presence of *Pseudomonas aeruginosa* with mean values ranging from 2.5±2.3 cfu/100ml at W_2 to 16.7±3.1 cfu/100ml at W_4 (Table.2) may suggest a possible threat from the consumption of untreated water from these wells. The entire samples from the wells showed presence of contamination and were beyond of the limit of WHO guideline value which should be 'nil' in drinking water samples (WHO, 1989) (Table 2). W_4 is significantly different from others at $p<0.0031$. [[[As *Pseudomonas* spp. shows more growth in biofilms, there may be the development of biofilms in this well. Moreover, surface runoff that might have infiltrated may have contributed to the presence as well as the relatively higher counts of *P. aeruginosa* in this well. Shallow ground water samples commonly contain *Pseudomonas* spp. which occurs in both soil and fecal material (Aydin, 2007).

The results of *Staphylococcus aureus* counts are shown in Table 2. The mean values of *S. aureus* counts ranged from 0.7±0.58 at W_4 to 8.3±3.3 at W_2. All the wells (100%) were not in the acceptable limit (0cfu/100ml) set by WHO guideline. The difference between W_2 and others were significant at $p<0.0134$. The higher level of *S.aureus* count at W_2 could be due to the ageing and corrosion of well casing in addition to a possible occurrence of infiltration of runoffs from the surrounding roads and agricultural lands. Well age is an important factor in predicting the likelihood of contamination. The result of the presence or absence test for *Salmonella/ Shigella* is shown in Table 2. Except $W_{3,}$ all the samples from other wells were free from *Salmonella/ Shigella*. Aydin (2007) obtained *Salmonella* in 15% of the ground water samples and associated the problems with contamination of water from different sources (septic tanks, waste water and livestock).

Analysis of Yeast and Mould Count

In this study, the counts of yeasts and moulds were recorded in the water samples ranging from 10±2.6 cfu/100ml (W_4) to 52.3±6.6 cfu/100ml (W3) for Yeasts and 1.2±0.29 cfu/100ml (W_4) to 4.1±1.2 cfu/100ml (W_3) for moulds (Table 2). All the samples (100%) contain yeast and mould whose counts were not conforming to the recommendations made by WHO (1993) (0 cfu/100ml in drinking water).

Well$_2$ and Well$_3$ are significantly different from W_1 and W_4 at p<0.0001. Higher counts of yeasts and moulds were obtained in W_3 and W_2 and their presence being primarily attributed to the ability of surface colonization as biofilms (Gottlich et *al*., 2002; Kelly et *al*., 2003). The similarity between W_1 and W_4 might be because of their proximity to one another.

The biological and chemical oxygen demand of ground water

BOD values of water samples collected from wells ranged from 6±1 mg/l in W_2 to 8.3±0.58 in W_3. From the four wells, only W_2 (6±1mg/l) and W_4 (6.3±0.58mg/l) are within the range of acceptable levels (5-6mg/l) provided by WHO (1993 & 2008). W_3 is significantly different from others at p<0.0340.

Table 31. Mean levels of BOD and COD from wells (n=3 for each)

Parameters	Units	Sample source				Standard	
		W1	W2	W3	W4	WHO	EU
BOD	mg/l	7±1^{ab}	6±1^{b}	8.3±0.58^{a}	6.3±0.58^{b}	5	NA
COD	mg/l	41.3±2.5^{c}	66.7±4.5^{b}	78±6.56^{a}	42.3±4.1^{c}	10	NA

Means with the same letter across row are not significantly different.

Key: BOD, Biological oxygen demand; COD, Chemical oxygen demand; W1=Well 1; W2=Well 2; W3=well 3; W4=well; WHO standards (1989, 1993, 1996, and 2004) and EU standards (1998).

The COD mean values also ranging from 41.3±2.52 mg/l in W_1 (lake-bed) to 78±6.56mg/l in W_3. These values for all the wells (100%) were higher than the acceptable values (<10mg/l) set by WHO guideline for drinking water (WHO, 1993 & 2008). In general, the results indicated the presence of high organic and inorganic pollutants in the water. With regards to COD, W_2 and W_3 showed significantly higher values than W_1, and W_4 at P<0.0001. The higher values attributed to oxidation of some metals and presence of runoff from upstream agricultural activities and horticulture and seepage from sewage drainage or industrial discharge in nearby localities (Almaz, 2011; Reza *et al.*, 2009).

Analysis of Water Samples from Reservoir and Distribution Points

Bacteriological analysis

As shown in Table 4, the mean FC counts ranging from 0.6 cfu/100ml at Z_2 to 1.5±2.59cfu/100ml at reservoir. Likewise, the mean TC counts ranging from 0cfu/100ml at Z_1 to 0.9±1 cfu/100ml at Z_2 while the mean level of FS ranging from 3±0 MPN/100ml at Z_3 to 5.3±3.2 MPN/100ml at Z_2 (Table 4). Except for Z_1 which is zero for TC count, all the sample sites contain bacteria unlike the zero level recommendations made by WHO (0cfu/100ml for FC and TC and 0MPN/100ml for FS). The difference between reservoir and distribution points and among distribution points were not significant at P<0.9075, P<0.5012 and P<0.4529 for FC, TC and FS, respectively. This showed that the bacteriological load of the water both in the reservoir and distribution points was almost similar with respect to those parameters.

Parameter	**Unit**	**Sample source**				**Standard**	
		R	Z1	Z2	Z3	WHO	EU
FC	cfu/100ml	1.5±2.59[a]	1.2±1.25[a]	0.6±0.67[a]	1±1[a]	0	0
TC	cfu/100ml	0.7±1.2[a]	0±0[a]	0.9±1[a]	0.9±0.51[a]	0	0
FS	MPN/100ml	4.7±2.1[a]	3.3±0.58[a]	5.3±3.2[a]	3±0[a]	0	0
HPC(37^{0}C)	cfu/ml	395±30.4[a]	164±113.7[b]	204.3±70[b]	86±22[b]	100	20
HPC(22^{0}C)	cfu/ml	146.7±35.1[b]	235.3±13.4[a]	136.7±20[b]	121.7±23[b]	100	20
S. aureus	cfu/ml	1±1.73[a]	1.8±3.17[a]	1.3±1.5[a]	1.2±0.29[a]	0	nil
Salmonella/Shigella	P/A	+	+	+	+	nil	NA
P. aeruginosa	cfu/100ml	4.7±3.5[a]	3.7±2.9[ab]	1.2±0.29[ab]	0.3±0.58[b]	1	0
Yeasts	cfu/100ml	77.7±38.4[a]	76.3±45.9[a]	53±7[a]	44.7±8.3[a]	nil	NA
Molds	cfu/100ml	1.2±1.3[b]	7.1±3.3[a]	2.8±0.68[b]	8.1±2.71[a]	nil	NA

Table 32. FC, TC, FS, HPC, *S. aureus*, *P. aeuroginosa*, Yeast and Mould counts of reservoir and distribution points (n=3 for each)

Means with the same letter across the row are not significantly different.

Key: FC, Fecal Coliforms; TC, Total Coliforms; FS, fecal streptococci; HPC, Heterotrophic Plate Count, R =reservoir, Z1=Zone1, Z2=Zone 2, Z3=Zone 3; WHO standards (1989, 1993, 1996, and 2004) and EU standards (1998).

The count of HPC at 37^{o}c ranged from 86±22.7cfu/ml at Z_3 to 395 ±30.4 cfu/ml at reservoir. Only HPC counts from Z_3 was in the WHO limit which is 1x10^{2}cfu/ml. The other exceeds the WHO guideline value. Z_1 was identical to Z_3 where as reservoir was significantly different from distribution zones at $p<0.0036$. Similarly, HPC counts at 22^{o}C showed a range from 121.7±23.6 at Z_3 to 235.3±13.4 cfu/ml at Z_1 (Table 4). Z_1 was significantly different R, Z_2 and Z_3 at $p<0.0019$. Reservoir and all distribution points were not in the limit of WHO guideline value. The high counts of TC and FC may attribute to contaminations such as intrusions of the soil through leaks/cracks or due to seepage of sewage water in to the supply lines (Hashim *et al*., 2011). Moreover, it may be due to inadequate chlorination and storage as well as lack of treatment or low frequency of reservoir (Razollini *et al*., 2011).

According to Chaidez *et al*.(2008), the natural ageing and corrosion of the pipe lines may comprise the water disinfectant residual creating conditions that favor the growth of biofilm forming bacteria. The walls of the pipes in the distribution system provide ideal surfaces for microbial colonization and the biofilms formed causing a number of problems for water companies (charmain *et al*., 2003)

The mean counts of *P. aerugionosa* ranged from 0.3± 0.58 cfu/100ml at Z_3 to 4.7±3.5 cfu/100ml at reservoir. At the entire sample sites, count of *P.aeruginosa* was beyond the acceptable level of WHO which is l cfu/100ml (WHO, 1989). The counts at reservoir and zone 1 was significantly different at p<0.1090. The mean level of *staphylococcus aureus* at reservoir and distribution points ranged from 1±1.73 cfu/ml at R to 1.8±3.17cfu/ml at Z_1. The difference between reservoir and distribution points and among distributions points was not significant at P<0.9576. The reservoir and all the distribution points were 100% contain *Staphylococcus aureus* and exceeds the WHO guidline value (WHO, 2004) which is 0/100ml. The presence/absence test showed that *Salmonella* and *Shigella* were present in the reservoir and all distribution points. All samples (100%) showed values exceeding the recommended value of WHO which is 0 cfu/100ml (WHO, 2004). Its ability to multiply at low substance concentrations enables *P. aerugionosa* to growth in surface water pipe lines (Chaidez *et al*., 2008) and contamination by *staphylococcus aureus* may be due to the intrusion of sewage water from the open drain sanitation system in to the drinking supply (Baig *et al*., 2012).

Analysis of yeast and mould counts from reservoir and tap water

Table 4 showed the mean level of yeasts and moulds ranging from 44.7± 8.32 cfu/ml at Z_3 to 77.7±38.4 at reservoir for yeasts and 1.2±1.3 cfu/100ml at R to 8.1±2.71 cfu/100ml at Z_3 for moulds. There were no significant difference at P<0.4843 between the reservoir and the distribution points and among the distribution points for yeast and there were significant differences between the reservoir and the distribution points at P<0.0146 for moulds. In all the sample sites, yeast and moulds were highly distributed and exceeded the WHO guideline value which is 'nil' for drinking water. Lack of sufficient concentrations of residual disinfectants throughout the system contributes in allowing the establishment of fungi entering the system (Grabinska-Loniewski *et al*., 2007).

The BOD and COD levels of water samples collected from a reservoir and distribution points

As shown in table 5, the mean level of BOD and COD range from 4±1 mg/l at Z_2 to 6.7±0.58 mg/l at reservoir for BOD and 27±4 mg/l at Z_1 to 52.7±4.1 mg/l at R for COD. There were significant differences between the reservoir and the distribution points and among the distribution points at P<0.0120 for BOD and P<0.0004 for COD, respectively. Z_1 and Z_3 were identical with respect to BOD values and R and Z_3 were identical with respect to COD values, respectively. Except BOD at reservoir, all BOD values from other sites were within the limit of WHO guide line where as for COD all the sites exceeded the guideline value of WHO which is <10mg/l.

Table 33. Mean levels of BOD and COD from reservoir and distribution points, 2012 (n=3 for each)

Parameters	Units	Sample source				Standard	
		R	Z1	Z2	Z3	WHO	EU
BOD	mg/l	6.7±0.58[a]	5.3±0.58[b]	4±1[c]	5.3±0.58[b]	5	NA
COD	mg/l	52.7±4.1[a]	27±4[c]	38±4.6[b]	52.3±6.1[a]	10	NA

Means with the same letter are not significantly different.

Key: BOD, Biological oxygen demand; COD, Chemical oxygen demand; R = reservoir, Z1= Zone1, Z2=Zone 2, Z3=Zone 3; WHO standards (1989, 1993, 1996, and 2004) and EU standards (1998).

Conclusion

In this study, water samples were collected from wells, taps of different zones, and reservoir and tested in the laboratory for different microbiological quality parameters. Comparisons of microbiological, BOD and COD water quality parameters were made first between the water samples of the wells and then between the zones and the reservoir. The results suggested the presence of serious problem in the microbiological quality especially due to the presence of microbial indicators that showed fecal contamination. Among the wells, W_2 and W_3 require immediate solutions.

Aknowledgment

The authors would like to thank the Office of the Vice President for Research Affairs for funding this project.

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Physical Characterization of Water used by HU and the Effects of Heating and Cooling on the Amount of Extracted Solids

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Abstract: *This study was conducted at Haramaya University to assess the levels of physical water quality parameters in water samples collected from four wells, the main water reservoir and taps delivering water to three zones of the campus. The physical water quality parameters examined were total solids, dissolved solids, suspended solids, turbidity, pH and electrical conductivity. Besides, heating and cooling temperatures at which most of the solids could be extracted were also tested. The results from the wells were compared pair-wise and likewise the results of each water sample from the three zones with the water sample from the main reservoir. One of the four wells (W_3) and two of the distribution zones (Z_1 and Z_2) had total solids in excess of 1000 mg L^{-1}. All the sampling sites showed dissolved solids in excess of 500 mg L^{-1}. Suspended solids at all the sites accounted for less than 25% of the total solids. One of the wells (W_3) showed significant difference (at $p<0.05$) from the rest in most of the physical parameters. Except this well, the rest were within WHO limits when it comes to total, dissolved, and suspended solids. Two distribution zones (Z_1 and Z_2) showed significant differences from the reservoir in most of the physical parameters. Both heating and cooling showed effects on the amount of solids extracted from the water. From the temperatures tested, heating the water above 80^oC and cooling it to less than 15^oC resulted in more solid extraction. Heating and cooling at temperatures close to these temperatures removed most of the cations that accounted for water hardness.*

Key words: *Total Solids, Dissolved Solids, Suspended Solids, Turbidity, Electrical Conductivity*

Introduction

Water needed for domestic use does not always occur in nature in sufficient quantity, due to the presence of dissolved or suspended impurities in most natural water bodies (Goldface, 1999). The major fresh water sources for human use are surface water bodies such as rivers and lakes, and underground aquifers (groundwater). Groundwater quality can be affected by various pollution sources. Hamilton and Helsel (1995) have indicated the connection between agricultural practice and groundwater pollution. Land application of waste or storm water may also have impact on groundwater.

Water quality is defined by physical, chemical, and biological characteristics (FAO, 1998). The quality of water varies due to variation both in the natural geological and hydro-geological conditions and human impact. Water-soil interaction plays an important role in controlling the quality of groundwater. Some of the minerals found in groundwater are due to dissolution of minerals and weathering reactions taking place close to the earth's surface (Andualem Eshetu, 2008). Well heads that are not well-protected can also let in some hazardous chemicals that are created either naturally or due to human activities (Hailemariam Hailu, 2010).

Physical testing of water for domestic use is necessary not only to assure its safety and palatability but also to determine treatment techniques (Avcievala, 1991). Water has a wide range of physical parameters with which its quality is gauged. Total solids in water are generally in the form of dissolved solids (DS), a portion that passes through a filter of 2 µm or smaller pore sizes (Sawyer et al., 2003) and suspended solids (SS), which is retained by the filter. DS includes inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulfates, and small amounts of organic matter that are dissolved in water (WHO, 2004). In domestic water, DS mostly originate from natural sources and vary considerably in different geological regions owing to differences in the solubility of minerals. The presence of high levels of DS in domestic water may be objectionable (WHO, 2004) and concentrations above 500 ppm may necessitate treatment (Sawyer et al., 2003) since it may have adverse effect on the taste of drinking water**.** Suspended solids in water systems reduce clarity and act as binding sites for toxic substances and lead to increased water temperature by absorption of sunlight (Manahan, 2000). Furthermore, it decreases the depth of water container while settling. Suspended particles regulate mineralization, oxygen consumption and concentration (Hakanson, 2005).

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through water sample. It is a measure of the cloudiness of water and is used to indicate water quality and filtration effectiveness. Turbidity is generally caused by total solids but primarily influenced by the amount of suspended solids in water (WHO, 2004). In natural water turbidity is caused by the presence of compounds such as clay, mud, organic matter, bacteria, and algae. In the form of suspended particles, turbidity is associated with colloids and settleable particles. Hence, turbidity is basically used to measure the presence of colloids since true solutions and coarse suspensions do not produce light scattering effect (Sawyer et al., 2003). The standard for turbidity measurement according to Viessman and Hammer (2005) is a suspension of silica of specified particle size selected so that a 1.0 mg L^{-1} suspension measures 1.0 NTU (Nephelometric Turbidity Unit).

Specific conductance (SC) is a measure of how well water can conduct electrical current (Lechevallier *et al.*, 1990). Conductivity increases with increasing amount and mobility of ions (Lehtola *et al.,* 2002). These ions come from the breakdown of compounds and conduct electricity because they are either negatively or positively charged when dissolved in water (Lee *et al.*, 2003). Therefore, SC is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution (Murphy, 2007). Changes in conductivity of water sample may signal the changes in mineral composition of water's seasonal variation in reservoirs and pollution of water from other sources (AWWA, 2000).

Heating and cooling is one of the methods of extracting among others calcium and bicarbonate, which are responsible for water hardness. Both, boiling and cooling, result in coagulation of solid particles (Sawyer *et al.,* 2003). Boiling modifies the degree of hydration of solid particles and enables the particles to overcome the energy barrier. Cooling on the other hand, forces colloids to come close together (i.e., diminishes the diffuse layer thickness) so that the particles can coalesce after which they settle to the bottom of a container.

Haramaya University gets its water from several wells situated at different locations on and off campus. The levels of solid particles of these wells have not been scientifically tested so far. The solid contaminants may be from the water from the wells, from the reservoir in which the water is stored or from the distribution pipes most of which are generally old and leaky. This study aimed at assessing the level of solid (dissolved and suspended) particles in water samples collected from four wells, the main water reservoir and taps delivering water to three zones of campus.

Accordingly, this study focused on three main objectives i.e., to compare the physical quality of water obtained from four wells that serve the university community; compare the physical quality of water obtained from the three distribution lines with that of the main reservoir and finally, determine the optimum heating and cooling temperatures for removal (extraction) of extractable solid particles from the water so as to reduce the concentration of total solids.

Materials and Methods

Description of the Area

The study was conducted at Haramaya University, which is located at 510 km east of Addis Ababa. The site is located at an altitude of 1980 m above mean sea level with latitude of 9^0N and longitude of 42^oE. The mean annual maximum and minimum temperatures are 23^0C and 8^0C, respectively.

Sampling Locations

In this study a total of eight sampling points were selected to collect water samples. These included four water wells, a water reservoir and three water distribution zones (Table 1). W_1, W_2, $W_{3,}$ and W_4 are the codes of the wells used in the same table. All the wells are located on or very close to the campus. In addition to the wells, the other four sampling points were: the main reservoir (R) in which water from three wells (W_1, W_2 and W_4) are collected and water samples collected from taps of three zones (i.e., the west-zone distribution line (Z_1) serving student cafeterias and student dormitories, the south–zone (Z_2) serving staff cafeteria and the surrounding areas, and the east-zone (Z_3) serving the PhD students' residences).

Table 1. Information regarding the water wells and distribution zones

Code	Location	Depth (m)	Average discharge rate (L s^{-1})	Altitude (m)	Latitude	Longitude
W_1	Lakebed	77	6	2016	09°24.605'N	042°01.644'E
W_2	Close to weather station	53	3	2024	09°24.886'N	042°01.174'E
W_3	Near motor pool	39	1	2020	09°25.370'N	042°01.774'E
W_4	Lakebed	*	*	2023	09°24.040'N	042°01.764'E
R	Main reservoir			2087	09°25.603'N	042°02.226'E
Z_1	Student cafeteria			2059	09°25.410'N	042°02.102'E
Z_2	Staff cafeteria			2047	09°25.352'N	042°02.258'E
Z_3	PhD residence			2064	09°25.523'N	042°02.377'E

**Even though the fourth well (W_4) does not belong to the university, water is obtained on daily basis for the university from this well.*

All sampling points were selected to test the physical parameters of the groundwater. Sampling was made from each of the four wells (i.e., W_1-W_4) so as to assess the contamination status of water at the particular well before it is transferred into the main reservoir. Water samples were obtained from each well. Likewise, samples of water were also collected from the three distribution zones (i.e., Z_1-Z_3) and compared with the sample from the main reservoir.

Sample Collection and Preparation

The water samples were collected once every week for a period of five weeks from each sampling point. A total of forty water samples were collected from the eight sampling points. Water samples from all the points were collected in two-liter plastic bottles for different water physical quality tests. Prior to sample collection, sampling bottles were washed with nitric acid and then rinsed with distilled water to avoid contamination. Sampling from the wells was done close to the sources. Reservoir sample collection was done by tying the sampling bottle using a clean rope and directly immersing the sampling bottle into the reservoir. For the distribution lines, water samples were taken directly from the water taps. The samples were then taken to the laboratory and were analyzed within a time limit of an hour of collection, except for the total, dissolved and suspended solids, which were analyzed within six hours of collection.

Sample Analysis

The collected water samples were analyzed for the important physical water quality parameters that include total solids, dissolved solids, suspended solids, turbidity, pH and electrical conductivity (standard physical water test parameters (WHO, 2004)). Total solids and dissolved solids were determined by evaporation method. Since the total solids contain both dissolved and suspended particles, filtration technique was applied to separate the suspended particles. Centrifugation and gravity settlement methods were employed to separate suspended solids but both of them did not yield measurable amounts of suspended particles. Hence, determination of suspended solids (SS) was done by filtering 50 ml of stirred water by pre weighed filter paper. The pre weighed filter paper was wetted in distilled water and 50 ml of the stirred sample was filtered. Then the filter paper was transferred to evaporating dish and dried in an oven until the liquid completely evaporated. The filter paper was then removed from the desiccators and allowed to cool after which it was weighted. Finally, the weight of suspended solid was calculated by subtracting the weight of the filter paper as shown in Eq. 2.1.

$$Suspended\ solids\ (mg\ L^{-1}) = \frac{(W_2 - W_1)\ x\ 1000\ (mg)}{Volume\ of\ sample\ used\ (ml)} \tag{2.1}$$

Where W_1 = weight of the filter paper (mg) and W_2 = weight of filter paper and dried residue (mg).

Determination of total solids (TS) was done using a 50 ml of stirred samples measured into a pre-weighed evaporating dish, which was then dried in an oven until the water completely evaporated. The dish was then transferred into desiccators and allowed to cool to room temperature and was weighed. The total solids was obtained using the relation

$$Total\ solids\ (mg\ L^{-1}) = \frac{(W_2 - W_1)\ x\ 1000\ (mg)}{Volume\ of\ sample\ used\ \ (ml)} \tag{2.2}$$

Where W_1 = initial weight of evaporating dish and W_2 = final weight (evaporating dish and residue).

For the determination of dissolved solids (DS) by gravimetric method, a portion of stirred water was filtered out and 50 ml of the filtrate measured into a pre-weighed evaporating dish. Following the procedure for the determination of total solids above, the dissolved solids' content of the water was calculated as

$$Dissolved\ solids\ (mg\ L^{-1}) = \frac{(W_2 - W_1)\ x\ 1000\ (mg)}{Volume\ of\ sample\ used\ \ (ml)} \qquad (2.3)$$

Where W_1 = initial weight of evaporating dish and W_2 = final weight (evaporating dish and residue).

Turbidity was determined using a standardized turbidimeter (ELE paqua lab model-T950513). Each sample was poured into the sample vial and the sample bottle was then inserted into the turbidimeter and readings were obtained. The pH of each water sample was determined on the spot using portable pH meter (Jenway, model-3310). The pH meter was calibrated just before analysis using calibration samples of pH 4.0, 7.0 and 10.0. It was rinsed with distilled water in-between successive measurements. Electrical conductivity measurement was done using a Jenway conductivity meter (model 4310).

Determination of optimum temperatures to which the water has to be heated and cooled to extract maximum amount of solid particles were determined by heating 250 ml of water to different temperatures in five degree centigrade intervals between 50^0C and 90^0C in pre weighed glasses. The maximum temperature was limited to 90^oC since heating water above this temperature results in evaporation loss. Preliminary tests were made to determine maximum and minimum cooling temperatures. Accordingly, the minimum temperature was set to 50^oC because using temperatures below this value did not result in sufficient solid extraction. Then the heated water was subdivided and transferred into five smaller containers and cooled to temperatures of 20, 18, 15, 13 and 10^0C. The minimum cooling temperature was selected based on the amount of extracted solids, which did not increase below this temperature. The cooled water samples were removed from the refrigerator and distilled into other containers and the settled solids in the glasses were heated again until all the water evaporated. Then the glass containers of the solid particles were cooled again to room temperature in the desiccators and the total weights of the glasses were measured. Finally, the extracted solids were calculated by subtracting the glass weight from the total weight of the glass and the dried residue. This process was repeated and the maximum average extracted solids were recorded.

Data Analyses and Interpretation

Data were recorded, organized, summarized and objectives one and two were achieved by statistical methods using completely randomized design (CRD) first by using one way ANOVA and thereafter by using pair comparison. For the third objective, results were compared using the amount of extracted solids.

Results and Discussion

Total Solids (TS) Differences between the Wells

The total solids of the wells ranged between 715.4 mg L^{-1} (W_2) and 1087 mg L^{-1} (W_3). There were significant differences among the wells (at α=0.05) as shown in Table 2. All the wells were different except the well from lakebed (W_1) and the well serving Harar town (W_4), both of which showed similar TS. Except for W_3, concentration of TS in all other wells remained below 1000 mg L^{-1}. This well has objectionable concentration for potable water according to Sawyer et al. (2003). However, water from this well is not added to the main reservoir and it is not used for human consumption. The highest TS in W_3 may be explained in terms of the amount of dissolved and suspended solids in this well. The fact that this well is the shallowest of all the wells must have contributed to higher TS, which must have passed to the soil after only partially filtered. This well is also one of the oldest and more solids must have passed into the aquifer overtime.

Table 2. Comparisons of water samples collected from the water wells

Site	Mean values					
	TS (mg L^{-1})	**DS (mg L^{-1})**	**SS (mg L^{-1})**	**Turbidity (NTU)**	**EC (µS cm^{-1})**	**pH**
W_1	848.2	670.2 (79)	178.0 (21)	1.11	942.2	7.06
W_2	715.4	573.6 (80)	141.8 (20)	1.11	749.2	7.29
W_3	1087.0	970.8 (89)	116.2 (11)	1.34	931.8	6.95
W_4	879.0	677.2 (77)	201.8 (23)	1.09	905.4	7.55
F-test (α= 0.05)	*	*	*	*	*	ns
CV (%)	17.4	23.8	23.8	10.2	10.2	3.7
Identical pairs	W_1 & W_4	W_1 & W_4	W_1 & W_4 W_2 & W_3	W_1 & W_4 W_1 & W_4 W_2 & W_4 -	W_1 & W_3 W_1 & W_4 W_3 & W_4	All

*TS = total solids; DS = dissolved solids; SS = suspended solids; EC = electrical conductivity; W_1 = well no.1; W_2 = well no.2; W_3 = well no.3; W_4 = well no.4; * = significant at $p < 0.05$. Numbers in brackets represent the percents of DS and SS in terms of TS. For the parameters considered, average values were not considered since the wells did not have equal contribution when it comes to water getting into the main reservoir.*

Dissolved Solids (DS) Differences between the Wells

The amount of dissolved solids is one measure of suitability of water for domestic use. In potable water most of the solids are in dissolved form (Sawyer *et al.*, 2003) and in this study, DS in all the well waters accounted for over three fourth of the TS (Table 2). Hardness increases with increase in DS and affects taste and lathering of water. DS for potable water generally falls within the range of 20-1000 mg L^{-1} but DS of less than 500 mg L^{-1} is more desirable for domestic use (Sawyer *et al.,* 2003). Based on this value, three of the four wells fall within this range and their DS may not be considered to be high for domestic use. To bring DS of all the wells to a more desirable level, water from all the wells may require some kind of treatment.

Analysis of one way ANOVA of DS indicated significant differences between the water samples of all the wells as in the case of the TS. Well at the weather station located at the eastern side of the campus (W_2) showed the lowest average dissolved solids (573.6 mg L^{-1}) and the well close to the motor pool at the northern part of the campus (W_3) showed the highest value (970.8 mg L^{-1}). Unlike location of other wells, this well was dug in an area, which has been under lake for a long time until the lake dried up. That makes the soil formation (close to surface) of the area predominantly of fine particles (silt and clay) and also rich in dissolvable minerals. Furthermore, the location of the well gets runoff from student residential areas and the motor pool, which means that there is high probability that the runoff contains more dissolved solids that percolate into the well. Pair comparisons showed significant differences between all the wells except W_1 and W_4. The two wells showed similar DS possibly because of their proximity (both located on the southern part of the campus).

Suspended Solids (SS) Differences between the Wells

Variability of SS among the wells ranged from 116.2 mg L^{-1} (W_3) to 201.8 mg L^{-1} (W_4) (Table 2). The reason why there is low SS in water sample of W_3 may be due to better filtration in the soil that takes care of most of the suspended solids, which is generally true in soils of smaller particle sizes (silt and clay). W_1 and W_4 showed pair-wise similarities in their amounts of SS because of their proximity (i.e., similarities of the soil types through which the water percolate). Compared to the level of DS in all the wells, the levels of SS were generally lower (less than one fourth fraction of the TS). Since SS carry larger fraction of pollutants in proportion to their sizes, reducing the fraction of these solids is very important not only for the clarity of the water but also to reduce the amount of contaminants (Butler and Davis, 2004).

Turbidity Differences between the Wells

The turbidity values were approximately the same for water samples of all the wells except for W_3, which showed slightly higher turbidity of 1.34 NTU (Table 2). But it is not of concern since the water from this well is not used for human consumption. As far as the standard limit of turbidity is concerned (which is less than 1 NTU for potable water (Sawyer et al., 2003)), turbidity values of the water samples from of all the wells were higher. The fact that the water from W_3 showed low SS but high turbidity may be due to the contribution of other sources such as DS to turbidity. Pair-comparisons using mean differences indicated significant differences in turbidity between W_1 and W_3 but no such differences were observed among W_1, W_2 and W_4.

pH Differences between the Wells

The benefit of measuring pH is for water softening and corrosion control (Sawyer et al., 2003). Water samples from all the wells showed pH between 6.95 (W_2) and 7.55 (W_4) as shown in table 2. The values obtained are within acceptable limit of 6 to 7 (WHO, 2004) for water of domestic use. The pH values less than 6 becomes acidic and the one greater than 7 becomes alkaline. Statistically, there is no significant difference between the mean pH values of the water samples of all the wells.

Electrical Conductivity Differences between the Wells

The average electrical conductivity for all of the well water samples were found to fall between 749.2 $\mu S\ cm^{-1}$ (W_2) and 942.2 $\mu S\ cm^{-1}$ (W_1) (Table 2). The low average conductivity in W_2 is related to the low DS in the same well. In fact, according to Sawyer et al (2003), DS is directly related to conductivity with a proportionality constant ranging between 0.55 and 0.9. Most dissolved inorganic substances in water are in ionized form and their conductivities increase with increase in temperature (Sawyer et al., 2003). In this study, conductivity versus DS computed for three data points (excluding data of W_3) gave a constant of proportionality of 0.75 and the error between the measured and calculated DS was less than 5%. Data of W_3 did not conform well to the other points during this computation perhaps due to anthropogenic influences on this well such as addition of organic and inorganic DS that are added to this well unlike the other three.

Total Solids of Water at Distribution Zones Compared to the Reservoir Water

TS of the three distribution zones compared with that of the reservoir ranged between 890 mg L^{-1} at R and 1144 mg L^{-1} at Z_2 (Table 3). Pair comparisons showed R and Z_3 to be similar at the low end and Z_1 and Z_2 similar at the high end. The high TS reading at Z_1 and Z_2 may be due the leaks and rusts of the water pipes since the pipes of these distribution zones are older than the line serving the PhD residence zone. The average number of solids in the reservoir is not exactly equal to the mean total solids of the wells since the water contribution of the wells to the reservoir is not the same for all the wells (weighted averaging would have been better but the discharge rates vary because of reasons such as down times of the pumps and fluctuation in the amount of water discharged from every well).

Table 3. Comparisons of water samples collected from the three distribution zones with the water from the reservoir

Site	Mean values					
	TS (mg L^{-1})	**DS (mg L^{-1})**	**SS (mg L^{-1})**	**Turbidity (NTU)**	**EC (μS cm^{-1})**	**pH**
Z_1	1125	1010 (90)	115 (10)	1.19	756.0	7.63
Z_2	1144	1011 (88)	133 (12)	1.16	749.6	7.64
Z_3	939	726 (77)	213 (23)	1.04	742.4	7.17
R	890	704 (79)	186 (21)	1.11	727.6	7.24
$\bar{W}$	882	723	159	1.16	882.2	7.21
F-test (α= 0.05)	*	*	*	*	*	ns
CV (%)	15.5	19.9	29.3	5.9	1.6	3.4
Identical pairs	Z_1 & Z_2	Z_1 & Z_2	Z_1 & Z_2	Z_1 & Z_2	Z_1 & Z_2	All
	Z_3 & R	Z3 & R	Z_3 & R	Z_1 & R	Z_3 & R	
				Z_2 & R	Z_1 & Z_3	
				Z_3 & R		

*TS = total solids; DS = dissolved solids; SS = suspended solids; EC = electrical conductivity;R = reservoir; Z_1 = distribution line of zone one; Z_2 = distribution line of zone two; Z_3 = distribution line of zone three; * = significant at $p < 0.05$; ns = not significant at $p < 0.05$. Numbers in brackets represent the percents of DS and SS in terms of TS. What got into the reservoir was the weighted average of the three wells (W_1, W_2 and W_4) and the reservoir parameters represent the true values than the average of all the wells.*

Dissolved Solids of Water at Distribution Zones Compared to the Reservoir Water

DS varied among the distribution zones and also with the reservoir (Table 3). The DS ranged from 704 mg L^{-1} at R to 1011 mg L^{-1} at Z_2. Zones Z_1 and Z_2 showed similarity at the high end and Z_3 and R at the low end as in the case of TS. The increase in DS in the two former zones might be due to increased amount of inorganic and organic loads in the water distribution pipes. Organic matter that can enter the pipes through joints and leakage points and dissolving metals due to the age of pipes might have contributed to the high value of DS at Z_1 and Z_2.

Suspended Solids of Water at Distribution Zones Compared to the Reservoir Water

SS of the zones and reservoir water samples were found to fall between 115 mg L^{-1} (at Z_1) and 213 mg L^{-1} (at Z_3). Table 3 indicates statistically significant differences among the three zones and the reservoir. Pair comparisons showed similarity between Z_1 and Z_2 at the low end and between Z_3 and R at the high end. The fact that Z_1 and Z_2 showed low suspended solids may be due to coagulation and settling of suspended particles or due to conversion of some of the SS into DS, but either way the mechanism is unclear. Compared to the level of DS of Z_3 and the reservoir, the proportion of SS at the other two zones was lower.

Turbidity of Water at Distribution Zones Compared to the Reservoir Water

The average turbidity ranged from 1.04 NTU (Z_3) to 1.19 NTU (Z_1). All turbidity values were above the allowable limit of 1 NTU. Pair comparisons depicted in Table 3 showed similarities between Z_1, Z_2 and R. Perhaps this may be due to the amount of the TS or the sensitivity of the turbidimeter. The high turbidity at Z_1 and Z_2 did not go well with the amount of SS. Overall, turbidity did not show clear differences between the reservoir and the different zones.

pH of Water at Distribution Zones Compared to the Reservoir Water

The pH levels of the three zones and the reservoir indicated that the mean pH at the zones and the reservoir did not show significant statistical differences at $p< 0.05$. However, pH values of the samples were higher than 7 showing slight alkalinity.

EC of Water at Distribution Zones Compared to the Reservoir Water

Conductivity among the three sampling zones and the reservoir showed R to have the lowest and Z_1 the highest values. Pair-comparisons showed similarities between Z_1, Z_2 and Z_3. Except Z_2, the other two zones showed significant differences from the electrical conductivity of the reservoir. Fluctuation in conductivity throughout sampling period was greater at the distribution zones. The high electrical conductivity of the water samples of Z_1 and Z_2 correlated well with the high DS.

Optimum Heating and Cooling Temperatures to Extract TS from Water

In figure 1, a plot of total solids extracted versus heating temperature is shown for different cooling temperatures. Generally, there is a positive correlation ($R^2 > 0.95$; Fig 1) between heating temperature and the amount of solids extracted after cooling the water. Heating breaks bonds between the ions and the water molecules thereby freeing the ions to coagulate. At higher temperatures, more energy is supplied to the compound and more ions have chances to liberate themselves from the bond.

The amount of solids precipitated increased as heating temperature increased from 50^{0}C to 90^{0}C but the increment was dependent on cooling temperature as well. The amount of solids extracted at 90^{0}C was close to the maximum amount extractable compared to the amount of dissolved solids in the reservoir (93%) but only 64% of the dissolved solids in Z_1 (zone from which the water was obtained for test, Table 3). Above 80^{o}C, more DS could be removed from the water provided that sufficient time was given for the precipitate to settle out or the water is cooled to the right temperature. Heating the water above 90^{o}C was not tried since higher temperature also increases the amount of water that evaporates.

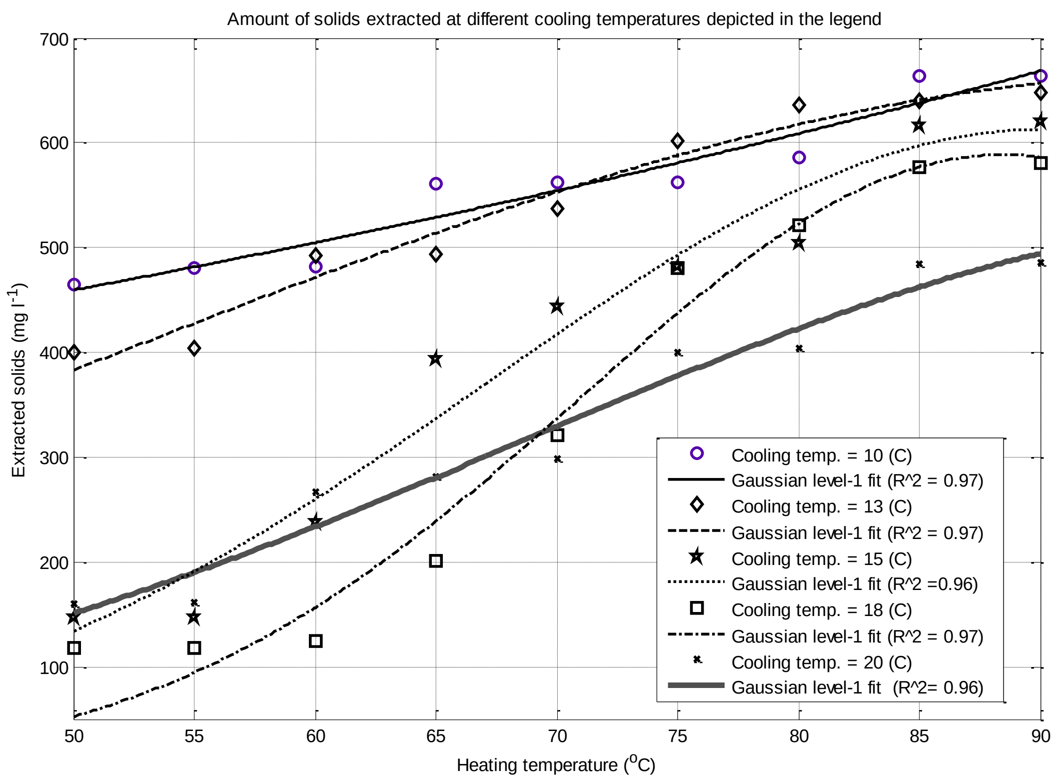

Figure 1. Total amount of solids precipitated as a function of heating temperature shown for different cooling temperatures. The (C) shown in the legend represent (^{o}C).

Both heating and cooling have influence on the amount of solids extracted. Heating temperature resulted in high solid extraction when the temperature exceeded 80^{o}C. Only 10 and 13^{o}C cooling temperatures resulted in higher dissolved solids extraction at lower heating temperatures ($T < 80^o$C). For heating temperatures above 80^{o}C, cooling temperature of 15^{o}C resulted in nearly the same amount of solid extraction as 10 and 13^{o}C.

The influence of cooling is more pronounced at low heating temperatures ($T < 80^oC$) where the slope shows fast increase especially for cooling temperatures of 15 and 18^oC (Fig.1). It means that at low heating temperatures cooling temperatures have more influence while, at high heating temperatures the differences between cooling temperatures are subdued as the cooling temperatures fell below 20^oC. From among the five cooling temperatures, cooling to 10^oC has resulted in maximum solid extraction followed by 13^oC, which also peaked at the same heating temperature.

The difference between the 10^oC and 13^oC at the same curve fitted heating temperature of 85^oC is less than 4%. Whether it is important to cool the water to 10^oC to extract the remaining less than 4% dissolved solids or to cool it to only 13^oC and tolerate the remaining extra 4% dissolved solids is the choice that has to be made by the user. When looked at from energy conservation view point, heating to 85^oC and cooling to 13^oC seems to be more beneficial than heating to the same temperature and cooling to 10^oC.

The amount of solids precipitated was about 660 mg L^{-1} for water cooled to 10^0C and this was the maximum value for the given heating temperature of 85^oC. The minimum average value of solids precipitated was nearly 480 mg L^{-1} when the water was cooled to 20^0C. When the water was cooled to 13^0C, the amount of solids precipitated was about 640 mg L^{-1}, which was almost the same (within margin of error) to the amount of precipitated solids when the water was cooled to 10^0C at the same heating temperature of 85^oC. As cooling temperature of the water decreased, the amount of solids precipitated increased. Similarly, as heating temperature increased, the effect of cooling temperature relatively diminished. Cooling temperature showed a more observable effect particularly for water that was heated to modest temperatures ($50\text{-}60^0C$). There was no difference between heating temperature of 85 and 90^0C at all cooling temperatures except cooling to 20^oC. In general, for 85 and 90^0C heating temperatures, cooling the water to 13^0C produced almost the same amount of precipitated solids as the water cooled to 10^0C. For the sake of energy saving, it is sufficient to heat the water to $80\text{-}85^0C$ and to cool it to around 13^0C to extract substantial amount of solids. Overall, heating has more impact than cooling when it comes to removal of total dissolved solids. Removal of dissolved particles reduces hardness of water, which improves its leatherability and its test. Heated water must be well aerated by pouring the water back and forth between two containers to incorporate adequate oxygen to bring the taste of the water to an acceptable level.

Conclusions

In this study water samples were collected from four wells of Haramaya University, three taps of different zones and a reservoir and tested in the laboratory for different physical water quality parameters. Comparisons of these parameters were made first between samples of water from the wells and then between samples of water from the zones and the reservoir. Heating and cooling temperatures suitable for extraction of maximum amount of solids were also tested and the following conclusions were drawn from the study.

Among the four wells, the well near the motor pool (W_3) showed the highest level of total solids and dissolved solids and turbidity. The level of suspended solids was the highest in the well serving Harar town. The well at the lakebed (W_1) and the wells serving Harar town (W_4 is combination of a couple of wells) showed similarity in most physical parameters. The well at the eastern part of the campus (W_2) showed the lowest total solids, dissolved solids, and electrical conductivity. The ratio of dissolved solids of all the wells exceeded the amount of suspended solids by a ratio of 3:1. As far as physical water parameters are concerned, all the wells fell within the range recommended by WHO (2004). Water samples of the staff and student cafeteria zones showed higher total and dissolved solids compared to the water sample of the reservoir. In order to extract most of the total solids, heating the water to a temperature close to 85^{o}C and cooling to about 13^{o}C resulted in optimum extraction of solids. When heating temperature increased the effect of cooling temperature relatively diminished. Cooling water to appropriate temperature after heating helps in removing most of the perceptible solids. To get precise temperatures of heating and cooling to extract maximum amount of dissolved solids, more tests have to be made with smaller temperature intervals.

Acknowledgements

The authors would like to thank HU research office for funding this project.

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Chemical Characterization of Groundwater and Water from Distribution Lines found in the Main Campus of Haramaya University

Gelana Amente, …………………

Abstract: *This study was conducted at Haramaya University to assess the levels of some of the chemical water quality parameters in water samples collected from four wells, one common water reservoir and from water taps delivering water to three different areas of the campus. The chemical quality of the water was tested for the content of four cations (calcium, magnesium, sodium and potassium) and four anions (chloride, fluoride, nitrate-N and sulfate). Besides, water alkalinity, hardness, and pH were determined. The results indicated high calcium and magnesium concentrations in all water samples analyzed and this agreed well with the result obtained for hardness, which corresponded to very hard water with concentrations in excess of 300 mg* L^{-1}*. The nitrate-N and fluoride concentrations in all samples remained within acceptable limits of 0-10 mg* L^{-1} *and 0.5–1.4 mg* L^{-1}*, respectively. The chloride concentrations were also below the objectionable level of 250 mg* L^{-1}*. Since sulfate concentrations of all the water samples were less than 250 mg* L^{-1}*, the values obtained for the anion are obviously far below the WHO guideline value of 400 mg* L^{-1} *set for sulfate ions in drinking water. Alkalinity values were higher than what is considered aesthetically acceptable level of 400 mg* L^{-1}*. All in all, except for alkalinity and hardness, the chemical quality parameters of the water samples could not pose any apparent threat. However, distribution lines of the two zones (*Z_1 *and* Z_2*) may require rechecking.*

Key words: *Chemical Water Quality, Groundwater, Total Hardness, Alkalinity, Ion balance*

Introduction

Water is one of the necessities of life, which is required to be free of pollutants but yet it is rarely found in a pure form. Even as water vapor condenses in air and falls in the form of precipitation it absorbs particulate matters in the air such as dust, pollens, bacteria, and also dissolves gasses like oxygen and carbondioxide (Chatterjee, 2005). Waters moving on the surface and in the ground come in contact with both organic and inorganic chemicals and with bacteria, all of which can adversely affect its purity (Chatterjee, 2005).

Contamination of water can take place due to various causes. Natural process is one major cause by which leaching of chemical deposits such as chlorides, sulfates, nitrates, iron, and other inorganic chemicals can take place (Charbeneau, 2000). Man-made causes include waste disposal practices and accidental spills and leaks from storage systems. Sometimes runoff can transport contaminants from land to bodies of water.

Groundwater contains a variety of chemical constituents at different concentrations. The greater part of the soluble constituents in groundwater comes from soluble minerals in soils and sedimentary rocks. A much smaller part has its origin in the atmosphere and surface water bodies. For most groundwater, 95% of the ions are represented by only few major ionic species, the positively charged cations; sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}), and the negatively charged anions; chloride (Cl^-), fluoride (F^-), nitrate (NO_3^-), sulfate (SO_4^{2-}) and bicarbonate (HCO_3^-). These ionic species when added together account for most of the salinity that is commonly referred to as total mineralization or total dissolved solids (TDS).

Generally, dissolved impurities in water, which mainly consist of carbonates and bicarbonates of divalent cations of calcium and magnesium, are responsible for the alkalinity and hardness of water. As a matter of fact, calcium and magnesium naturally exist in the earth's crust at average value of 3.6% and 2.1%, respectively (Spiro and Stigliani, 2003). Owing to its dominant abundance in the earth's crust, the amount of calcium carbonate in a given water sample may be more than that of magnesium carbonate even though the latter is quite soluble in it (Spiro and Stigliani, 2003). Hence, the abundance of these cations in soil contributes significantly to the formations of their carbonates and bicarbonates in groundwater mainly found under geologic formations rich in limestone (Hammer and Hammer, 2006). In effect, waters rich in these cations are classified as hard waters. Furthermore, hardness due to calcium, which presumably causes calcium deposits in boilers and in water pipes is referred to as temporary hardness (Garg, 2008). Because calcium carbonate being insoluble in water can easily be precipitated out by boiling thereby temporary hardness can be removed as such (Garg, 2008). On the other hand, hardness due to magnesium or the one due to soluble salts of calcium such as calcium sulfate, calcium nitrate or calcium chloride is considered to be permanent hardness (Garg, 2008).

Sodium may appear in water with bicarbonate and carbonate and thus, it can contribute to water alkalinity, but not to water hardness as in the cases of calcium and magnesium. Sodium with chloride affects taste of water and it has to be limited to within the range of 30 to 60 mg L^{-1} for taste threshold or even to less than 20 mg L^{-1} for individuals whose daily sodium intake is restricted to 500 mg (EPA, 2012). Potassium is an ion that may not pose great threat to drinking water and it is rather well known for softening hard water (Chatterjee, 2005). In places where there is neither limestone nor clay for mineralization, the water is generally soft (Spiro and Stigliani, 2003).

Anions such as nitrate, chloride, and fluoride can exist in water in dissolved forms and can influence the purity of water when found in excess of certain limits. Nitrate poses health threat especially to infants below the age of six months since it is capable of causing 'blue baby syndrome' or methemoglobinemia (Spiro and Stigliani, 2003; EPA, 2012). Nitrate oxidizes the ferrous ion in hemoglobin and converts it to ferric ion that is not capable of binding with the oxygen molecule and becomes a problem in babies. In grownups, reconversion of ferric ion to ferrous ion is possible faster than in babies and hence not of major concern (Spiro and Stigliani, 2003). Nitrate is a form of inorganic nitrogen that can get into water by runoff from areas where there is intense use of nitrogen fertilizer or leakage of septic tanks and sewages or by erosion from natural deposits (EPA, 2012). Unused nitrogen fertilizer can leach to groundwater over extended period of time depending on the hydraulic conductivity of the soil. Sometimes even faulty well heads may allow some of the surface water already rich in nitrate to get directly into groundwater unhindered. Surface water can also be polluted by this anion due to runoff carrying this ion from areas where it is found in abundant quantity (Hammer and Hammer, 2006). Nitrate ion has to be limited to within 0-10 mg L^{-1} if in the form of NO_3^--N for safe consumption by everyone, but it is restricted to concentrations between 11-20mg $L^{-1}$for pregnant women and for babies less than six months old (LWCNRI, undated). Chloride is another chemical that is present in water but can pose threat when found in excess amount. The chemical is present in mineral deposits from where it can leach to groundwater. Large amount of chloride is found in sewages since human excreta contains substantial amount of this anion (Chatterjee, 2005). Hence, unusually large quantity of chloride in groundwater may signal (though not conclusively), contamination of groundwater with sewage (Chatterjee, 2005). EPA (2012) puts this anion as a secondary threat when its concentration reaches 250 mg L^{-1}. Chemicals categorized as secondary threats under drinking water regulation are not under enforceable guidelines since the problems they cause is not of direct health threat but rather they have either cosmetic effects on teeth or skin or they may have aesthetic effect such as odor, taste or color (EPA, 2012). Fluoride is another chemical, which has adverse effect in drinking water when both in deficient and in excess amounts. Public waters generally contain from 0.8 to 1.2 mg L^{-1} (Hammer and Hammer, 2006). Fluoride ion in excess of 1.5 mg L^{-1} is responsible to cause mottling (dental fluorosis) whereas, when it is below 0.5 mg L^{-1} it causes dental carries (Sawyer et al., 2003). Under extreme case, i.e., when in excess of 4 mg L^{-1} it can cause skeletal fluorosis (Sawyer et al., 2003). Therefore, it is very important to know the level of this ion, which has to be maintained to around 1.0 mg L^{-1} for optimal dental health. Sulfate is present in all surface water as it arises from rocks and sea-water, which contains a high sulfate concentration. On the one hand it has a role as a plant nutrient, but at high concentration it can be problematic since it is corrosive to building materials (e.g., concrete) and is capable of being reduced to hydrogen sulfide (a toxic, foul smelling gas) when zero oxygen conditions prevail in the water body. Normally, sulfate concentrations in surface water are between 2 and 80 mg L^{-1} although they may exceed 1000 mg L^{-1} if industrial discharges or sulfate-rich minerals are present. The WHO guideline value for sulfate in drinking water is 400 mg L^{-1}.

Alkalinity of water indirectly indicates the amount of hydroxides, carbonates and bicarbonates since these three anions are the major causes of alkalinity (Sawyer et al., 2003). Most water is alkaline due salts that can add alkalinity to water in the ground (Chatterjee, 2005). Alkalinity of groundwater is generally higher than that of surface water because of soil and rock formations through which water moves as it percolates into groundwater. In addition to the inorganic salts, alkalinity may be due to humic acids that are resistant to biological oxidation since they can form salts that can add to alkalinity. Alkalinity of surface water may be high in waters that contain algae, which is capable of removing carbondioxide (a gas which increases acidity to water) and as a result causes water pH increases (Sawyer et al., 2003). Alkalinity in excess of 400 mg L^{-1} may cause the water to have 'soda' taste (LWCNRI, undated).

Knowledge of hardness of water is important first to estimate the levels of hardness causing cations predominantly calcium and magnesium, which is indicative of the rock or soil formations through which water moves to aquifers. The other reason is to know the amount of detergent consumption for cleaning. In hard water, the doubly charged calcium and magnesium ions interact with detergents especially on the side of their polar head groups and make detergent molecules aggregate to micelles with hydrocarbon tails pointing to the interior rather than reacting with the dirt (Spiro and Stigliani, 2003). This makes the micelles unavailable for solublizing dirt but rather precipitate themselves and form scums instead (Spiro and Stigliani, 2003). Generally, hardness has little health effect but due to aesthetic and economic reasons (cost of appropriate detergent), water hardness in excess of 120 mg L^{-1} is enough to necessitate softening (LWCNRI, undated).

Chemical tests are important not only for health reasons but also for economic reasons such as financial losses due to corroded and damaged pipes or cost of cleaning stained materials or even cost spent on special or additional detergents in the case of hard water. The list of chemical contaminants of water is very extensive and requires various techniques and equipment not to mention the skill, time, and cost required. Besides, not all places require testing of all of the chemical water pollutants. In this study, attention was given more to the inorganic pollutants rather than to those of organic origins and the study focused on eleven parameters viz., four cat ions (calcium, magnesium, sodium, and potassium), four anions (chloride, fluoride, sulfate, and nitrate), and water hardness, alkalinity, and pH.

There were two main objectives for this study. The first was to compare the eleven chemical parameters of water of four water wells from which the university community gets water supply and to identify if any of the wells is under threat in any of the parameters. The second objective was to compare water sample from the three wells that serve as the source of water for the main campus water reservoir, and the water of this reservoir before it is distributed to the public as well as with water samples from three distribution zones. The pipes of the three distribution zones have different ages and the purpose of this study was to assess the levels of contaminations of the pipelines compared to the water of the reservoir.

Materials and Methods

Description of the Area and Sampling Locations

The study was conducted at Haramaya University, which is located at 510 km east of Addis Ababa. The site is located at an altitude of 1980 m above sea level with geographical coordinate of 9°N latitude and 4°E longitude. The mean annual maximum and minimum temperatures are 23°C and 8°C, respectively.

In this study a total of eight sampling points were selected to collect water samples. These included four water wells, a water reservoir, and three water distribution zones. The four wells were: a well at the main lake-bed (W_1), a well at the weather station (W_2), a well near the motor-pool (W_3), and a well serving Harar town (W_4). All the wells are located on or very close to the campus. The water reservoir sampled was the main reservoir (R) of the Haramaya University in which water from the three sample wells are collected. The three distribution zones is represented by water samples collected from west-zone distribution lines (Z_1) serving student cafeterias and student dormitories, the south–zone (Z_2) serving staff cafeteria and the surrounding areas, and the east-zone (Z_3) serving the PhD students' residences).

Table 1: Information regarding the water wells and distribution zones

Code	**Location**	**Depth (m)**	**Average discharge rate ($L\ s^{-1}$)**	**Altitude (m)**	**Latitude**	**Longitude**
W_1	Lake bed	77	6	2016	09°24.605'	042°01.644'
W_2	Close to weather station	53	3	2024	09°24.886'	042°01.174'
W_3	Near motor pool	39	1	2020	09°25.370'	042°01.774'
W_4	Lake bed	*	*	2023	09°24.040'	042°01.764'
R	Main reservoir			2087	09°25.603'	042°02.226'
Z_1	Student cafeteria			2059	09°25.410'	042°02.102'

Z_2	Staff cafeteria			2047	09º25.352’	042º02.258’
Z_3	PhD residence			2064	09º25.523’	042º02.377’

**Even though the fourth well (W_4) does not belong to the university, water is obtained on daily basis for the university from this well.*

All sampling points were selected to represent the contamination profile of the groundwater. Sampling was made from each of the four wells so as to assess the contamination status of water at the particular well before it is transferred into the main reservoir. Likewise, samples of water were also collected from the three distribution zones (i.e., Z_1-Z_3) and compared with the sample from the main reservoir.

Water Sample Collection and Preparation

The water samples were collected once every week for a period of five weeks from each sampling point. A total of forty water samples were collected from the eight sampling points. Water samples from all the points were collected in two-liter plastic bottles for different water physical quality tests. Prior to sample collection, sampling bottles were washed with nitric acid and then rinsed with distilled water to avoid contamination. Sampling from the wells was done close to the sources. Reservoir sample collection was done by tying the sampling bottle using a clean rope and directly immersing the sampling bottle into the reservoir. For the distribution lines, water samples were taken directly from the water taps. The samples were then taken to the laboratory and tested for the different chemical parameters.

Testing Methods

The temperatures of the samples were noted at the sampling points. The samples were put to examination in the laboratory to determine some chemical parameters. Analyses were carried out for various water quality parameters such as Magnesium, Calcium, Sodium, Potassium, Nitrate (NO_3^-), Fluoride, Chloride, Sulfate, Total alkalinity, Hardness and pH using standard methods. The reagents used for the analyses were AR grade and double distilled water was used for preparation of solutions.

Anions-Cations Balance

The accuracy of the laboratory analysis was readily checked by looking at the anions-cat ions balance. Since water is neutrally charged, the sum of anions was checked against the sum of cat ions (in milli-equivalents). The balance is normally expressed as percentage

$$Percent\ difference = \frac{SC - SA}{SC + SA} X100 \qquad (1)$$

Where, *SC* is the sum of cat ions and *SA* is the sum of anions. Generally, for groundwater and for surface water, the percent error should be less than 10%. If it is greater, the analysis may not pass validation check. On the other hand, an accurate ion balance does not necessarily indicate correctness of the analysis. There may be more than one error that may cancel each other out.

Data Analysis and Interpretation

Data were recorded, organized, summarized and analyzed by statistical methods using completely randomized design (CRD) first by using one way ANOVA and thereafter, by using pair comparisons. First, water samples from the four wells were compared for all the eleven parameters. Then water sample from the main reservoir was compared with the samples from different distribution zones.

Results and Discussion

Table 2: Comparisons of water samples collected from different wells

Site	Values (mg L^{-1})										pH
	Mg(II)	**Ca(II)**	**Na(I)**	**K(I)**	**NO_3^- (N)**	**F^-**	**Cl^-**	**SO_4^{2-}**	**Alkalinity**	**Hardness**	
W1	20.86	27.94	12.77	7.17	0.20	0.77	106.1	12.98	859.7	311.1	7.6
W2	28.84	53.84	12.00	5.88	1.12	0.70	113.3	12.70	894.4	301.8	7.8
W3	11.61	65.52	10.45	6.93	3.37	0.70	156.6	12.89	894.4	329.3	7.2
W4	21.76	38.10	14.32	9.49	0.73	0.80	111.6	12.75	951.4	307.6	7.9
F((□ =	*	*	*	*	*	*	*	ns	*	*	Ns

0.05)											
Identical pairs	W1 & W4	None	W1 & W2	W1 & W3	None	W1 & W4 W2 & W3	W2 & W4	None	W2 & W3	None	W2 &W3 W3& W4

*W_1 = well no.1; W_2 = well no.2; W_3 = well no.3; W_4 = well no.4; * = significant at $p < 0.05$ and ns = not significant*

Concentrations of Magnesium Ions

Mean values of the magnesium concentration ranged between 11.61 mg L^{-1} (for W_3) and 28.84 mg L^{-1} (for W_2). The similarity between W_1 and W_4 is understandable because of the proximity between the two wells indicating that the two wells could be under the same geologic and soil formations. The differences between W_2 and W_3 could be due to the rock formations through which rainwater moves to reach the aquifers. W_3 is located at a place where the soil is predominantly a lake deposit (silt and clay which have been transported from far away). Since magnesium carbonate is soluble, most of the magnesium in these soils must have dissolved in the process of the movement. On the other hand, W_2 is located in firm soil and the infiltrating water travels longer distance in this well (> 50 m) compared to about 40 m of W_3.

The limit of magnesium ion for hardness of water is 10 mg L^{-1} (Sawyer et al., 2003). Based on this value, all the wells have water with magnesium concentrations higher than the limit. Concentration of magnesium ion in the main water reservoir is less than the maximum value of the wells. This is because in the reservoir the water from the three wells mix (except water from W_3 which is not added to the reservoir) and therefore, the reservoir showed concentration less than the maximum. Besides, there were no significant differences in magnesium concentrations between the water from the reservoir and the water at the distribution zones and even among water samples from the different distribution zones. This was because there was no source or sink once the water left the reservoir until it reached the distribution zones. All in all, since concentration of magnesium ion has to be less than 150 mg $L^{-1}$to be acceptable (Chatterjee, 2005), the water from the wells and the different zones were all within the acceptable limits.

Table 3: Comparisons of water samples collected from the three distribution zones with the water from the reservoir

Site	Values (mg L^{-1})										pH
	Mg(II)	**Ca(II)**	**Na(I)**	**K(I)**	**NO_3^- (N)**	**F^-**	**Cl^-**	**SO_4^{2-}**	**Alkalinity**	**Hardness**	
R	26.6	65.5	11.4	5.85	2.56	0.70	107.7	11.5	955.6	318.2	7.61
Z_1	24.8	63.2	12.6	6.25	0.38	0.66	110.0	12.7	877.8	294.7	7.88
Z_2	26.7	50.8	10.3	6.31	1.99	0.64	96.6	12.3	901.4	293.8	7.93
Z_3	23.6	45.2	11.6	6.31	0.39	0.72	107.2	12.4	902.8	304.4	7.47
F ($p < 0.05$)	ns	*	*	ns	*	ns	*	*	*	*	*
Identical pairs	All	R & Z_1	R & Z_3	All zones	Z_1& Z_3	All	R & Z_1 R & Z_3 Z_1& Z_3	Z_1& Z_3 Z_2& Z_3	Z_2& Z_3	Z_1& Z_2	Z_1& Z_2 R & Z_3

*R = reservoir; Z_1 = distribution line of zone one; Z_2 = distribution line of zone two; Z_3 = distribution line of zone three; * = significant at $p < 0.05$; ns = not significant at $p < 0.05$.*

Concentrations of Calcium Ions

The range of calcium concentration of the wells was relatively large. Unlike magnesium ions, concentrations of calcium ions were higher for all the wells and this must be due to more abundance of calcium ions in earth's crust of the region. In the case of calcium (unlike magnesium) W_3 showed higher concentration of 65.5 mg L^{-1} and W_1 the lowest of 27.9 mg L^{-1}. All the wells showed significant differences at $p < 0.05$ with no two wells revealing identical concentrations. The high calcium concentration at W_3 must be due to the calcium that has been transported to the area with the soil and lake deposited.

The minimum limit of calcium concentration in water for water to be classified as hard water is 15 mg L^{-1} (Sawyer et al., 2003). Since the calcium concentration of water of all the wells exceeded this value, even disregarding the other cations the water could be categorized as hard water.

Concentration of calcium in the main water reservoir is the highest even compared to the water in W_3 despite the fact that water from this well is not added to the reservoir. The reason for such high calcium concentration is unclear but one possible explanation could be due to gradual accumulation of calcium in the reservoir since water stays in the reservoir relatively undisturbed during late night hours. Concentration differences among the three zones must have something to do with the age of the lines.

Concentration of calcium in drinking water is considered objectionable when it exceeds 200 mgL^{-1}(Chatterjee, 2005). A value close to 75 mg L^{-1} is considered acceptable and hence, for all the wells and distribution lines the concentration levels were within acceptable limits.

Concentrations of Sodium Ions

The concentrations of sodium ions in water of all the wells were close to the concentration of magnesium ions. The concentration for all the wells ranged between 10.5 mg L^{-1} (W_3) to 14.3 mg L^{-1} (W_4) with W_1 and W_2showing nearly identical concentrations. The situation was not that much different when it comes to differences between the main water reservoir and the distribution zones. As expected, both the reservoir and Z_3 showed identical values. This is because Z_3 has relatively newer pipelines that transfer water from the reservoir to the destination with minimum contamination. Sodium ions in drinking water have impact on the taste especially when it combines with chloride ions (Chatterjee, 2005).

Concentrations of Potassium Ions

Potassium, like sodium ions is important for water softening. Concentrations of potassium ions in water of all the wells was from half to two third that of sodium ions. Minimum potassium concentration was observed in W_2 (5.9 mg L^{-1}) and maximum, in W_4 (9. 5 mg L^{-1}). All the wells showed significant differences at $p < 0.05$ with W_1 and W_3showing nearly identical values. No clear explanation could be given for the similarities between the two wells. When it comes to potassium concentration differences between the main reservoir and the distribution zones, no differences were observed at $p < 0.05$.

Concentrations of Nitrate Ions

The nitrate concentrations in two wells (W_2 and W_3) were relatively higher than the other two. W_2 is located in agricultural area, which means that unused nitrogen fertilizers must have leached into the underlying aquifer. W_3 is located in the area of lake deposited soil and is also close to the surface, both of which contribute to high amount of nitrate leaching to groundwater. Both W_1 and W_4 (not under farmland) showed slightly lower nitrate concentrations as expected.

High nitrate concentration in R is not due to contribution from the wells since water from W_3 (with high nitrate concentration) is not added to the reservoir and water from the other wells had lower nitrate concentrations. One possible explanation could be surface pollution perhaps due to organic debris getting into the reservoir.

Drinking water standard by EPA for health concern is 10 mg L^{-1} for nitrate-N (Hammer and Hammer, 2006). As far as the limit is concerned, the values observed in the wells and in the reservoir may not be of concern right away but care has to be taken not to exceed the limit.

Concentrations of FluorideIons

Fluoride is a sensitive ion that has to be kept within a narrow range for optimum health. All the wells showed fluoride concentrations between 0.7 and 0.8 mg L^{-1}. This is within the acceptable limit of 0.5 and 1.0 mg L^{-1}(Sawyer et al., 2003). Fluoride is a stable ion in water (Spiro and Stigliani, 2003) and its concentration is not changed unless there is a source or a sink. That is also why the concentrations in the reservoir and at the distribution zones were nearly the same.

Concentrations of ChlorideIons

Chloride is one of the ions that exist in large quantities, especially in rivers and in groundwater (Sawyer et al., 2003). Chloride concentration of rivers and groundwater is higher than upland areas since water dissolves and moves the chloride ions from higher to lower areas (Sawyer et al., 2003). In the same manner, water also dissolves chloride from the upper profiles of the soil to groundwater. If not dissolved by percolating water the chloride remains in the soil (Charbeneau, 2000). In water it exists in the form of sodium chloride.

Only one of the four wells (W_3) had relatively higherchloride concentration of about 157 mg L^{-1}. W_3 being at the location of lake deposited soil and also a place where flood water can get to,had the potential to depict high chloride concentration. Chloride has a concentration limit of 250 mg L^{-1}since with higher concentration it imparts salty taste to drinking water and is objected (Garg, 2008).Based on the study results, the concentrations of chloride ions in waters of all the wells and distribution lines were within limit.

Sulfate Ions

Sulfate in ground water is due to naturally occurring minerals such as epsomite ($MgSO_4.7H_2O$), gypsum ($CaSO_4.2H_2O$) and barite ($BaSO_4$) (Greenwood and Earnshaw, 1984). The sulfate ions in all the wells remained within an acceptable limit (less than 250 mg L^{-1}), which is the taste and odor threshold of drinkable water (EPA 2012).The fact that sulfate is much less than the acceptable limit indicates, that the water is not risky for children and the elderly, which are susceptible to high sulfate concentrations because of high risk of dehydration that is caused from diarrhea caused by high concentration of sulfate in drinking water.

Alkalinity

Alkalinity is the measure of ions such as bicarbonate, carbonate or hydroxide that make water alkaline. The carbon dioxide that is dissolved in water forms bicarbonate and hydrogen ions. Alkali metals such as magnesium, calcium, sodium and potassium in water are responsible for water alkalinity. These metals are common in earth’s crust and transported by rainwater from the soil to groundwater. In all the four wells alkalinity ranged from 860 mg L^{-1} in W_1 to 951 mg L^{-1} in W_4. Since pH of the well waters was less than 8.5, most of the alkalinity was attributed to bicarbonate (Sawyer et al., 2003). The high alkalinity of $W_4$was not entirely due to the carbonates and bicarbonates. Since the water sample from this well was not obtained from the well-reservoir but rather from the tap, the water was aerated during sampling. Aeration removes volatile chemicals and carbon dioxide. The carbon dioxide removed from the water must have slightly reduced its acidity, which means the removal of carbon dioxide had the effect of increasing alkalinity of the water (Spiro and Stigliani, 2003). The high alkalinity of water in the reservoir wasalso partly due to aeration during water transfer.

Hardness

Water of relatively high concentrations of calcium and magnesium ions is considered hard water. Such hard water can cause corrosion and incrustation of pipes and can also adversely affect the taste of foods prepared by such waters (Garg, 2008). Water from all the wells showed hardness from the lowest of 302 mg L^{-1} (W_2) to the highest of 329 mg L^{-1} (W_3). All wells showed significantly different values with no similarities. On the other hand, water hardness of the distribution zones Z_1 and Z_2slightly decreased possibly because of reactions taking place in the pipes and causing the insoluble calcium carbonate to precipitate (Garg, 2008).

Generally, groundwater is harder than surface water (Garg, 2008). Water with hardness equal to or lower than 50 mg L^{-1} is considered soft, the softer it is the more it loses its taste (Chatterjee, 2005). On the other hand, hardness in excess 300 mg L^{-1} is considered very hard (Garg, 2008) and based on this, water from all the wells were very hard. Hardness level suitable for drinking is between 50 and 150 mg L^{-1} (Chatterjee, 2005). It is possible to remove some of the hardness by boiling since boiling precipitates the insoluble calcium carbonate (Garg, 2008).

Estimation of bicarbonate ions from total alkalinity

In this study before the anion-cation balance is determined for the wells concentrations of bicarbonate of the different wells were estimated from the concentration of total alkalinity in units of mg L^{-1} $CaCO_3^{2-}$ for every mmol of calcium carbonate as suggested by Murray and Wade (1996).

$$[HCO_3^-] = \frac{Alkalinity\,(mg\,L^{-1} CaCO_3^{2-})}{50} \qquad (2)$$

The total mmol of calcium carbonate in turn was estimated from the measured values of calcium concentrations. Hence, bicarbonate concentrations estimated for the four wells using Eq. 2 and estimated mmol of $CaCO_3^{2-}$are summarized in table 4.

Table 4. Estimates of the bicarbonate ions concentrations based on Eq. 2 as mmol L^{-1} of calcium carbonate calculated from measured concentrations of calcium ions.

Site	Alkalinity (mg L^{-1})	Calcium (mg L^{-1})	mmol L^{-1} of $CaCO_3^{2-}$	$[HCO_3^-]$ (mg L^{-1})	$[HCO_3^-]$ (meq)
W_1	859.7	27.9	0.70	12.0	0.20
W_2	894.4	53.8	1.34	24.0	0.39
W_3	894.4	65.5	1.63	29.2	0.48
W_4	951.4	38.1	0.95	18.1	0.30

Cation-anion balance

Cation-anion balances of the water samples in each well were determined using four cations (calcium, magnesium, potassium and sodium)and five anions (chloride, fluoride, sulfate, nitrate and bicarbonate). Except the bicarbonate ion, the measured concentrationsof all the other anions were usedfor calculation of the cation-anion balance.Other than the bicarbonate ion, the contributions of carbonate and hydroxide ions to the ion balance were considered to be insignificant based on the pH values of the waters from all wells which ranged between 7 and 8.

Table 5. Percent difference between cations and anions of the four wells

Site	$[Mg^{2+}]$	$[Ca^{2+}]$	$[Na^+]$	$[K^+]$	Sum of Cations	$[SO_4^{2-}]$	$[NO_3^-]$	$[F^-]$	$[Cl^-]$	$[HCO_3^-]$	Sum of Anions	% diff.
	(meq L^{-1})							(meq L^{-1})				
W_1	1.72	1.40	0.56	0.18	3.85	0.270	0.003	0.040	3.03	0.20	3.54	4.2
W_2	2.37	2.69	0.52	0.15	5.74	0.265	0.018	0.037	3.24	0.39	3.95	18.5
W_3	0.96	3.28	0.45	0.18	4.86	0.268	0.054	0.037	4.48	0.48	5.32	-4.5

W_4	1.79	1.90	0.62	0.24	4.56	0.266	0.012	0.042	3.19	0.30	3.81	9.0

Except inwell number two, the percent differences between anions and cations in the other wellswereless than ten percentand this may suggest that there are small differences between the total number of anions and cations. Well number two showed higher percent difference than the rest and this may be due to error in estimation of the bicarbonate anion or due to significant contribution of other anions,which were not measured in this study.

Conclusions

In this study water samples were collected from wells, taps of different zones and reservoir and tested in the laboratory for different chemical quality parameters. Comparisons ofthesequality parameters were made first among the samples of water from the different wells and then between the samples from the different zones and thereservoir.

From among the four wells, the well closer to the motor pool (W_3) showed the highest concentrations of calcium, nitrate-N, chloride and hardness, but contained the lowest magnesium concentration and pH. As far as calcium, nitrate and hardness were concerned no two wells were found to be identical. Overall, calcium, magnesium, alkalinity and hardness were found to be beyond the aesthetically acceptable levels, while all the remaining tested chemical parameters were within the permissibleranges for all the wells.

More uniformity was observed between water of the reservoir and those of the different distribution zones and this is understandable since water from the three wells (W_1, W_2 and W_4) were collected in the same reservoir, where theyall mixed. Such mixing diminishedvariability between the zones and the reservoir as these were reflected in the similarities with theconcentrations ofmagnesium, potassium and fluoride in the different sources.

Acknowledgements

The authors would like to thank HU research office for funding this project.

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Enhancement of Tolerance to High Salinity and Extreme pH Conditions in Broad Bean *(Vicia faba)*-Nodulating Rhizobial Isolates from Hararghe Highlands, Ethiopia through Chemical and Physical Mutagenesis

By

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Abstract: *Soil salinity and pH are the most important factors, which affect rhizobia, their legume hosts and the symbiosis process. Thus the aim of this study was to examine the effectiveness of chemical and physical mutagenesis on enhancement of tolerance of Vicia faba-nodulating rhizobial isolates from Hararghe highlands to extreme salinity and pH conditions. Their symbiotic effectiveness was determined on sterilized sand and subsequent ratings showed that 2(4%), 8(16%), 26(52%) and 14(28%) of the isolates were ineffective, less effective, effective and highly effective, respectively. N content was positively correlated with shoot dry weight (SDW) (r = 0.68, P< 0.0001). Physiological tests revealed that 21(42%),17(34%) and 5(10%) of the isolates grew at salt concentrations of 2%, 4% and 6%, respectively Fifty (100%) of the isolates grew in the range of pH 5.5- pH 9 Nineteen(38%), and 11(22%) of the isolates were grown at pH 9.5 and pH10, respectively, while 34(68%) and 6(12%) of the isolates were able to grow at pH 5 and pH 4.5, respectively. The symbiotic effectiveness of mutants on sand culture showed that 10%, 60%, 10% and 10% were highly effective, effective, less effective and ineffective, respectively. The nodule number of mutants were positively and significantly correlated with NDW (r = 0.63, P < 0.0001) on sand culture. The average NDW and SDW of mutants on soil test scored 13.07% and 122.56% increase, respectively, over the average NDW and SDW of mutants on sand culture. The correlation data on soil experiment displayed that nodule number was associated positively and significantly (r = 0.71, P < 0.001) with NDW, while SDW was positively correlated with percent N (r=0.57 P<0.01) and total nitrogen content (r = 0.73, P < 0.001). Physiological test of mutants also showed that, 10(100%) and 3(30%) of mutants grew at salt concentrations of 11% and 12%, respectively. All mutants (100%) were able to grow at pH 10.5- 12, while only 3 (30%) of mutants grew at pH 4.*

Key words: ***Mutagenesis, Faba bean, Physiological test, Rhizobia, Symbiotic effectiveness***

Introduction

Salinity is one of the major environmental threats to agriculture and affects approximately 7% of the world's total land area (Ben-salah *et al*., 2011) and nearly 40% of the world's land surface can be categorized as suffering from potential salinity problem (Payekapong *et al*., 2006). Salt stress is one of the major environmental stress conditions that adversely affect legume production in arid and semi arid regions, particularly because these plants obtain most of their nitrogen demands from symbiotic N_2 fixation (El-Sheikh and Wood, 1995). High saline soils limit the productivity of legumes by adversely affecting the growth of the host plant, the symbiotic development of root-nodule bacteria (Zahran, 1999), and the nitrogen fixation capacity (Delgado *et al.*, 1993 and Georgiev and Atkias, 1993). Salt stress also accelerates greening of the nodules and reduces the Leg-hemoglobin content inside the nodules; and forms ineffective nodules (Delgado *et al.*, 1993). Successful *Rhizobium*-legume symbiosis under salt stress conditions requires the selection of salt tolerant rhizobia from the indigenous population (Zahran, 1991). It also requires selecting plant genotypes that are tolerant to salt stress and then match them with the salt tolerant and effective strains of rhizobia (Cordovilla *et al*., 1995).

Legumes commonly fail to nodulate under acid-soil conditions, especially in soils of pH less than 5.0. The inability of some rhizobia to persist under such conditions is one cause of nodulation failure (Graham *et al*., 1982; Carter *et al*., 1994 and Bayoumi *et al.*, 1995). Researchers had also shown that the amount of N_2 fixed by forage legumes on low-fertility acidic soil is dependent on legume growth and persistence (Thomas *et al*., 1997). However, selection of acid-tolerant rhizobia to inoculate legume hosts under acidic conditions will ensure the establishment and the successful performance of symbiosis (Glenn and Dilworth, 1994; O'Hara and Glenn, 1994 and Correa and Barneix, 1997). Some works also showed that elevated inoculation levels have the ability to enhance the nodulation response under acidic conditions (Pijnenborg *et al*., 1991). The growth, nodulation, and yield of *V. faba* were also improved after inoculation with resistant strains of *R. leguminosarum bv. viciae* in acid soils (Carter *et al.*, 1994). Inoculation of *Vicia fab*a with efficient strains of the rhizobia has significant economic and ecological benefits. Thus, the major objective of this study was to examine the role of chemical and physical mutagenesis on enhancement of tolerance to high salinity and extreme pH conditions in broad bean nodulating rhizobia isolated from soils of Hararghe highlands.

Materials and Methods

The sampling sites for this study were selected from pulse growing highlands of Hararghe which are located at about 320-530 km east of Addis Ababa, the capital of Ethiopia. Soil samples were collected from two districts of western Hararghe i.e., Chiro and Tullo, and three districts of eastern Hararghe highlands i.e., Goro Gutu, Meta and Deder. The altitude, the mean annual rainfall and the mean minimum and maximum temperature of these areas range from 1800 to 2400 masl, 900 to 1250 mm yr^{-1} and 10 to 20^{O}C, respectively (Abdu Abdelkadir, 1997).

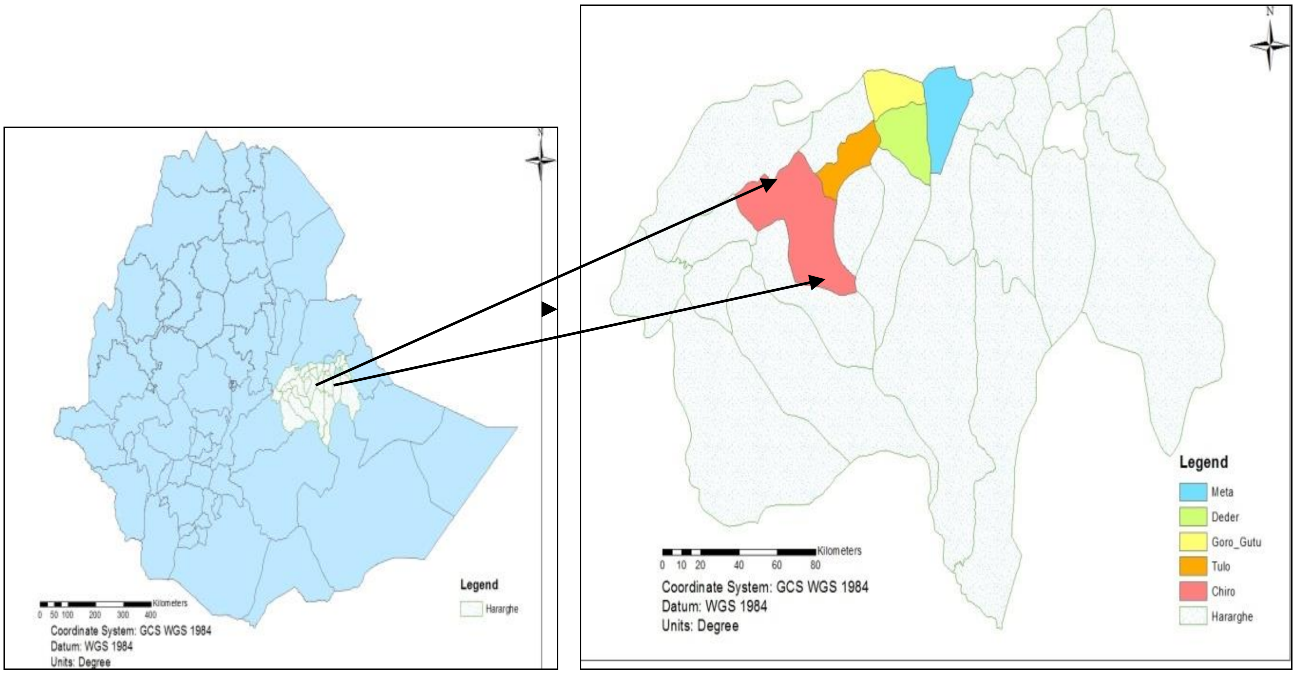


Figure 1: Location of the sampling sites

The collected soil samples were used for isolation of indigenous rhizobia by the host trap method as indicated in Somasegaran and Hoben (1994). All isolates were gram stained for rapid identification of gram-positive contaminants as indicated in Lupwayi and Haque (1994). Presumptive tests were done by re-culturing the primary isolates into YEMA containing CR and peptone glucose agar (PGA). Stock solution of Congo red (CR) was prepared by dissolving 0.25g of CR in 100ml sterile distilled water (Vincent, 1970). Ten ml of the resulting CR stock solution was then added to one liter of YEMA. PGA was prepared by dissolving 5g of glucose, 10g of peptone, 15g of agar and 10ml of 1% Bromcresol purple in a liter of distilled water. Bromothymol blue (BTB) was also incorporated into YEMA to detect the production of acid or alkaline which in turn was used as a means of distinguishing the slow growers from fast growers. Plates were examined for growth and single colonies were picked up and periodically purified by re-streaking on new YEMA plates. Pure isolates were then preserved on YEMA slants containing 0.3% (w/v) CaCO3 and stored at 4^{o}C (Vincent, 1970). The cultural characteristics of the isolates were performed according to Lupwayi and Haque (1994).

Acid sterilized river sand was filled into alcohol sterilized plastic pots. Seeds of uniform size and color were surface sterilized as described before (Vincent, 1970) and transferred to 0.75% (w/v) water agar plates for germination and incubated at 25^{o}C for 3 days. Seedlings were transferred to each pot. Each seedling was inoculated with pure culture (1ml/seedling) of a single *Rhizobium* isolate grown on YEM liquid medium to logarithmic phase (10^9cells/ml). The experiment was conducted in green house having mean minimum and mean maximum temperatures of 19±2^{O}C and 30±1^{O}C, respectively, using a randomized complete block design with three blocks or replications. All seedlings were allowed to grow with 12hrs photoperiod on sterilized sand. Forty five days after planting, data on nodule number, nodule color, nodule dry weight, shoot dry weight and symbiotic effectiveness were determined. Selected wild isolates were further tested on unsterilized soil. In the later test, however, additional data such as N content and N percent were determined by the methods described in Ogutcu *et al*. (2008). Percent relative symbiotic effectiveness (SE) of each isolate was computed using the following formula (Beck *et al*., 1993).

$$SE\ (\%) = \frac{\text{Shoot dry weight of innoculated plants}}{\text{Shoot dry weight of N supplied plant}} \times 100$$

Finally, the symbiotic effectiveness (SE) values of the isolates were rated as per the scale suggested by Beck *et al*. (1993) as highly effective (SE> 80%), effective (50-80%), less effective (35-50%) and ineffective for SE < 35%.

Salt tolerance of wild *Rhizobium* isolates was determined by the method described by Ahmet *et al*. (2010). Isolates were streaked on YEMA plates containing various concentrations of NaCl (2%, 4%, 6%, 8%, 9%, 10%, 11% and 12%) and incubated at 28^{O}C. The susceptibility of isolates to NaCl was recorded as positive or negative. The pH tolerance test of the isolates was carried out according to Bernal and Graham (2001) on YEMA-medium whose pH values has been adjusted to values ranging from 4 - 10.5. Hydroxylamine hydrochloride and sodium azide were used as chemical mutagenic agents to induce mutation in *Rhizobium* isolates. From the stock solution of each mutagenic substance (1.17g/ml), 0.0, 100, 200 and 300µl was added into each ml of rhizobial suspension. The isolates were also exposed to a physical mutagen (UV radiation at 2000µw/cm^2) according to the method described by Miller (1972). Symbiotic effectiveness of mutants were determined on both sterilized sand and unsterilized soil following the same methods described above. Salt tolerance of mutants was tested by streaking on sterile TY agar media containing various concentrations of sodium chloride (11, 12, 14, 16 and 18%). Colonies that appeared on TY agar media containing concentrations of NaCl higher than the maximum required (i.e., 10%) for the wild type *Rhizobium* were selected as salt tolerant mutants as per the methods used by Abbdel Hamid *et al*. (2011). All statistical computations were done with SAS software, version VIII.

Results and discussion

A total of fifty isolates were obtained from the nodules of faba bean plants grown at Haramaya University greenhouse. All isolates were found to be gram negative and did not absorb Congo red from

YEMA-CR media. None of the isolates in this study showed growth on peptone-glucose agar (PGA). Failure of these isolates to absorb Congo red from YEMA-CR media and to grow on peptone glucose agar media presumptively indicated that they were root nodule bacteria (Lupway and Haque, 1994). All isolates turned Yeast Extract Mannitol Agar containing bromothymol blue (YEMA-BTB) into deep and moderate yellow color after the incubation of 3-5 days at 28^{O}C.

The colony diameters of 48 (96%) isolates were within the range of 2 mm to 5.2mm. Forty two (84%) and 6 (12%) isolates were found to have diameters of colonies in the range of 2-4 mm and 4-5.2 mm, respectively, after 3-5 days of incubation. Two isolates (4%) i.e., HUFBR18 and HUFBR19, from Tullo districts showed colony diameters of 1.5mm and 1mm, respectively. The largest colony (5.2mm) was shown by HUFBR35 from Deder district. On the basis of their colony morphology, 41 isolates (82%) were categorized as large mucoid and eight isolates (16%) as small dry. Only isolate HUFBR25 from Gorogotu was found to form large watery colonies. The above results were in line with the findings of Getaneh Tesfaye (2008), who reported that 70% of faba bean rhizobial isolates showed large mucoid colonies with diameters lying between 2 and 5.5mm. Zerihun Belay (2006) also reported that colony diameters of faba bean rhizobia were in the range of 2-5mm with milky color, large mucoid and raised colony characteristics.

Forty seven isolates (94%) showed the mean doubling time of 2-4 hrs, but three isolates (6%) i.e., HUFBR10 from Chiro, HUFBR20 from Tullo and HUFBR29 from Gorgotu, showed the mean doubling time of 4.3 hrs, 4.5 hrs, and 4.1 hrs, respectively. These three isolates were slower in their growth rate than the other isolates. This result is in agreement with Zerhari *et al.* (2000).

Evaluation of the Symbiotic Effectiveness of Wild Isolates of Rhizobia on Sterilized Sand

All the presumptive rhizobial isolates were tested in pot experiment using sterilized sand culture to evaluate their nodulation and symbiotic effectiveness on faba bean variety *Gachena* under controlled greenhouse conditions in Haramaya University. All of the rhizobial isolates were found to induce nodulation, and hence were authenticated as faba bean nodulating *R. leguminosarum* (Giller, 2001; Depret *et al*., 2004). On the basis of host plant specificity for infection and nodulation, these species were generally assumed to be *R. leguminosarum* bv. *viciae* (van Berkum *et al*., 1995).

All rihizobial isolates used as inoculants induced nodulation in the bean plants grown on sterilized sand as compared to the complete absence of nodules in the negative and positive controls (Table 1). The maximum nodule number produced was 193/plant by HUFBR14 and the minimum nodule number recorded was 93/plant for isolates HUFBR45 and HUFBR39. In addition, the mean nodule number produced in this study was 124 nodules/ plant. The mean nodule number in this study showed a 29.16% increase over the mean nodule number recorded by Alemayehu Workalemahu (2009) on faba bean rhizobia from Ofla, southern Tigray, Ethiopia. Regarding the nodule color, as shown in (Table 1), 7 (14%) of the isolates [HUFBR45 (Meta), HUFBR40, HUFBR37 and HUFBR 32 (Deder), HUFBR17 (Tullo), HUFBR27 (Gorguto) and HUFBR7 (Chiro)] showed white colored and small sized nodules upon inoculation. The formation of white nodules is associated with weak vigor and poor yield that may be related to poorly developed bacteroid (Subba Rao, 1988). In this study, 36 (72%) of the isolates showed pink and slightly dark red colored nodules, whereas 7 (14%) isolates displayed deep dark red.

In terms of nodule dry weight, Plants inoculated with isolate HUFBR11 produced the highest dry weight of nodule (119.9 mg/plant). The minimum nodule dry weight (43.6mg/plant) was obtained by isolates HUFBR26 and HUFBR35 (Table 1). The mean nodule dry weight recorded in this study was 79.58 mg/plant which was higher than the one reported by Zerihun (2006) and Getaneh (2008) who demonstrated a mean nodule dry weight of 71.99 and 74.99 mg/ plant, respectively.

The correlation analysis in the sand experiment revealed that nodule numbers were associated positively and significantly ($r = 0.53$, $P < 0.0001$) with nodule dry weight. A similar correlation result was documented by Khondaker *et al*. (2003) who reported a correlation coefficient of $r = 0.32$ for the association of nodule number with nodule dry weight after inoculation.

Eighty four percent of the inoculated isolates of faba bean have been shown to significantly increase the shoot dry weights over the negative control, whereas 72% of the inoculated isolates were shown to have significantly decreased SDW as compared to the positive control (Table 1). The maximum shoot dry weight, i.e., 2.4 g per plant, was recorded from plants inoculated with HUFBR23. The minimum shoot dry weight was 0.82g/plant which was produced by plants inoculated with HUFBR17 & HUFBR40 isolates. Moreover in this study, isolate HUFBR23 showed a 147.4% increase in shoot dry weight over the negative control.

Somasegaran and Hoben (1994) and Peoples *et al.* (2002) had shown that shoot dry matter is a good indicator of the relative symbiotic effectiveness of isolates. In the current study, most isolates of eastern and western Hararghe highlands showed better biomass accumulation in their tissues as compared to the negative (uninoculated) control.

The percentage symbiotic effectiveness in this study ranged from 34 % to 100% (Table 1). Of the total inoculated isolates, 2 (4%) were ineffective in their SE, whereas 8 (16%) of the isolates were less effective. 26 (52%) and 14 (28%) of the isolates were effective and highly effective, respectively. Ayneabeba Adamu *et al.* (2001) also reported 66-87% effectiveness in nitrogen fixation on sand culture of *R. leguminosarum* var.*viceae* isolates from Ankober, Molale, Keyt, and Mehalmeda sites from northern Shewa, Ethiopia.

Evaluation of Symbiotic Effectiveness of Selected Wild Isolates on Unsterilized Soil

Selected wild isolates were tested on unsterilized soil. The data showed that, most of the inoculated isolates and the negative control displayed significantly higher nodule numbers over the positive control ($p<0.05$). Whereas only two isolates (HUFBR23 and HUFBR6) showed significantly lower nodule number as compared to the negative control. The highest nodule numbers (134 per plant) were recorded from the plant inoculated with HUFBR4.The lowest nodule numbers (79 and 72 per plant) were recorded from the plant inoculated with isolate HUFBR23 and isolate HUFBR6, respectively. Nitrogen treated control faba bean on unsterilized soil produced a significantly lower number of nodules (44 per plant). This result was similar to the report of Abdel-ghaffar (1988).

The poor nodulation of the positive control was primarily resulted from the inhibitory effect of supplied mineral N to nodule formation and functioning on root colonization of N fixing legumes (Giller, 2001). Therefore the poor nodulation of the positive control as compared to the inoculated plants could have resulted from the inhibitory effect of the added fertilizer in the greenhouse and some of the nitrogen content of the soil.

Regarding nodule dry weight, 57.14% of the isolates showed significantly ($p\leq 0.05$) higher nodule dry weight than the positive control. Similarly only two isolates (HUFBR4 and HUFBR23) showed significantly higher nodule dry weight than the negative control. The maximum nodule dry weight (92 mg per plant) was displayed by the plant inoculated with isolate HUFBR23, whereas the least nodule dry weight (51mg/plant and 53mg/plant) were recorded by the plants inoculated with isolate HUFBR6 and HUFBR53, respectively. The average nodule dry weight of the plant inoculated with the isolates was 74mg/plant, which was higher than the record obtained by Zerihun Belay (2006) on Ambagiorgis soils (32mg/pl).

Table 1. Nodulation and symbiotic effectiveness of wild isolates on sterilized sand

Isolate Code	Nodule number mean ± Std Dev	NDW (mgpl^{-1}) mean ± Std Dev	SDW (gpl^{-1}) mean ± Std Dev	Nodule color	SE (%)	SE index
HUFBR45	93 ± 3^{o}	69.3 ± 5.2^{k-s}	0.89 ± 0.04^{uvw}	1	37.2	less effective
HUFBR46	165 ± 6^{a-g}	58.8 ± 1.0^{p-u}	1.45 ± 0.05^{l-t}	2	60.7	effective
HUFBR47	129 ± 6^{g-h}	84.7 ± 2.9^{f-o}	1.17 ± 0.02^{o-v}	2	48.9	effective
HUFBR48	116 ± 1 $^{j-o}$	91.5 ± 2.5^{e-l}	1.61 ± 0.06^{h-o}	2	67.4	effective
HUFBR49	122 ± 3^{h-o}	108.5 ± 0.9^{a-e}	2.14 ± 0.03^{a-g}	4	89.5	highly effective
HUFBR50	165 ± 1^{a-g}	95.6 ± 3.0^{b-i}	1.80 ± 0.03^{e-l}	2	75.3	effective
N^+	0.00	0.000	2.39 ± 0.03^{ab}		100	
N^-	0.00	0.000	0.97 ± 0.04^{w}		40.5	
LSD ($p<0.05$)	36.653	22.668	0.4852			

Units within a column followed by the same letter(s) are not significantly different at $p \leq 0.05$. 1= White; 2= pink; 3= slightly dark red; 4= Deep dark red; N^-= Uninoculated and unfertilized control; N^+= N fertilized control; LSD= Least significant difference; NDW= Nodule dry weight; SDW= Shoot dry weight; SE= Symbiotic effectiveness; Std Dev= standard deviation.

No isolate was found to increase shoot dry weight significantly over the negative control. All isolates were also found to increase shoot dry weight by (3.42- 44.09%) higher than their respective isolates on sand culture. This finding was quite comparable with the findings of Aynabeba Adamu *et al*. (2001).

The data on percent nitrogen showed that the positive control was significantly higher than plants inoculated with HUFBR6, HUFBR23 and HUFBR42 isolates. The average percent N value of inoculated plants was 2.79% which was lower than the result reported by Abere Mnalku *et al*. (2009). In the determination of N content, isolates such as HUFBR6, HUFBR23 and HUFBR42 showed significantly lower N content than the positive and negative control. The negative control showed (2- 100%) increased N content over all isolates. The isolates such as HUFBR6, HUFBR23 and HUFBR42 were very ineffective on unsterilized soil to fix nitrogen; hence they showed 100%, 64.5% and 61.9% decrease in N content as compared to the negative control.

The result obtained in this study showed N content was very strongly significantly and positively correlated with shoot dry weight ($r = 0.68$, $P < 0.0001$) and with percent N ($r = 0.85$, $p < 0.0001$). In line with this result, Abere Mnalku *et al. (*2009) reported that significant and positive correlation on N content ($r = 0.73$ and 0.81; $P < 0.001$) with shoot dry weight and percent N respectively.

Physiological Characteristics of Wild Type Rhizobium Isolates

In this study, salt tolerance of isolates had been tested and they showed difference in growth on YEMA adjusted at different salt concentration. Twenty (40%) of isolates were growing at the salt concentration of 2%. Seventy (34%) of isolates showed positive growth at 4% salt concentration. Isolates such as HUFBR12, HUFBR18, HUFBR28, HUFBR31 and HUFBR33 were able to survive at the salt concentration of 6%. This result was similar to the finding of Aregu Amsalu (2007).

The most salt tolerant isolate HUFBR31 (Deder district) grew with high range of salt concentration (2-8%). Similarly, Boredleau and Prevost (2002) reported that some rhizobia can survive up to extremely high levels (12%) of salt concentrations both in culture and in soil.

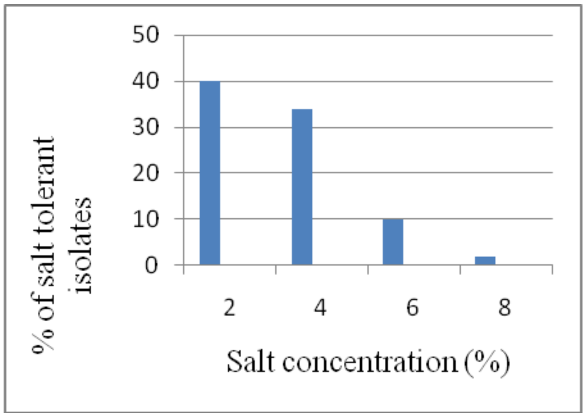


Figure 2: Tolerance of wild rhizobia isolates at different concentration of salt

Fifty (100%) of the isolates grew in between slightly acid pH 5.5 and alkaline pH 9 interval. 18 (36%), and 11 (22%) of the isolates managed to grow at pH 9.5 and pH 10, respectively. The ability of the isolates to grow in alkaline media is in agreement with the finding of Surange *et al*. (1997) In addition 34 (68%) of the isolates could grow on pH 5 and 6 (12%) of isolates grew at pH 4.5. However, all isolates that tolerate pH 4.5 were found to be sensitive to alkaline pH greater than 9. Isolate HUFBR47 was the most tolerant isolate which grows with wide range of pH (4.5- 10.0). Isolates which grew on pH 4.5 are the most desirable isolates which can be used in acidic soil.

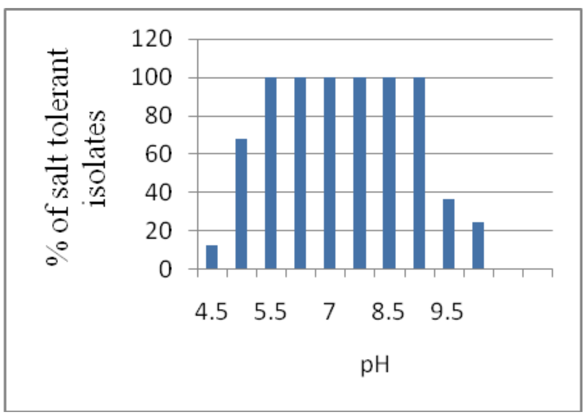


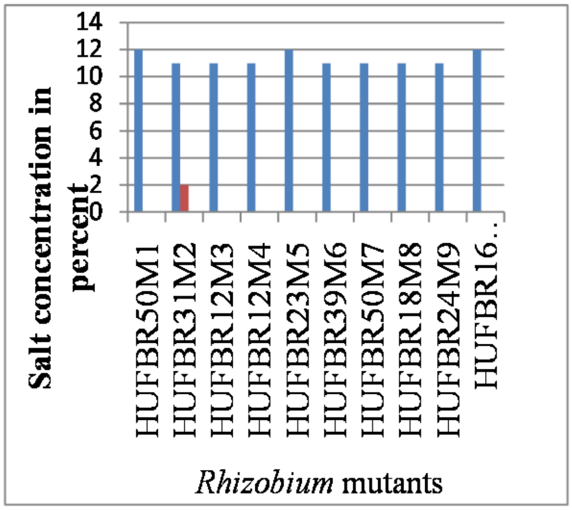
Figure 3: Tolerance of wild rhizobia isolates at different pH

Physiological Characteristics of the Mutants

All selected mutants 10 (100%) were able to grow at salt concentration of 11%. 3 (30%) of mutants (HUFBR50M1, HUFBR23M5 and HUFBR16M10) were able to grow significantly better than other mutants at salt concentration of 12%. In agreement with this result, Abdel Hamid *et al*. (2011) reported that clover-nodulating rhizobium mutants were capable to tolerate high concentration of NaCl (tolerance to 12%) following treatment with ethyl methane sulphonate as a mutagen. The only wild type of rhizobia which grew at salt concentration of 8%

was HUFBR31 and its mutant has shown significant change to tolerate salt concentration up to 11%. In this experiment all mutagens were potent to mutate the rhizobium isolates significantly.

Figure 4:



Tolerance of mutant rhizobia at different salt concentration

Three mutants (30%) such as HUFBR12M4, HUFBR39M6 and HUFBR18M8 showed growth on TY agar medium which was adjusted to pH 4. All mutants (100%) were able to grow on TY agar media adjusted to pH 10.5- 12. In agreement with this result, some mutants of *R. leguminosarum* have been reported to be able to grow at a pH as low as 4.5 (Chen *et al*., 1993).

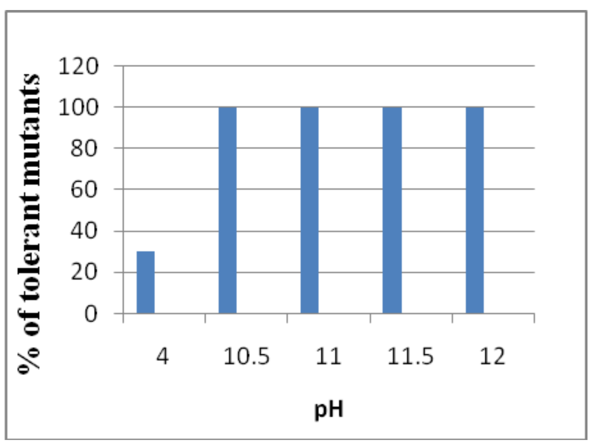


Figure 5: Tolerance of mutants at extreme pH

Symbiotic Effectiveness of Rhizobium Mutants on Sand Culture

Mutants were tested using sterilized sand to determine their nodulation and symbiotic effectiveness on healthy faba bean variety of *Gachena* in controlled environment using growth chamber. The data indicated that all mutants were able to form nodules upon inoculation. Faba bean plants inoculated with mutant HUFBR31M2 produced a maximum nodule number of 180 per plant. This isolate showed a statistically significant difference from other mutants at ($P < 0.05$). The maximum nodule number produced by the mutant is slightly lower than the maximum nodule number produced by the wild isolate (HUFBR14). The minimum nodule number (45/plant) was produced by plant inoculated with mutant HUFBR23M5. The minimum nodule number of the mutant showed 106.66% decreased nodule number as compared to minimum nodule number produced by wild type *Rhizobium* isolates (HUFBR39 and HUFBR45). The average nodule number produced by plants inoculated with mutants was 89, which was 39.32% lower than the average nodule number of the wild type (124 nodules per plant). Most mutants showed decreased nodule number as compared to its original parental isolates. Similar to this study, Sindhu and Dadarwal (2001) reported that Cicer nodulating chickpea rhizobium mutants showed decreased nodule number than parental strains. Furthermore, two mutants (HUFBR31M2 and HUFBR16M10) showed increased nodule number than plants inoculated with its parental isolates. Similar to this result William (1981) reported that some mutants of cow pea rhizobium produced more nodule numbers than plants inoculated with the wild type isolates.

Mutant HUFBR12M3 scored significantly higher nodule dry weight (133mg/plant) than other inoculated mutants on sterilized sand culture. Minimum nodule dry weight was induced by plants inoculated with mutant HUFBR24M9 (35.3mg/plant. The mean nodule dry weight in this study was 54.4mg/plant, which was lower than the mean nodule dry weight of wild isolates (76.52mg/plant).

Table 2: Nodulation and symbiotic effectiveness of mutants on sterilized sand

Mutant Code	**Nodule number mean ± Std Dev**	**NDW (mg/pl) mean ± Std Dev**	**SDW (g/pl) mean ± Std Dev**	**Nodule Color**	**SE (%)**	**SE index**
HUFBR50M1	$139{\pm}10^{b}$	$85{\pm}7.9^{b}$	$1.79{\pm}0.78^{b}$	2	79.5	Effective
HUFBR31M2	$180{\pm}13^{a}$	$63.3{\pm}1.5^{cd}$	$1.61{\pm}0.1b^{cd}$	2	71.6	Effective
HUFBR12M3	$113{\pm}11^{cd}$	$133{\pm}2.6^{a}$	$0.58{\pm}0.03^{g}$	1	25.8	Ineffective
HUFBR12M4	$102{\pm}36^{d}$	$58.3{\pm}3.5^{cd}$	$0.44{\pm}0.05^{g}$	1	19.6	Ineffective
HUFBR23M5	$45{\pm}22^{e}$	$49.3{\pm}21.5^{ed}$	$1.19{\pm}0.08^{def}$	2	52.9	Effective
HUFBR39M6	$65{\pm}7^{e}$	$48{\pm}6.6^{ed}$	$1.1{\pm}0.2^{ef}$	1	48.9	Less effective
HUFBR50M7	$123{\pm}7^{bcd}$	$72.3{\pm}4.9^{bc}$	$2{\pm}0.15^{ab}$	4	88.9	highly effective
HUFBR18M8	$52{\pm}3^{e}$	$55.7{\pm}24^{cd}$	$1.2{\pm}0.2^{efd}$	2	53.3	Effective
HUFBR24M9	$118{\pm}8^{bcd}$	$35.3{\pm}3.8^{e}$	$1.3{\pm}0.15^{ced}$	2	57.8	Effective
HUFBR16M10	$128{\pm}4^{bc}$	$53{\pm}6.6^{d}$	$1.7{\pm}0.1^{bc}$	3	75.6	Effective
N^{+}	0.00	0.000	$2.25{\pm}0.25^{a}$		100	

N^-	0.00	0.000	0.76 ± 0.06^{fg}	33.8
	23.614	17.185	0.4436	

Units within a column followed by same letter(s) are not significantly different at P ≤0.05.1= White; 2=Pink; 3= slightly dark red; 4= Deep dark red; N^-=Uninoculated and unfertilized control; N+ = N fertilized control; LSD = Least significant difference; NDW = Nodule dry weight; SDW = Shoot dry weight; SE = Symbiotic effectiveness;
Std Dev= Standard deviation

Generally some mutants (HUFBR12M3 and HUFBR23M5) showed higher number of nodule dry weight as compared to its parental isolates of HUFBR12 and HUFBR23, respectively. However, about 80% of the mutants showed decreased nodule dry weight as compared to their parental types of wild isolates (Table 2). In line with this finding, Williams (1981) found two mutants (M1 and M2) of Cow pea *Rhizobium* that showed decreased nodule dry weight as compared to plants inoculated with the wild type isolates and he also found mutants (M3) which produced more nodule numbers and increased nodule dry weight than plants inoculated with its parental type strain.

With reference to SDW, 50% of theinoculated mutants induced significantly increased accumulat ions of shoot dry mass over the negative control, whereas 80% of inoculated mutants showed significantly decreased SDW than the positive control (Table 2). The least shoot dry weight 0.44g/plant and 0.58g/plant were produced by plants inoculated with mutant HUFBR12M4and HUFBR12M3, respectively. The maximum SDW (2g/plant) was scored by plants treated with HUFBR50M7 followed by SDW of 1.79g/plant, 1.7g/plant and 1.61g/plant produced by plants inoculated with mutant HUFBR50M1, HUFBR16M10 and HUFBR31M2, respectively. The mean SDW produced by plants inoculated with mutants was 1.33g/plant, which was slightly lower than the mean shoot dry weight (1.61g/plant) of plants inoculated with wild isolates.

In this study only two mutants (HUFBR50M7 and HUFBR16M10) showed higher shoot dry weight than its parental type isolates of HUFBR50 and HUFBR16, respectively, but all other mutants recorded lower shoot dry weight than plants inoculated with its parental type. In this regard, Sharma and Yadav (2012) reported that shoot dry weight of pigeon pea plants infected with $PRODH^-$ mutants of *Rhizobium* sp. (*Cajanus*) was significantly lower for all mutants than the plants inoculated with parental strain.

The overall correlation in the sand experiment revealed that nodule number was associated positively and significantly ($r = 0.63$, $P < 0.0001$) with nodule dry weight. Shoot dry weight showed a positive correlation with nodule number at ($r = 0.1$, $p > 0.05$). Similar to this finding, Tejera *et al.* (2005) showed a positive and significant correlation of SDW with nodule numbers upon mutant inoculation on *Phaseolus vulgaris.*

The mutants were also evaluated by nodule color examination scaled visually from 1 to 4 (Table 2). Seven (70%) of mutants displayed pink to dark red colored nodules hence, these mutants showed a positive symbiosis. Three other mutants such as HUFBR12M3, HUFBR12M4 and HUFBR39M6 produced white nodules and showed poor nitrogen fixation (Table 2). Mutants such as HUFBR12M3 and HUFBR12M4 lost their ability to fix nitrogen, but their parental isolate (HUFBR12) was highly effective in nitrogen fixation. Similar to this finding, Qing-Sheng *et al*. (1982) identified eight mutant strains of *R. leguminosarum,* which formed nodules on pea plants but were unable to fix nitrogen.

Symbiotic effectiveness data of mutants showed that mutant like HUFBR50M7 was highly effective, and 60% of mutants were effective. Mutant HUFBR39M6 was less effectiv e, whereas 20% of mutants (HUFBR12M3 and HUFBR12M4) were ineffective

This study showed that two azide resistant mutants (HUFBR50M1 and HUFBR31M2) showed similar symbiotic effectiveness with their parental type but one azide resistant mutant (HUFBR12M3) and Hydroxylamine hydrochloride resistant mutant (HUFBR12M4) exhibited ineffective nitrogen fixation unlike their parents which were highly effective in nitrogen fixation. Another Hydroxylamine hydrochloride resistant mutant (HUFBR39M6) showed decreased nitrogen fixation ability than its parental type isolates (HUFBR39), but two other mutants HUFBR16M10 (UV resistant) and HUFBR50M7 (Hydroxylamine hydrochloride resistant) exhibited better symbiotic effectiveness as compared to their parental isolates HUFBR16 and HUFBR50, respectively. In line with this result, Shashi *et al*. (1997) identified that nine AzR mutants of *R. loti* were characterized for their symbiotic behavior with *Lotus pedunculatus* plants. In comparison to the wild type parent strain, AzR mutants exhibited either similar or higher symbiotic effectiveness. The *azi* mutations which enhanced nitrogen fixation as well as improving shoot dry weight of the inoculated plants also increased nodulation.

SE (%) measurement showed that 2 (20%), 1 (10%), 6 (60%) and 1 (10%) characterized to be ineffective, less effective, effective and highly effective, respectively. Here, 60% of the mutants were identified to be symbiotically effective; likewise, 78% of the wild isolates were symbiotically effective. Similar to this result, AZR mutants with improved symbiotic effectiveness have also been reported in *R. leguminosarum bv.viciae* (Ram *et al*., 1978) and in R. phaseoli (Membrillo-Hernandez *et al.*, 1990). Two mutants (HUFBR12M3 and HUFBR12M4) have lost their symbiotic effectiveness due to the mutagens which could result in the loss of symbiotic effectiveness. These mutants induced nodulation upon inoculation on faba bean plants, but they were unable to fix nitrogen. This finding is in line with Qing-Sheng *et al.* (1982) who reported that eight mutant strains of *R. leguminosarum* were identified which formed nodules on pea plants, but were unable to fix nitrogen.

Evaluation of Symbiotic Effectiveness of Selected Mutants on Unsterilized Soil

Selected mutants were evaluated in their performance on unsterilized soil under green house condition. The performance of the isolates was evaluated with the parameters such as nodule number, nodule dry weight, and shoot dry weight, percent of nitrogen as well as N content of the plant. With regard to nodulation; the highest nodule number (170/plant) was recorded by plants inoculated with mutant HUFBR50M7. This mutant showed 55.9% and 220.75% increased in nodule number over the negative and positive control, respectiv ely. All mutants significantly stimulated higher number of nodule production than the positive control. The average nodule number produced by the mutants was 120 nodules per plant which showed 34.83% increase than the average nodule number of mutants on sand culture. The mean nodule number of effective mutants on unsterilized soil showed 17.64% of increase over the mean nodule number produced by effective wild isolates on unsterili zed soil.

Inoculation of mutants in faba bean did not show significant difference with that of the negative control. Only one mutant (HUFBR50M1) showed significantly higher NDW over the positive control (Table 3).The highest nodule dry weight was induced by plants inoculated with HUFBR50M1. This mutant showed 49.78% and 23.57% of increase over the positive and negative control, respectively. The least nodule dry weight (59.3mg/plant) was scored by plants inoculated with HUFBR31M2. The mean nodule dry weight (61.56mg/plant) on soil test scored 13.07% of increase over the mean nodule dry weight (54.44mg/plant) produced by mutants over sand culture.

Plants inoculated with HUFBR50M1 mutant showed significant variation in SDW than other inoculated mutants on unsterilized soil at ($p < 0.05$). The mean SDW (2.96g/plant) was 122.56% higher than the mean SDW (1.33g/plant) of plants inoculated with mutants on sand culture. The data on percent nitrogen showed that the positive control was significantly higher than plants inoculated with mutants such as HUFBR31M2 and HUFBR50M7. Plants inoculated with HUFBR50M1 produced significantly the highest percent nitrogen (3.77) than all other inoculated mutants on unsterilized soil. The average percent N (3.02) of inoculated plants with selected mutants was slightly higher than the average percent of N (2.97) inoculated plants with selected wild isolates on faba bean of unsterilized soil. Similarly, Sharma and Yadav (2012) reported that percent shoot nitrogen and total shoot nitrogen of the plants infected with ProDH- mutants of *Rhizobium* sp. (*Cajanus*) were significantly lower for all mutants than the pigeon pea plants inoculated with parent strain.

In the determination of N content, mutant HUFBR50M1 showed significantly the highest N content (0.142) than other inoculated plants. This mutant was very effective to compute with the wild isolates. From the selected mutants 3 (75%) such as HUFBR31M2, HUFBR50M7 and

HUFBR16M10 were not significantly different in N content with that of the negative control (Table 3). This indicates that the nitrogen fixing capacity of mutant inoculated plant was not effective to make a difference and slightly less competent than indigenous rhizobium on unsterilized soil. To this regard, Jansen *et al. (*2005) and Ma *et al. (*2004) reported that some factors such as genotype of the competing rhizobial strains and adaptation to stress during early symbiotic intraction in the new environment have been shown to contribute for the variations of the outcomes of N- fixation. It is therefore different factors in the soil which may have played a role for superior competitiveness of indigenous rhizobia over the isolates on unsterilized soil.

In this study the overall correlation in the soil experiment revealed that nodule number was associated positively and significantly ($r = 0.71$, $P < 0.001$) with nodule dry weight. Shoot dry weight was found to be positively correlated with percent N ($r=0.57$ $P<0.01$) and with plant total nitrogen content ($r = 0.73$, $P < 0,001$). A similar result was reported on *R. leguminosarum* var. viciae nodulating lentil by Anteneh Argaw (2012).

Conclusion

A total of 50 rhizobial isolates were obtained and characterized wigth respect to their salt tolerance, pH tolerance, and symbiotic effectiveness. All isolates were exposed to physical and chemical mutagens to evaluate the effect of mutagen on enhancement of tolerance to salt and pH. Azid mjutation was the most potent mutagen to enhance salt tolerant mutant by maintaining its symbiotic effectiveness at significant level.

Acknowledgment

The financial support provided by the Research Office, Haramaya University, Ethiopia, Haramaya, is gratefully acknowledged.

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Enhancement of tolerance to high Salinity and Extreme pH conditions in Common Bean (*Phaseolus vulgaris L.*)-Nodulating Rhizobial Isolates from Hararghe Lowlands and Mid-altitudes, Eastern Ethiopia, through Physical and Chemical Mutagenesis

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Abstract: The intent of this study was to examine the effectiveness of chemical and physical mutagenesis on enhancement of tolerance of common bean (*Phaseolus vulgaris L.*) nodulating rhizobial isolates of Hararghe lowlands and mid altitudes to extreme salinity and pH conditions. A total of 50 isolates were obtained from soil samples of these areas using the host trap method and were presumptively identified as rhizobia. Of these, only five isolates were highly effective in forming symbiotic association with common bean. With the exception of HUCR 3D, all the highly effective isolates showed significantly higher ($p < 0.05$) nodule number than both positive and negative controls did. Physiological tests revealed that among the 50 wild isolates, 43(86%), 37(74%), 29(58%), 6(12%), 4(8%), and 2(4%), grew at 2%, 4%, 6%, 8%, 9%, and 10% NaCl concentration, respectively. 50(100%) of the isolates grew in the range of pH 5.5 - 8.5. Two (4%) and 38(76%) of the isolates also grew at pH 4.5 and pH 5 while 48(96%), 43(86%), 40(80%) and 37(74%) of the isolates were able to grow at pH 9, pH9.5, pH10 and pH 10.5 respectively. After mutagenesis, a total of 8 mutants were selected based on their ability to survive at extreme salt and pH conditions. Of these, six of the mutants were found to be symbiotically highly effective. The nodule number of the mutants was positively and significantly correlated with nodule dry weight ($r = 0.85$, $P < 0.0001$) on sand culture. Six of the highly effective mutants were also tested on unsterilized soil in controlled growth chamber. The data showed that the different rhizobial inoculants displayed variation in nodule number, nodule dry weight, shoot dry weight, plant total nitrogen and N content of the inoculated common bean plants. The correlation data on soil experiment displayed that nodule number was associated positively and significantly ($r = 0.73$, $p<0.0001$) with nodule dry weight while shoot dry weight was positively correlated with percent nitrogen ($r = 0.8$, $p<0.0001$) and total nitrogen content ($r = 0.9$, $p<0.0001$). Physiological test of mutants also showed that 5(63%) and 3(36%) of mutants were able to grow at salt concentrations of 11% and 12%, respectively; 3(38%), 4(50%), 2(25%) and 2(13%) of the mutants were able to grow at pH 4, 11, 11.5 and 12 respectively. Among the observed *Rhizobium* isolates, HUCR (3D, 3A), HUCR 2D and HUCRM 2D showed the highest symbiotic effectiveness. In contrast, only the mutant isolates HUCRM2D tolerated 12% NaCl, pH4-pH12; HUCRM5C tolerated 12% NaCl, pH 4 and pH 5; HUCRM3B tolerated 12% NaCl; and HUCRM9C tolerated 11% NaCl. Thus, on the basis of their symbiotic effectiveness and tolerance to extreme environmental conditions, these wild and mutant isolates were recommended to be used as candidates for future development of rhizobial inoculants of common bean grown under extreme saline and pH conditions.

Key words: Common bean, Physical and Chemical mutagenesis, Rhizobia, Tolerance to extreme salinity and pH

Introduction

In Ethiopia common bean is considered as the main cash crop and protein source of farmers in many lowlands and mid altitude areas. The country's common bean export earnings is estimated to be over 85% of the export earnings from other pulses; exceeding that of the other pulses such as lentils, faba bean and chickpea (Negash, 2007). Overall, common bean ranks third as an export commodity in Ethiopia, contributing to about 9.5 % of the total export value from agriculture (FAOSTAT, 2010). Total national production of common bean was estimated at 421,418 tons in 2008, with a market value of US$ 132,900,609 million (FAOSTAT, 2010).

Common bean contains high protein content and a good source of energy; provides folic acid, dietary fiber and complex carbohydrates (Buruchara, 2007). Common bean protein is high in lysine, which is relatively deficient in maize, cassava and rice, making it a good complement to these staples in the diet. Consumption of common bean is high mostly because it is relatively inexpensive compared to meat. For the poor, common bean plays a strategic role in alleviating malnutrition but other health related functions exist (Pachico, 1993).

Common bean is an important component of subsistent cropping systems because of its ability to form nodules in symbiosis with rhizobia, which convert atmospheric nitrogen (N_2) into utilizable form of ammonia, to add substantial amount of organic matter to the soil and to grow better than many other crops with low inputs under harsh climatic and edaphic conditions (Peoples and Craswell, 1992). Thus, the inclusion of common bean into the existing cropping systems has the potential to reduce or eliminate inorganic nitrogen fertilization due to its ability to fix N_2 from the atmosphere (Houngnandan *et al*., 2000). Common bean is specifically nodulated by different groups of root nodulating bacteria belonging to the genus *Rhizobium*.

The host legume appears to be a limiting factor for establishing *Rhizobium*-legume symbiosis under acidic and saline soil conditions. Legumes have different reaction to low pH with regard to growth and nodulation. In recent times, it has been found that the amount of N_2 fixed by forage legumes on low-fertility acidic soil is dependent on legume growth and persistence (Thomas, 1995). On the other hand, selection of acid-tolerant rhizobia to inoculate legume hosts under acidic conditions will make certain establishment of the symbiosis and also successful performance (Correa and Barneix, 1997; Glenn Dilworth, 1994). Therefore, acid tolerance in *Rhizobium* species is an advantageous agronomic attribute. In addition, some natural isolates of *Rhizobium* are reported to be salt tolerant. Inoculation of *Phaseolus vulgaris L.* with efficient and more successful *Rhizobium* strains (wild or mutants) will have significant economic and ecological benefits.

Almost no work has been done on *Rhizobium* mutagenesis to enhance their tolerance to high salinity and extreme pH conditions in Ethiopian soils. So this study was undertaken with the aim of examining the effect of chemical and physical mutagenesis on the enhancement of tolerance to high salinity and extreme pH conditions in some Ethiopian lowland and mid altitude common bean nodulating *Rhizobium*.

Materials and Methods

Soil Sample Collection

The soil samples were collected from ten areas known for growth of tropical pulses in Eastern Hararghe lowland and mid altitude areas around Babile, Ethiopia, in April, 2012. From each area, five bulk samples (about 3 kg of soil) were randomly excavated using auger and collected in sterile polyethylene bags from farmer̓s fiels.

Induction of nodulation

Soil samples were sieved to (0.2mm) and each filled in 3kg sterile plastic pots to induce nodulation on the host. Five seeds of common bean (*Phaseolus vulgaris L*.) Gofta (G-2816) variety was sown in each pot (3 Kg) in the greenhouse of Haramaya University. The pots were watered every three days for 45 days. After 45 days, the plants were uprooted from the pots and intact pink nodules from the root were detached and transported through vials containing silica gel to Haramaya University Microbiology Laboratory.

Isolation and Preservation of Rhizobia

Nodules were surface sterilized in 70% ethanol and then in 0.15 acidified $HgCl_2$ for 3 minutes (Subba Rao, 1999). Surface sterilized nodules were washed at least 10 times by successively washing with sterile water to Fig 1. The geographical location of the sampling sites (Fedis, Babile, and Gursum woreda) within the map of Ethiopia. The nodules were washed to remove the contaminants completely. The nodules were then placed in 0.1N NaCl solution and a few drops of distilled sterile water and crushed with a sterile glass rod. The suspension was then plated on YEMA (Yeast Extract Mannitol Agar) and incubated at 28^{o}C for 3 to 5 days. All isolates were repeatedly sub cultured on YEMA for purity and were preserved on YEMA slants containing 0.3 % (w/v) $CaCO_3$ in a slant culture and stored at 4 ^{0}C for future use (Somasegaran and Hoben, 1994; Suba Rao, 1998). In this manner, 50 isolations were isolated.

Designation of the isolates

Each isolate was designated as HUCR (Haramaya University Common bean *Rhizobium*) for the wild isolate and HUCRM (Haramaya University Common bean *Rhizobium* Mutant) for the mutant isolates followed by different numbers.

Determination of Salt and pH Tolerance of wild Rhizobia

The *in vitro* pH tolerance among the isolates was determined using the method described by Lupwayi and Haque (1994). Media plates of YEMA containing various concentrations (2%, 4%, 6%, 8%, 9%, 10%, 11%, and 12%) of sodium chloride or TY agar media adjusted to pH levels of 4-10.5 (for pH tolerance) were prepared and inoculated with appropriately diluted pure cultures. The plates were then incubated at 30^{o}C for four days. Finally, the growths of the rhizobial strains were qualitatively evaluated as negative (-) for no growth and positive (+) for growth.

Evaluation of symbiotic effectiveness of wild common bean rhizobia in sterilized sand culture

Fifty pure isolates that qualified the presumptive test were further tested for authentication. Fine graded river sand was washed in tap water and immersed in concentrated sulfuric acid (H_2SO_4) for two days. It was washed in several changes of tap and distilled water to get rid of the last traces of the acid and autoclaved for 1.5 hours before filling into 3 kg capacity plastic pots which were surface sterilized with 95% ethanol (Lupwayi and Haque, 1994). Two hundred fifty common bean seeds, of Gofta (G-2816) variety, and uniform size and color were surface sterilized by suspending for 10 minutes in 3-5% H_2O_2 with washings of several changes of distilled water (Lupwayi and Haque, 1994). The sterilized seeds were then transferred to petridishes filled with distilled water and incubated at 25^{o}C for 3 days for germination. Five pre-germinated seedlings were transferred into each pot, which were later thinned to three after a week of planting. Each seedling was inoculated with 1ml culture of each isolate adjusted to an inoculums size of 10^{9}cell/ml. The pots with seedlings were subsequently supplied with distilled water every two days and fertilized once a week with quarter strength of Broughton and Dilworth N-free medium described in Somasegaran and Hoben (1994).

The pot experiments were laid down in randomized complete block design (RCBD) with three blocks or replications in a greenhouse. As controls, each block contained two pots, negative control with no chemical fertilizer (no KNO3) and no inoculum (Con-) and positive control with chemical fertilizer (Con^{+}) (0.05% KNO3) and absence of inoculum.

Forty five days after sowing, the plants were harvested and their roots were scored for nodulation. The shoots of plants as well as the nodules were then oven dried to determine their dry weight at $70^{0}C$ for 48 hrs at HU Microbiology laboratory. Symbiotic effectiveness (SE) of the isolates was calculated according to the equation:

$$SE= \frac{Inoculated\ plant\ SDM}{N-Fertilized\ plant\ SDM} \quad x \quad 100$$

Then, symbiotic effectiveness (SE) of isolates were rated as ineffective, lowly-effective, effective and highly effective, when the calculated values were <35%, 35-50%, 51-80%, and >80 %, respectively (Beck *et al*., 1993). The same methods were used for the symbiotic effectiveness of mutant isolates

Evaluation of Symbiotic Effectiveness of Wild Common bean Rhizobia in Unsterilized soil

The effectiveness of five selected isolates was determined in the pot experiment using unsterilized soil in the greenhouse of Haramaya University. The soil was well mixed, sieved (<2mm) and air–dried. 3 Kg of Babile soil was distributed to plastic pots. Twenty five common bean of “Gofta (G-2816) Variety” was surface sterilized as before and rinsed in five changes of sterile distilled water. Five un-germinated seeds were sown in each pot and later thinned down to three after germination for one week. After a week, each seedling was inoculated with 1 ml of each isolate grown for 72 hrs in YEM broth (10^{9}/ml). The experiment was set up in triplicates in the greenhouse and the pots were arranged in complete random design with each block consisting of negative control (without nitrogen and without inoculum) and positive control (without inoculum but with nitrogen). The nitrogen fertilizer (KNO_3) was given at a concentration of 0.5 g / l per week until the plants were harvested. All the pots were watered every two days. The same methods were used for the symbiotic effectiveness of mutant isolates.

Plant total nitrogen content analysis

The modified Kjeldhal method was used to evaluate the nitrogen content of the plant samples.

$$\text{Nitrogen (\%)} = \frac{(a_1-b_2) \times N \times 0.014}{S} \times 100$$

Where, a1 = ml of titrant used for the sample

b_2 = ml of titrant used for the blank

N= Normality for the acid

S = weight of the plant material

Total N uptake was calculated as:

$$\text{N content} = \frac{\%\ N \times SDW}{100}$$ (Ogutcu *et al.*, 2008)

Chemical mutagenesis

Hydroxylamine hydrochloride and sodium azide were used as chemical mutagenic agents to induce mutation in *Rhizobium* isolates as described by O'Connel *et al.* (1990). Late exponential phase cultures (approximately 2 x 10^8 cfu ml^{-1}) were used in all mutagenesis experiments. The cells of rhizobial isolates were first pelleted in an eppendorf micro centrifuge, washed once with phosphate-buffered saline (0.876gm NaCl, 0.522gm K_2HPO_4, 0.136 gm KH_2PO_4 per 100 ml), and re-suspended to the original volume in phosphate-buffered saline solution. From the stock solution of each mutagenic substance (1.17g/ml), 0.0, 100, 200 and 300µl was added into each ml of rhizobial culture suspension. After mixing with a vortex, the cells were incubated at room temperature for 60 minutes. The mixture was then diluted and spread plated on TY agar medium without salt. After three days of incubation at 28±2 ^{O}C, colonies of *Rhizobium* were observed and only those colonies that were grown in all the three different mutagenic chemical concentrations were selected as survivors. These survivors subjected to high salinity (< 10% NaCl) and extreme pH (pH <4 & pH >10.5) conditions in a growth media. Only those rhizobia grown in these extreme conditions were taken as true mutants.

Physical mutagenesis

Physical mutagenesis was carried out according to the method described by Miller (1972). Late exponential phase cultures (approximately 2 x 10^8CFU ml^{-1}). Pure culture of each *Rhizobium* isolate was first plated in an eppendorf micro centrifuge, washed twice; and re-suspended in phosphate buffer. The cell suspension (5ml) was spread thinly on an open glass petridish and exposed for 15 seconds to UV radiation at 2000µw/cm^2(315-400 nn) intensity. Each irradiated suspension was streaked on a petridish containing TY agar media and incubated at 28^{O}C for three days. The surviving colonies were transferred to other fresh media for preservation and further physiological tests. Thus, further screening was made to select desired mutants based on their ability to withstand extreme pH conditions, high salt concentrations, and temperatures higher than the usual.

Selection of Salt and pH Tolerant *Rhizobium* Mutants

Serial dilution of pure culture of selected mutants was prepared. Following this, aliquots of the appropriate dilutions were spread on sterile TY agar media containing various concentrations of sodium chloride (11, 12, 14, 16 and 18%) and measuring different levels of pH (pH < pH 4 and pH>10.5) to test the levels of salt and pH tolerance of the test strains. Colonies that appeared on TY agar media containing concentrations of NaCl higher than the maximum required for the wild type *Rhizobium* (i.e 10%) and colonies on media adjusted to pH values lower than the minimum (pH 4) or higher than the maximum (pH 10.5) required for the wild type *Rhizobium* were selected as salt and pH tolerant mutants, respectively (Bernal and Graham, 2001; Abbdel Hamid *et al*., 2011).

Determination of Symbiotic Effectiveness of Mutant Rhizobial Isolates

The symbiotic effectiveness of the selected mutant rhizobial isolates on sterilized sand and unsterilized soils was determined using pot experiments in a growth chamber of Agronomy laboratory at Haramaya University. Percentage symbiotic effectiveness of isolates was calculated according the equation proposed by Lupwayi and Haque, (1994). Symbiotic effectiveness was then classified as in the classification used for the non-mutant isolates, i.e. ineffective, <35%; lowly-effective, 35-50%; effective, 51-80%; and highly effective, >80% (Beck *et al*., 1993).

RESULTS AND DISCUSSION

Physiological Characterization of Wild Type *Rhizobium* Isolates

Salt tolerance

The isolates displayed growth differences on YEMA medium adjusted to different NaCl concentrations. Among the 50 isolates 43(86%), 37(74%), 29(58%), 6(12%), 4(8%), and 2(4%), were grown at 2%, 4%, 6%, 8%, 9%, and 10% of NaCl on YEMA medium, respectively. The most salt tolerant isolates were HUCR9A and HUCR7B from Babile grown at 10% NaCl concentration. On the other hand, isolates HUCR (9C, 10A, 10B, 10C, 12B, 12C) from Babile were found to be within a narrow range of salt tolerance up to 2% of NaCl concentration and HUCR(3C,5D,12E,13A,13B,13C,13E) were the most sensitive isolates which did not grow at 2% of NaCl concentration. In the same way, Anteneh Argaw (2007) reported that usually fast growing rhizobia grew well between 3-5 % concentrations of NaCl. It is obvious that *Rhizobium phaseoli* is amongst the salt tolerant rhizobia and a number of isolates have been reported to tolerate high salt concentrations between 4%-5%. Likewise, two isolates of common bean from southern Ethiopia tolerated higher concentration of salt as reported by Alemayehu Workalemahu (2006).

pH Tolerance

The tolerance to pH changes varied amongst the tested isolates. In this study growth was evidently detected from pH 4.5-10.5. 100% of the isolates were found to grow in the range of pH 5.5-8.5. Four percent of isolates were adapted to grow at pH 4.5, whereas 80% of the isolates managed to grow at pH 10. Only two isolates from Babile HUCR (2C,5C) managed to grow on all the tested pH values whereas, the isolates that were found to be sensitive at pH 10.5 were isolates HUCR(2A,5E,7E,10A,10B,10C,10E,12D,13A,13C,13) from Babile and HUCR (3A,3E) from Fedis. All isolates from Gursum, Fedis and 96% of the isolates from Babile failed to grow at pH <5. In line with this, Alemayehu Workalemau (2006), Anteneh Argaw (2007) revealed that acid producing rhizobia are poor in tolerance to low soil pH conditions.

Evaluation of symbiotic effectiveness of common bean wild rhizobia under sterilized sand in pot experiment

All the 50 rhizobial isolates in this study were able to induce nodulation on common bean (*Phaseolus vulgaris L.*) and were subsequently authenticated as true rhizobial isolates (Vincent, 1970). In line with this, Rahmani *et al*. (2011), Esubalew Sintie,(2011) and Kassa Baye,(2011) on common bean, with lupine and field pea legumes reported that all their rhizobial isolates were successful in nodulating their host plants. Visual observation of the outward appearances of inoculated plants had also shown that they were visibly different from the negative control. The control plants (specially the negative control) appeared relatively dwarf and pale green while the inoculated plants appeared deep green with long shoots, many branches and pink to red nodules, indicating that the latter performed better than the control in terms of atmospheric nitrogen fixation process. The inoculated plants showed significant variations ($p< 0.05$) in nodule number, nodule dry weight and shoot dry weight. The least number of nodules was recorded for the plant inoculated with isolate HUCR13C (28/plant) and the highest was for the plant inoculated with isolate HUCR2A (140/plant) both from Babile woreda. Similarly, 0.043g/plant and 0.28g/plant were the smallest and highest nodule dry mass recorded for plants inoculated with isolates HUCR10B and HUCR3C, respectively. In line with this, Anteneh Argaw (2007) reported that the smallest and the highest nodule dry mass were 0.041gm/pl and 0.215 gm/plant in eastern Ethiopian soils. The highest (1.8g/plant) and the least (0.33g/plant) shoot dry matter accumulations were recorded from plants inoculated with isolate HUCR3D and isolate HUCR5A, respectively. Plants inoculated with isolates HUCR2A, HUCR3A and HUCR3D showed significantly ($p<0.05$) higher nodule number, nodule dry weight and shoot dry weight than any of the other inoculated plants, respectively.

The accumulated shoot dry matter in host plants was used to evaluate the relative symbiotic effectiveness of the isolate. According to Somasegaran and Hoben (1994), Lupwayi and Haque (1994) shoot dry matter is a good indicator of the relative symbiotic effectiveness of the isolates and a positive correlation between the nitrogen fixing capacity of legumes and their shoot dry matter accumulation. Such correlation of nodule number and nodule dry weight with shoot dry weight is a good indicator of the nitrogen fixing efficiency of isolates and, hence, these parameters can be used to determine the symbiotic effectiveness of legume nodulating-rhizobia (Peoples *et al.*, 1992). Correlation among variables in the sand experiment for wild rhizobia confirmed that nodule number were correlated positively and significantly ($r = 0.4$, $P < 0.0001$) with nodule dry weight. A similar correlation result was documented by Khondaker *et al*. (2003) who reported a correlation index of $r = 0.32$, for the association of nodule number with nodule dry weight with regard to inoculation of pea varieties.

Regarding the relative symbiotic effectiveness 52%, 46% and 2% of the isolates were found to be highly effective, effective and ineffective respectively. Considering the site of location, all isolates from Gursum, 61% of the isolates from Babile and 17% of the isolates from Fedis woreda were highly effective. Four percent of the isolates from Fedis and 96% of the isolates from Babile woreda became effective.

The highest scores of effectiveness of symbiotic nitrogen fixation were displayed by HUCR (3D, 3A,2D,2C,3C,14D,14C,6B,7B,9C,13A,13B,14A,14E,2A,6C,13C,2B,2E,3E,7C,13D,14B) shoot dry mass >0.8g/plant. Isolate HUCR5A from Babile soil obtained to be ineffective which was observed to be smaller than the ineffective equivalent of 0.414g/plant showed by negative control. In this study, 98% of the isolates were categorized into effective and very effective groups. In a similar work, Alemayuhu Workalemahu, (2006), Anteneh Argaw, (2007) reported that more effective isolates were obtained from wide range of geographical locations and pH ranges of south and east Ethiopia soils respectively. Hopefully this is an indication for the survival and abundance of more effective soil rhizobia in Ethiopia.

Evaluation of Symbiotic Effectiveness of wild Common bean Rhizobia under unsterilized soil in pot experiment

From the sand culture HUCR(3D,3A) from Fedis, HUCR(2D,2C) from Babile and HUCR14D from Gursum were the five highly effective isolates selected as inoculants for Common bean plant and tested on Babile soil under greenhouse condition at Haramaya University main campus.

In this study the different rhizobial inoculants showed variation in nodule number, nodule dry weight, shoot dry weight, N percent and N contents on the inoculated common bean plants. In line with this, Amarger *et al., (*1996) reported that symbiotic effectiveness of rhizobial isolates showed variation in nodulation, shoot dry weight, nodule dry weight and total nitrogen of legumes.

HUCR3A was the isolate that induced the highest nodule number (120 per plant) followed by isolates HUCR2C and HUCR2D with nodule number of 117 per plant and 110 per plant respectively. The least number of nodules was induced by plants inoculated with isolates HUCR3D and HUCR14D with nodules number 52 per plant and 99 per plants correspondingly. All isolates except HUCR 3D showed significantly ($p < 0.05$) higher nodule number than both positive and negative controls and isolate HUCR 14D showed significantly ($p<0.05$) higher shoot dry weight than other plants.

This study, showed that there were positive correlations amongst number of nodules and dry weight of nodules ($r = 0.8$, $p<0.0001$), dry weight of shoot and N content ($r = 0.73$, $p<0.0001$). Lalande *et al*., (1990) and Mungai and Karubiw (2008) observed positive significant correlation ($r=0.96$, $p< 0.01$; $r=0.3$, $p<0.06$) between shoot dry weight and N content using *Rhizobium leguminosarum* bv *phaseoli* isolates.

Comparing the nodule number of the controls with the inoculated plants, the least nodule number for the inoculated plant (52 per plant) was greater than the nodule number of positive control by 85% and the nodule number of negative control by 42%. Even comparing the nodule number of the positive control with the negative control, the negative control nodule number was greater than the nodule number of the positive control by 73 %. Possibly beside other several influencing factors, inhibitory effects of fertilizer and nitrogen treatment were responsible for the inadequate symbiosis between the positive control and the rhizobia in the soil Giller, (2001); Ümmühan and Uyanoz, (2012).

In this study, 0.226 g/plant and 0.155 g/plant were the highest and the lowest nodule dry weight recorded from plants inoculated with isolate HUCR3A and HUCR14D correspondingly. Contrary to this, on common bean Ümmühan and Uyanoz, (2012) reported that 1.56 and 0.41 g/plant were the highest and the lowest dry weight of nodule, which is by far greater than the present result. The average nodule dry weight value obtained in this study 0.16 g/plant is found to be higher than the mean nodule dry weight values of other legumes such as Faba bean

0.032g/plant by Zerihun Belay,(2006) and 0.058g/plant by Getaneh Tesfaye,(2008) on Ambagiorgis and Sebeta soils, respectively. At the same time it is also higher than the nodule dry weight value 0.085g/plant and less than the nodule dry weight value 0.227g/plant of White Lupin (*Lupius albus L.*) by Esubalew Sintie, (2011) on Holeta and Sekela soil respectively.

HUCR14D was the isolate that induced the highest shoot dry weight 2.243 g/plant followed by isolates HUCR3A and HUCR2D with shoot dry weight of 1.333 and 1.103 g/plant in that order. The least shoot dry weight was 0.544 g/plant induced by isolate HUCR3D. The highest shoot dry weight 1.96 g/plant which is documented for Awash Melka Variety on Melkassa soil by Anteneh Argaw, (2007) is smaller than the highest shoot dry weight 2.243 g/plant of this study by 12% but the highest shoot dry weight of this study is less than the maximum shoot dry weight 3.07 g/ plant of Ayenew variety on Melkassa soil by 28%. On Babile soil, the highest shoot dry weight 1.14g/ plant of Awash Melka variety and 1.87 g/plant of Ayenew variety which is announced by the same researcher is smaller than the maximum shoot dry weight of the present study by 48% and 15% respectively. The recorded maximums shoot dry weight 2.243 g/plant of this study on Babile soil is greater than the shoot dry weight of the positive and negative control by 23% and 77%, respectively.

Concerning % N, 2.5% N/gm for a plant inoculated with isolate HUCR3D and 2.1% N/gm for a plant inoculated with isolate HUCR14D were the highest and the lowest record for this study. Here the % N of the negative control decreased from lowest value % N of this study by 24%.

Isolation of Mutant *Rhizobium* cells

Among the 50 presumptively tested and authenticated wild *rhizobium* isolates following the physical and chemical mutagenesis, a total of 65 survivors (22 from sodium azid, 24 from Hydroxylamine hydrochloride and 19 from UV) were isolated at Haramaya University Microbiology laboratory and Plant Science Pathology Laboratory. Out of these, only 8 of the survivors have been selected as mutants for further studies based on their ability to survive extreme conditions such as high salt concentrations, pH and temperature. Isolates HUCRM (2D, 5C, 7D, 9A, 9C, 12E) were mutants that were developed from chemical mutagenesis. Among these, chemically induced mutant isolates HUCRM (2D, 9C, 5C) and HUCR (7D, 9A, 12E) were induced through the effects of mutagenic chemicals sodium azide and hydroxylamine hydrochloride, respectively. HUCRM 3B and HUCRM 14A were the other mutant isolates that were obtained through physical mutagenesis at pathology laboratory. All chemically induced rhizobium mutants were isolated from Babile soils while the UV induced mutants were from both Fedis and Gursum, respectively.

Physiological Characterization of *Rhizobium* Mutant Isolates

Salt Tolerance of Rhizobium Mutant Isolates

From Table 1 below it is possible to observe how many of the mutants were tolerant to different sodium chloride concentrations on TY agar medium. 87.5% of the mutant isolates were successful to grow on a TY agar medium containing 11% NaCl, similarly, 36% and 0% of the isolates were tolerant to the same medium containing 12% and 14% of NaCl concentration.

Mutant isolates like HUCRM (2D, 5C, 3B) were the most tolerant *rhizobium* that grew on the entire medium containing different NaCl concentration except at 14% of NaCl. The most sensitive mutant isolate was HUCR 7 D, which did not, grew in any of the given percentages of NaCl concentration. Isolates HUCRM (9A, 9C, 12E, 14A) were the next other sensitive mutant rhizobia that grew only at 11% of NaCl concentration on TY agar medium.

Table 1. Salt and pH tolerance of rhizobial mutants.

Treatment	Salt tolerance (%)		pH range			
	11	12	4	11	11.5	12
HUCRM2D	+	+	+	+	+	+
HUCRM5C	+	+	+	+	-	-
HUCRM7D	-	-	-	+	-	-
HUCRM9A	+	-	-	-	-	-
HUCRM9C	+	-	-	-	-	-
HUCRM12E	+	-	-	-	-	-
HUCRM3B	+	+	-	-	-	-
HUCRM14A	+	-	+	+	+	-
% of tolerant mutant isolates	87.5	36	38	50	25	13

Key: - HUCRM= Haramaya University common bean rhizobium mutant.

Comparing to the wild *Rhizobium* isolates the mutant isolates observed to be by far tolerant to a medium containing higher concentration of NaCl as high as 11% to 12% of NaCl concentration. At the same time when the highest salt tolerant wild isolates (for example HUCR9A tolerated 10% NaCl on YEMA medium) compared with its mutant derivatives the wild isolate was very sensitive for higher percent of NaCl. In line with this result, Abdel Hamid *et al.* (2011) reported that rhizobial mutants that are induced through Ethyl methane sulphonate tolerated 12% NaCl concentration. Opposite to this, Tejera *et al.*, (2005) reported that the mutant derivatives for the wild salt tolerant *Rhizobium tropici* strain CIAT899 showed a decreased salt-tolerance.

pH Tolerance of rhizobium mutant isolates

In this study, 0 %, 38 %, 50 %, 25 %, 13 % of the isolates tolerated pH of 3.5, 4, 11, 11.5, and 12 on sterile TY agar media. Isolate HUCRM2D tolerated all the provided pH except at pH 3.5 and HUCRM14A was the second most tolerant isolate that tolerated all the given pH except at pH 3.5 and 12. The most sensitive mutant isolate that tolerated narrow ranges of pH condition were HUCRM9C and HUCRM5C all of them were isolated from wild rhizobium isolates of Babile soil. Mutant isolates HUCRM (7D, 9A, 12E and 3B) were not tolerated any of the given pH conditions.

Here comparing to the wild rhizobial isolates mutant rhizobum were observed to tolerate both the upper and lower extreme pH conditions (<4.5 and > 10.5); for example there was no wild rhizobial isolate tolerant for pH 4, 11, 11.5 and 12 except the observed mutants. Likewise comparing the wild type rhizobial isolates, their mutant derivatives showed comparatively superiority in tolerance for both extreme pH conditions. In line with this, Chen *et al*., (1993) reported that some mutants of *R. leguminosarum* have been reported to be able to grow at a pH as low as 4.5, These results are believed to be promising information for farmers to grow legumes particularly under extreme pH conditions in order to make better the yield of the legume.

Table 2. Nodulation data of *Rhizobium* mutants on sterilized sand

Treatment	NN	NDW	SDW	SE (%)	Effectiveness
HUCRM2D	131±1^{a}	0.14±0.04^{a}	1.6±0.4^{a}	177	HE
HUCRM5C	111±1^{b}	0.22±0.00^{a}	1.2±0.1^{b}	133	HE
HUCRM7D	86±31^{c}	0.21±0.01^{a}	1.2±0.1^{b}	133	HE
HUCRM9A	85±1^{c}	0.21±0.01^{a}	0.8±0.1^{c}	89	HE
HUCRM9C	74±1^{c}	0.08±0.00^{b,c}	0.7±0.0^{c}	78	E
HUCRM12E	68±1^{c}	0.08±0.00^{b}	0.8±0.0^{c}	89	HE
HUCRM3B	77±1^{c}	0.1±0.00^{b}	0.7±0.0^{c}	78	E
HUCRM14A	68±1^{c}	0.1±0.00^{c}	0.8±0.0^{c}	89	HE
Control^{-}	0^{d}	0^{d}	0.4±0.0^{d}	-	-
Control^{+}	0^{d}	0^{d}	0.9±0.0^{c}	-	-
LSD($p<0.05$)	18.328	0.0275	0.2469		

Key: SE= Symbiotic effectiveness; % SE= >80 % is highly effective; 51-80 % is effective; - Numbers in the same column followed by the same letters are not significantly different at $p<0.05$(Fisher's LSD).

Evaluation of Symbiotic Effectiveness of Common bean *Rhizobium* Mutant Isolates under sterilized sand in pouch experiment

All of the mutant isolates were tested for their nodulation and symbiotic effectiveness on common bean Gofta (G-2816) variety in sterile pouch using sterilized sand culture, and they were efficient in nodulation and symbiotic effectiveness (Table 2). Inoculated common bean showed significant ($p< 0.05$) increase in all parameters investigated in this study as compared with the both uninoculated common bean plants, negative control and positive control.

Concerning the outward appearances, inoculated plants were visibly different from the negative control. The control plant appeared relatively shorter, less dark green than the inoculated individuals. These indicate that the inoculated plants fixed atmospheric nitrogen well.

In this study, the smallest nodule number record was 68 per plant for a plant inoculated with mutant isolates HUCRM12E and HUCRM14A. The highest nodules number record were 131 and 111 per plant for plants inoculated with isolates HUCRM2D and HUCRM5C correspondingly. Similarly in nodule dry mass 0.08g/plant was the smallest and 0.22g/plant was the highest record for plants inoculated with isolates HUCRM (9C,12E) and HUCRM5C, respectively. The highest shoot dry matter accumulations 1.6 g/plant were recorded from the plant inoculated with isolates HUCRM2D from Babile soil and the least 0.7g/plant were recorded from the plant inoculated with isolates HUCRM3B and HUCRM9C from Fedis and Babile soil respectively. Furthermore, in this study, all isolates resulted in accumulation of shoot dry matter higher than the positive control (N^+).

Plants inoculated with isolate HUCRM2D showed significantly ($p<0.05$) higher nodule number, nodule dry weight and shoot dry weight than any of the other plants. The superiority of isolate HUCRM2D could more likely be due to the contribution of *Rhizobium* species in increasing the biomass through plant growth promoting hormone production such as auxins and indole acetic acid beyond N fixation (Zafar-ul-Hye *et al*., 2007).

Correlation response among variables in the sand experiment for mutant rhizobia confirmed that nodule number were related positively and significantly ($r = 0.85$, $P < 0.0001$) with nodule dry weight. Similar correlation response was documented by Khondaker *et al*. (2003) and Kassa Baye, (2011) who reported a correlation index of (r =

0.68; r= 0.32, P < 0.01) for the association of nodule number with nodule dry weight with regard to inoculation of pea varieties.

Table 3. The effect of *Rizobium* infection on the performance of common bean plants

Treatment	NN	NDW	SDW	Total N(%)
HUCRM2D	136±39^{a}	0.2±0.01^{a}	3±0.5^{a}	2.7±0.6^{a}
HUCRM5C	106±20^{bc}	0.17±0.04^{ac}	2.9±0.6^{ac}	2.4±0.6^{ac}
HUCRM7D	99±21^{bc}	0.15±0.1^{c}	3.4±0.6^{a}	2.6±0.6^{ab}
HUCRM9A	100±1^{bc}	0.16±0.00^{bc}	1.9±0.01^{bc}	2±0.01^{cd}
HUCRM12E	121±1^{ab}	0.19±0.02^{ab}	1.6±0.01^{ab}	2.3±0.1^{ac}
HUCRM14A	95±1^{bc}	0.15±0.00^{bc}	2±0.01^{bc}	2.1±0.1^{bd}
Control^{-}	91±1^{c}	0.15±0.00^{c}	1.6±0.01^{c}	1.6±d0.01^{d}
Control^{+}	77±1^{c}	0.17±0.00^{ac}	1.9±0.01^{ac}	2.4±0.01^{ac}
LSD(p<0.05)	29.41	0.04	0.59	0.61

Numbers in the same column followed by the same letters are not significantly different at p<0.05(Fisher's LSD).

Concerning the relative symbiotic effectiveness, 100% of the isolates were found to be highly effective. This may show us the existence and abundance of indigenous wild *rhizobum* around Babile area which can be induced chemically and become effective in nodulation and biological nitrogen fixation of legumes.

Comparing to the plants inoculated with wild isolates on sand culture, the plants inoculated with mutants got higher means in nodule number, nodule dry mass and shoots dry mass. The means of inoculated plants with mutants in nodule number, nodule dry mass, shoot dry mass were greater than the respective means of inoculated plants with the wild isolates by

13%, 27% and 0.5% correspondingly. In line with this, Ragchaudhuri *et al.*, (2005) reported that the chick pea (*Cicer arietinum*) inoculated with *N*-methyl-*N*-nitro-*N*-nitrosoganidine induced mutant isolates produced higher nodules number, nodule dry weight and shoot dry weight than the chick pea inoculated with wild rhizobia. Similarly, Williams *et al*., (1827) reported that plants inoculated with effective mutant (M_3) nodulated earlier, produced more nodules (58%), and had increased dry weights (26%) than plants inoculated with the wild type. In evaluation of the effectiveness of the wild isolates with that of their mutant derivatives, all mutant isolates scored highly effective (HE). Similarly, Shashi *et al.*, (1997) reported that in comparison to the parent strain, Azide-resistant (AzR) mutants exhibited either similar or higher symbiotic effectiveness.

Evaluation of symbiotic effectiveness of common bean *Rhizobium* mutant isolates under unsterilized soil in pouch experiment

Six highly effective isolates HUCRM2D, HUCRM5C, HUCRM7D, HUCRM9A, HUCRM12E, and HUCRM14A from the sand culture were selected as inoculants based on their symbiotic effectiveness for common bean and tested on Babile soil under growth chamber. The data showed that the different rhizobial inoculants displayed variations in nodule number, nodule dry weight, shoot dry weight, plant total nitrogen and N content of the inoculated common bean plants.

Isolates HUCRM (2D, 5C, 7D) showed significantly ($p<0.05$) higher N content than other plants. Isolate HUCRM2D induced the highest nodule number of 136 per plant followed by isolate HUCRM12E, HUCRM5C and HUCRM9A with nodule number of 121 per plant, 106 per and 100 per plant respectively. The lower nodule number was induced by plants inoculated with HUCRM14A with 95 nodules per plant. The highest nodule dry weight of 0.2g per plant was induced by isolate HUCRM2D. On the other hand, the lowest nodule dry weight of 0.15g per plant was recorded by plants inoculated with isolates HUCRM7D and HUCRM14A.

This study showed that positive correlations were observed with respect to the number of nodules and dry weight of nodules ($r = 0.73$, $p<0.0001$), dry weight of shoot and %N ($r = 0.8$, $p<0.0001$), dry weight of shoot and N content ($r = 0.9$, $p<0.0001$).

In addition to nodule number and nodule dry weight, it was also observed that dry weight of shoot was influenced by inoculation of isolates (Table 3). The highest dry weight of shoot 3.4g per plant was recorded with isolate HUCRM7D, which was 46% and 54% higher than the records in shoot dry weight of positive and negative controls, respectively. On the other hand, the lowest dry weight of shoot 1.6g per plant was recorded with a plant inoculate isolate HUCRM12E. In comparison generally shoot dry matter was found to be higher in soil cultures by 61% than the sand culture of tested isolates. Comparing the means of the inoculated plants with mutant isolates over that of plants inoculated with the wilds isolates, except in %N in all other parameters (nodule number, nodule dry mass, shoot dry mass and N content) the plants inoculated with mutants showed 26%, 6.6%, 47% and 50% higher means than the plants inoculated with wild types in nodule number, nodule dry mass, shoot dry mass and N content respectively. But the plants inoculated with the mutant isolates showed similarity in % N with the plants inoculated with wild isolates. In line with this, Ragchaudhuri *et al*., (2005) reported that in the non sterile soil, plants inoculated with mutant isolates (N15) strain consistently produce almost 35% more nodules of larger biomass and 25% or more increased dry shoot weight than plants inoculated with wild strain (BICC651). This means the mutants were relatively effective than the wild isolates in computing with other native rhizobia in the soil for infectivity, nodule occupancy and nodulation of the host.

Conclusion

All the isolates induced nodulation and proved to be true root noduleting bacteria. Among the inoculated plants, common bean plants inoculated with isolate HUCR2A produced the maximum nodule number, which was 140 per plant; whereas the minimum number of nodules recorded was 28 per plant for the isolate HUCR13C. In addition, there was a significant variation in dry weight of nodule per plant with different *Rhizobium* isolates. The highest and lowest dry weight of shoots were recorded for plants inoculated with HUCR3D (1.4 g per plant) and HUCR3A (0.33 g per plant), respectively. Correlation response among variables in the sand experiment for wild rhizobia confirmed that nodule dry weight were related positively and significantly ($r = 0.4$, $P < 0.0001$) with shoot dry weight.

Depending on their shoot dry weight in reference to the N-fertilized control plant, the isolates displayed variation in effectiveness ranging from 31% to 158%. In this study, isolates were also found to show difference in their response to various physiological responses. Similarity exist among isolates in terms of tolerance to 5.5-8.5 pH ranges whereas, isolates were very sensitive to concentrations of NaCl beyond 8%.

Effectiveness rating also showed that 1(2%), 23(46%) and 26(52%) of the isolates were found to be ineffective, effective, and highly effective, respectively. This shows that effective common bean rhizobial isolates are abundant in eastern Hararghae lowlands and mid altitude.

Symbiotic effectiveness (SE) test of five best isolates was also carried out in Babile soil. All isolates except HUCR 3D showed significantly ($p < 0.05$) higher nodule number than both positive and negative controls and isolate HUCR14D showed significantly ($p < 0.05$) higher shoot dry weight than other plants. The significant ($P < 0.05$) highest dry weight of shoot (2.2g/ plant) was recorded with isolate HUCR14D, which was higher than the records in shoot dry weight of uninoculated positive and negative controls by 23% and 77%, respectively. Positive correlations were observed with respect to the number of nodules and dry weight of nodules ($r = 0.8$, $p < 0.0001$), dry weight of shoot and N content ($r = 0.73$, $p<0.0001$) and %N and N content in shoot of common bean ($r = 0.43$, $p<0.04$).

Among the 50 isolates exposed both for chemical and physical mutagenesis totally eight mutants were induced, HUCRM (2D, 5C, 9C), HUCRM (7D, 9A, 12E) and HUCRM (3B, 14A) through Sodium Azid, Hydroxylamine Hydrochloride and UV, respectively. Among these isolates common bean plants inoculated with mutant isolate HUCRM2D produced the maximum nodule number 131 per plant whereas the minimum number of nodules recorded was 68 per plant for the isolates HUCRM (12E, 14A). The highest and lowest dry weight of shoots was recorded for plants inoculated with HUCRM2D (1.4 g per plant) and HUCRM (3B, 9C) (0.7g per plant), respectively. Plants inoculated with isolate HUCRM2D showed significantly ($p<0.05$) higher nodule number, nodule dry weight and shoot dry weight than any of the other plants.

Depending on their shoot dry weight in reference to the N-fertilized control plant, the isolates displayed variation in effectiveness ranging from 117% to 267%. In this study, isolates were also found to have diversity in their response to various physiological responses. Isolates were relatively very sensitive to concentrations of NaCl beyond <11%. The above results evidently made known the chance of having effective common bean rhizobial mutant isolates through chemical and physical mutagenesis. Correlation response among variables in the sand experiment for mutant rhizobia confirmed that nodule number were related positively and significantly ($r = 0.85$, $P < 0.0001$) with nodule dry weight.

Symbiotic effectiveness (SE) test of six best mutant isolates was also carried out in Babile soil. Isolate HUCRM7D showed significantly ($p<0.05$) higher N content per plant. The highest dry weight of shoot 3.4g per plant was recorded with isolate HUCRM7D, which was 46 % and 54% higher than the records in shoot dry weight of positive and negative controls, respectively. Positive correlations were observed with respect to the number of nodules and dry weight of nodules ($r = 0.73$, $p<0.0001$), dry weight of shoot and %N ($r = 0.8$, $p<0.0001$), dry weight of shoot and N content ($r = 0.9$, $p<0.0001$).

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7. College of Social Sciences and Humanities

An Analysis of Ancient Rock Paintings of Laga Oda and Goda Agawa: Signs, Symbols and Themes in the Ancient Rock Paintings of Laga Oda and Goda Agawa, Implications for social semiosis and history of Ethiopia[4]

By

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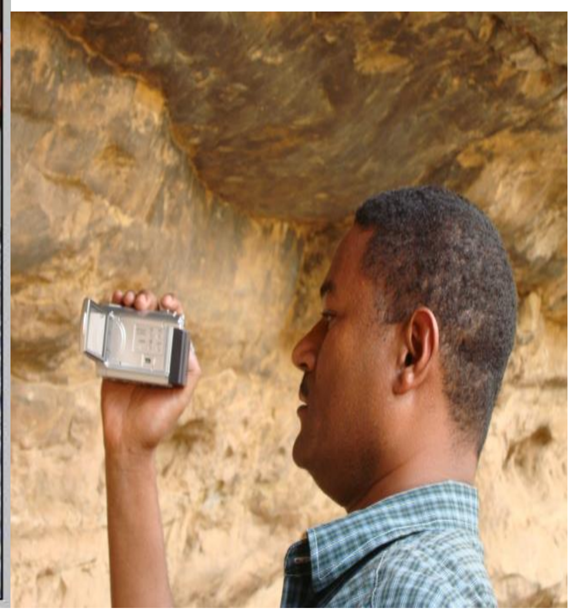
Funded by HrU Government Research Grant



Abstract: *In the year 2011, we applied for funding our project on studying the ancient rock paintings of Laga Oda and Goda Agawa in Hararqee (see Appendix), which we won and conducted our study, thanks to Haramaya University Research and Extension Office.We focused on this study because little or none is known about the social origin and meaning of the ancient rock paintings of* Hararqee[5]. *We believe this study contributes to advancing Ethiopia's cultural history and the tourism economy. Part of our strategy was to adopt*

[4] Many thanks to Haramaya University for sponsoring this study.

[5]The orthography 'Hararqee' is preferred to the usual 'Hararghe' for the latter conceals the fact that the toponym is composite of two free morphemes wherein the second morpheme *qee* (some also spell it *kee, keé, qêe, qe'e*) means 'home, house, dwelling, habitation; birthplace, native land, environ; homestead, property; home-born, native' (Gidada 2006: 100; Tutschek 1844: 60; Viterbo 1892: 89; Foot 1913: 35). It comes from non-finite *qā* 'orifice, disc, hole, black-hole'.

Multi-disciplinary approach that combined concepts from various disciples was adopted as a guiding theoretical framework, while the Eurocentric approach that mystifies and de-Ethiopinizes them was rejected. This report critically analyzed some of the signs/symbols/motifs obtained from Laga Oda and Goda Agawa (in addition to other known areas) with the intention to understand the social semiotical and rhetorical structures that underlie beneath these social 'texts'. It did so through using the ancient Gada-Qaallu Institutions of the Oromo of East and Horn of Africa as analytical device. It adopts van Leeuwen's (2005) advanced approach to social semiotics. *Informant expert with the local's social epistemology or wisdom were selected and used as 'critical friends'. The results revealed both substantive and methodological insights. Substantively, it suggests that the Oromo Gada-Qaallu Institution and its sub-themes such as the pre-Christian belief in Black Sky-God, line of descent and identity, kingdomization, pastoral festival, and bovine symbolism crosscutting all of these. Methodologically, the unique Oromo social semiosis which can be referred to as 'metaplasmic witticism' appeared as the underlying rhetorical structure. Overview of of our final study and findings are presented in this paper.*

Introduction

Hararqee, the vast land in the Horn of Africa (Eastern Ethiopia), is not only where the Qaallu Institution had been practiced since time immemorial up until the first half of the twentieth century, but is also where over 50% of Ethiopia's (possibly including Horn of Africa) rock painting sites are found (Bravo 2007:137). Among these is the famous Laga Oda Site "dating to at least 16,000 BP" (Shaw and Jameson 1999:349) and comprising depictions of bovines and many different types of animals. Today, Hararqee is part of Eastern Oromia State[6] as well as of Ethiopia. Corresponding to the Oromo oral history, the plausible Oromo historians (Gidada 2006, Hassen 1990, to mention a few) and non-biased European theologico-ethnologists (Krapf 1842; De Abbadie 1880; De Salviac 1980, to mention a few), all agree that the homeland and origin of the Oromo, the largest tribe of the Cushitic stock, is Eastern or Horn of Africa, specifically a place known as Hooro Ẃalaßu or Maɖɖ'a Wolabu 'the Spring Water of Genesis of Humanity' (Dahl and Megerssa 1990).

The Classical Greek writers wrote the Ancient Ethiopians were "inventors of worship, of festivals, of solemn assemblies, of sacrifice, and of every religious practice" (Bekerie, 2004:114). The oral history of the Oromo states that it was Makko Billii[7], whom Antonio

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[6] *Oromia* refers to Oromoland in accordance to current Federal System of Ethiopia.

[7] Without going to too details, the IPA transcription style with some necessary exceptions is pursued. The doubling of consonants signifies *gemination*, while the doubling of the vowel indicates *very long* vowels, a common feature of Oromo language that makes significant typological difference. Instead of the IPA /j/, /ʃ/

De Abbadie, one of the early European scholars who studied and lived with the Oromo, described as "African Lycurgus" (Werner 1914: 263; Triulzi and Triulzi 1990:319; De Abbadie 1880) and son of the primogenitor of the Oromo nation (Raya or Raâ), who hammered out the antique, generation-based egalitarian theologico-socio-political system known as Gada System (Legesse 1973, 2006; Bartels 1983; Gidada 2006). A key ingredient in Gada system is the Qaallu[8] Institution. Though narrower in scope compared to the generic Gada System, the "ancient" Qaallu Institution (Baxter 1987:168 quoted and elaborated in Gidada 2005:146-147) is as much cosmogonal, identificational as it is theologico-political to the Oromo nation, in particular, and, at large, the pre-colonial (pre-Christian, pre-Islam) Cushites who uniformly believed in Water as a source of life and *Waaqa*, a duality (naturally co-relative) concept/word that designates simultaneously the abstract 'Black-God, Heaven' and, on the other, the 'concrete' 'Sky, Divinely Milk'[9] (Hassen 1990).[10] For Oromo, the first Qaallu "Hereditary ritual officiant" and "high priest" was of "divine origin" and, as the myth tells us, "'fell from the sky itself'…with the first black cow" and he was the "'eldest son of *Ilma Orma'*" (Hassen 1990:6; Baxter, Hultin and Triulzi 1996:6). In its "dual[ity] nature", Waaqa, the black Sky-God "controlled fertility, peace, and lifegiving rains… [hence] prayers for peace, fertility, and rain" are the core recursive themes in Oromo religion (Hassen 1990:7). Hence, the concept/word Qaallu refers at large to "Divinity's fount of blessings in the world" (Baxter, Hultin and Triulzi 1996: 1996: 21).

As De Salviac (2005 [1901]: 285) explicated "The Oromo are not fetishists. They believe in Waaqa took, a unique universal creator and master. They see His manifestations in great forces of nature, without mistaking for Him." As a result of this 'pre-historic', Baruch de Spinozaean like *social epistemology*[11], but unlike Martin Heideggerean "ancients" who never dared questioning or confronting ontology but endorsed only veneering it, for the Oromo *social semiosis*[12] has never been new since time immemorial. Although Eurocentric

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and /ʧ/, the more familiar /y/ or 'y', /š/ and /č/ are, respectively, used. In the pre-1990s works, many scholars did not take care of the gemination (consonants) and elongation (vowels) issue. Therefore, in direct quotations, they are kept as original.

[8] Among the different orthographies known in the literature, such as *k'alu, k'allu, qaalluu, qalloo,* etc, here *qaallu* is adopted as most appropriate unless in direct quotations.

[9] An elderly Oromo versed in traditional Oromo wisdom says: *Waaqayyo núf roobuufi* 'God (hypocoristic) is to rain for us' or *Waaqni d'ad'aa nu dibé* 'God has smeared/painted us butter'(i.e., rained for us) and butter is a symbol of fertility.

[10]This concept/word *Waaqa* Black-Sky God is well documented—albeit less spoken/written--in Ancient Egyptian texts ((Bekerie 2004: 116 based on W.E.B DuBois).

[11] The term 'social epistemology', here, is used to refer to the whole lots of a society's accumulated, over thousands of years, and shared, and practiced, paradigmatic plausibility structure (including linguistic and non-linguistic, literary and non-literary, theological and scientific, political and moral, cosmogonal/mythical and cosmological, geneaological and ideological, etc., knowledge structures).

[12] The term 'social semiosis', here, is used to refer to a society's whole lots of 'devices' of representation, objectification and communication of its social epistemology--linguistic and non-linguistic, literary and non-

archaeologists rarely acknowledge, "the identification of cultural themes and symbolic interpretation" on Ethiopian rock arts " has revealed affinities between contemporary Oromo practices and those of other East African culture groups, both ancient and modern" (Grant 2000: np).

The so-far few studies made on the Ethiopian ancient rock paintings and rock arts are only positivist description (of types, size and/or number of the signs) rather than explanation of the social origin and the underlying social meaning, praxis or worldview (Brandt and Carder 1987). Partly, the reason is the studies are totally dominated by Eurocentric paradigms that de-Africanize and extrude the native people and their language, religion, social structure, material cultures and, in general, their interpretive worldview. Besides, some of the native researchers are no different since they have unconditionally accepted this Eurocentric, hegemonic epistemology (Bekerie 1997). As a result it isneither possible to understand the social origin of these amazing 'texts' nor is it possible to explain the underlying social semiosis. Furthermore, due to this kind of mystification or possible distortion of human (past) knowledge, we miss the golden opportunities that these ancient documents offer for advancing human knowledge about human past. In their interestingly critical-social study of the Horn of African ancient rock arts, Brandt and Carder (1987) formulate "cultural ecological model", for "cattle pastoralism in the Horn suggests that predictive relationships exist between rock art and human behavior" (1987: 208). They call for "an interpretation of the pastoral rock arts which goes beyond simple description" and that "must obtain securely dated environmental and culture/historical sequences in conjunction with regional analyses of settlement and subsistence patterns" (1987:209). Likewise, the aim of this paper is to use the ancient Gada-Qaallu Institutions of the Oromo and its two sub-themes—*qallačča* and *bokkuu* which shall be defined and discussed ahead--as a general sensitizing, analytical device in order to draw attentions, guide and explain the underlying social epistemological, semiotical and rhetorical structures.

Whose social origin are the rock paintings?—Review of literature

So far studies ascribe the socio-cultural origin of ancient rock paintings of Hararqee, like the rest of Ethiopian as well as African regions, is either ascribed to 'fabulous' communities or eclecticized or mystified. Cervicek and Braukämper ascribed it to an imaginary community they signify "Harla" or "Arla" (Cervicek and Braukämper 1975:49). Cervicek and Braukämper, based on a person they call "Huntingford (1965:74)", state:

> According to popular beliefs Harla generally refers to a mysterious, wealthy and mighty people, (frequently even imagined as giants!), who had once occupied large

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literary, natural (e.g., trees, hilltop, cattle) or designed (e.g., sticks), tangible objects or abstract signs, symbolic or physically enacted.

> stretches of the Harar Province before they were destroyed by the supernatural powers through natural catastrophies as punishment for their inordinate pride. *This occurred prior to the Galla (Oromo) incursions into these areas during the 16th and 17th centuries"* (Cervicek and Braukämper 1975: 49; Emphasis added).

Cervicek and Braukämper (1975:49) quote Huntingford on the identity of the Harla: "The name "Harla" is first mentioned, as far as we know, in the chronicle of the Ethiopian Emperor Amda Seyon[13] in the 14th century (Huntingford 1965:74)." Professor Claude Sumner (Sumner 1996: 26), however, shows us that it was not Huntingford but early twentieth century French Catholic missionaries by the name François Azais and Roger Chambard who not only documented the Hararqee ancient rock paintings (as also acknowledged by Cervicek and Braukämper 1975:49), but also who first reconstructed the imaginary "Harla" (spelling it rather as "Arla") from an oral history told to them by an Oromo old man from Alla clan of Barentuu.[14] The story itself is about a "wealthy" Oromo man called "Barento" [Barentuu] who was "very rich but very proud farmer" (Sumner 1996: 26). For it is both vital and complex (in its usual metaphoric rhetorics of Oromo, which cannot however be analyzed here) it is necessary to quote it in full:

> There was in the Guirri[15] country, at Tchenassen [Č'enāssan], an Oromo, a very rich but very proud farmer called Barento. A cloth merchant, an Arab who was also very rich, lived a short distance from there at Derbiga.[16] The merchant's daughter went one day to see the farmer and told him: "I would like to marry your son."—"Very well, I shall give him to you," he answered. The merchant in turn, gave his daughter and made under her daughter's steps a road

[13] See also Dr. Negasso Gidada (Gidada, 2006), the plausible historian and former president of Ethiopia who convincingly explained away this and many mystifications and deformations in Ethiopian history including the fact that the so-called "Amda Seyon" is in fact deformation of Sayyoo Mačč'aa, an early classical era Oromo War General of the Central-Western Oromo from who are the Sayyoo Clan, a sub-clan of the Mačč'aa Confederation, are descendant today.

[14] The Oromo are divided into two major *mo'o* 'moieties' (literally designates 'both sides of the back') namely "Borana" and "Barentu", each of which subdivides into sub-sub-moieties (*balbala*) and sub-sub-sub clans (*goça*). Legesse (2006:144) analyzes how various authors spell the latter "ancient moiety": *Bareytuma, Barentu, Barento, Bartuma, Barttuma, Barentuma, Barentoma,* etc. He states that Boorana ritual texts indicates that the ancient name of the junior moiety was, rather, "*Baréetum*(a)". Like the other retroflex liquids, /ɳ/ appears as an epenthetic consonant de-voicing the original voiced consonant. Yet, the very long vowel /ee/ is also a compensatory lengthening for the lost long /oo/. Hence, *Booreetuu* and *Booreetúma* are taken here as most appropriate orthography. While *Booreetuu* designates the Easter moiety, one of whose descendants are the Hararqee Oromo known as the Afran Qaalluu/Qalloo sub-tribe (comprising four or five clans), the term *Booreetúma* translates Booranization or Booranism principle..

[15] Garrii are Oromo clans speaking Afan Oromo but today delineated inside Ethiopian Somali Regional State without their will. Wakefield (Ravenstein and Wakefield 1884: 263) recorded with his own version of orthography that "Five great tribes of" Oromo occupying "to the West of Wébi" River among who are the "Gerēr" and the "minor" one named "Gūre".

[16] A strange toponym, Hecht (1987) quotes Wilding (1975:5) who claimed to have collected "Chinese porcelain" from that locality as well as Leslau (1963:58) who claimed the etymology "'Darbi Gar'--'Harari style stone building'."

> of cloth, from Derbiga to Tchenassen, residence of the rich farmer. The tailor replied to this act by making a road of dourah and maize under his son's steps, from Tchenassen to Derbiga. But God was incensed by this double pride and to punish him, shaked Tchenassen Mountain and brought down a rain of stones which destroyed men and houses; it was then that the race of Arla [Alla] was destroyed (Sumner 1996: 26).

Confirming the antiquity and unity of this story and the Oromo, similar story is found in Western Oromo as far closer to the Southern Sudan: "in interpreting certain of their [Oromo] myths about the beginning of things, it was because of man's taking cultivation and pro-creation too much into his own hands, that Waqa withdrew from him--a withdrawal resulting in a diminution of life on earth in all its forms" (Bartels 1975:512). Cervicek and Braukamper (1975:74) described the Laga Gafra area and its population as: "The area of the site is part of the Gafra Golla Ḍofa village, and the indigenous Ala [Oromo] call it Gada Ba'la ("large shelter")."[17] Here, let us only remember that Alla and Itt'u clans of the Hararqee Oromo who "provide[d] a basis for…construct[ing] models for prehistoric land and resource use" (Clark and Williams: 1978:19).[18] Thus, it is clear that the mystification by the imaginary "Harla" or "Arla" prefigures in the usual gesture of de-Africanizing civilization of Black Africans to justify what many scholars call "the Hamitic myths" (see Bekerie 1997; Smith 1997; Gusarova 2009; Vaughan 2003; Ehret 1979; Finneran 2007).[19]

Language and reality in early 'spelling' by painting on rocks

The Ancient Black Africans that some 19th century European missionaries and researchers referred to as 'Ancient Egyptians' (although still others refer to them by Ancient Cushites, Ancient Ethiopians, Ancient Nubians or Meroes) are the originators writing systems known by 'hieroglyphics'. Initially, hieroglyphics was pictogram or semagram. That is, pictures of real world were 'painted' to communicate a sememe or motif, the smallest meaningful structure or concept, for instance, a picture of sitting man for their word for the English 'sit', a picture of man stretching his/her arms to the sky for 'pray', a lion for 'great

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[17] The Oromo 'Gafra' means 'buffalo' (also *gafrẓa*), Golla means 'every enclosed place' (Tutscheck 1844), Ḍofa means 'fertile land; fat, big (bovine)' (Tutscheck 1844: 115; Stegman 2011: 30). Gada 'temple' and *baall'a* (*baalli*, nominative) 'very large, wide' are ordinary definitions and undermine the meaning of otherwise complex, social-philosophical concepts. Their "*Ba'la*" is strange form or Semiticized.

[18] Burton (1856: 1074-1075) wrote the Oromo "about Harar are divided into four several clans, separating as usual into a multitude of septs. The Alo [Alla] extend westwards from the city: the Nole inhabit the land to the east and north-east, about two days' journey between the Eesa Somal, and Harar: on the south, are situated the Babuli [Babilee] and the Jarsa at Wilensi, Sagharrah, and Kondura."

[19] This word, "*Harla"* or "*Arla",* violates the general Afro-Asiatic language principle of consonantal co-occurrence restriction or 'dissimilation' confirmed by Greenberg (1950) and Bender (1978), that /l/ and /r/ are isomorphic and, hence, cannot co-occur in any base word (excluding affixation). Consonantal co-occurrence restriction is also called consonantal compatibility restrictions, or dissimilation. This is very true as far as Oromo is concerned; nowhere do rhotic liquids /l/ and /r/ co-occur in base word.

man' etc. Based on their social philosophy/paradigm, literary/figurative symbolism, and/or their word's/language's phonology/syntax for the English 'woman', they might have also depicted a picture of a pigeon, or an owl or a cow. This zoomorphic mode of representation as the Sign-Language of Totemism and Mythology was the first and early writing system in human history (Diop 2000; Massey 1907).

The Ancient Egyptians used the principles of sound-meaning association, semantic and ontologic (what something/somebody **can cause**) similarization, principle of physical resemblance, principle of grouping (duplication or triplication of the same pictograms to represent meaning), principle of aggregation (pictograms are combined in or around a spot or a pictogram is duplicated as many as necessary and congregated in or around a spot), principle of sequencing vertically or horizontally (a semotactic for creating a lexical or syntactic structure) and so forth. Some of these or similar principles or 'stylistic features' are observed, particularly, in the Laga Oda painting styles. Cervicek (1971:132-133), for instance, observed in Laga Oda paintings such stylized 'discourse' as 'group of horseshoe-like headless[20] bovine motifs', from Bake Khallo [Qaallu]', 'oval symbols accompanied as a rule by a stroke on their left side', 'sun-like symbol in the centre with animal and anthropomorphic representations grouped around it', paired 'soles of feet', carefully profiled styles (overhead, side, back point-of-view of bovines), zooming (large versus small size of bovine motifs), headless versus headed bovines, H-shaped anthropomorphic representations with raised hands', superimposition and so forth. Any interpretation that renders these as isolated case, arbitrary or pointless marks can be rejected outright. Some of these 'early spelling' are found not only across the whole Horn of Africa but also in Ancient Meroitic-Egyptian rock paintings, hieroglyphics and, generally, organized social semiosis.

Social semiosis in Oromo social epistemology

Since Oromo social epistemology and semiosis is the analytical devices for this analysis, it is good to see them briefly. In the words of one leading social philosopher and researcher at Addis Ababa University, Oromo social epistemology and semiosis uniquely exploits "intimate link…between form, content and concrete situation in life" (Sumner 1996:17-18).[21] Professor Claude Sumner, who has produced three volume analysis of Oromo wisdom literature (Sumner 1995, 1996, 1997), sees that like any "ancient texts", in Oromo wisdom literature, "a same unit of formal characters, namely of expressions, of syntactic forms, of vocabulary, of metaphors, etc., which recur over and over again, and finally a vital situation…that is a same original function in the life of [the people]" (Sumner

[20] Cervicek (1971: 132) quotes in footnote another scholar on this "Even nowadays toy figures of humped cattle without heads are modelled of clay and dung by the Borana (Haberland: 1963a, PI. 28/6)"

[21] Claude Sumner did not use the term 'social epistemology' or 'social semiosis', but used 'Oromo wisdom' or 'Oromo wisdom literature'.

1996:19). An elderly Oromo skilled in Oromo wisdom speaks, to use the appropriate Marxian term, 'historical materialism', or he speaks "in ritual language, as it was used in old times at the proclamation of the law" (Bartels 1983:309). Moreover, he speaks in rhythmatic verses, full of "sound parallelism" (Cerulli 1922), "parallelism of sounds" or "image" or "vocalic harmony" (Bartels 1975: 898). Even Gada Laws used to be "issued in verse" (Cotter 1990: 70), in "the *long string of rhyme*, which consists of repeating the same verse at the end of each couplet" or "series of short sententious phrases" that are "disposed to help memory" (De Salviac 2005 [1901]: 285). The highly experienced researchers on the ancient Oromo system of thought, which is now kept intact mainly by the Booran Gada System, emphasize that "'the philosophical concepts that underlie the *gadaa* system'…utilize a symbolic code much of which is common to all Oromo" (Baxter, et al 1996: 21).

The symbolic and material reproduction of Oromo society is incredibly alike, a feature "surely has developed within the [Oromo][22] language" and "is also only imaginable in a sonorous language such as Oromo" which "as a prerequisite, [has] a formally highly developed poetical technique" (Littmann 1925:25 cited in Bartels 1975:899). Claude Sumner finally formulates a "double analogy" tactic as prototypical feature of Oromo wisdom literature, i.e., "vertical" and "horizontal" parallelism style (Sumner 1996:25), known for the most part to linguists, respectively, as 'paradigmatic' ('content' or 'material') and 'syntagmatic' ('form' or 'substance') relations or in both literature and linguistics, as contextual-diachronic and textual-synchronic, relations. Oromo social epistemological concepts/words/signs offer important data for historical and evolutionary social sciences for they recycle and, consequently, are resistant to change both in form and meaning (Legesse 1973).

Thus, this analysis jettisons the old Eurocentric view that narrows down the sphere of semiotics to only 'the sign', extruding the human agents and the social context, and attempts to use the ancient Qaallu Institutions of Oromo as sensitizing 'device' in order to understand the layers of social meaning and structure underlying the rock arts of the area in focus. Particularly, it adopts van Leeuwen's (2005) advanced approach to social semiotics. Primarily, Van Leeuwen (2005: 3) extends "semiotic resource" as involving "the actions and artefacts we use to communicate, whether they are produced physiologically" (with vocal apparatus, muscle, facial expressions, etc) or "by means of technologies" (e.g., ink, computer, fabrics, scissors, or sewing machines, etc). Van Leeuwen (2005: xi) introduces the changing semiosphere of social semiotics:

- From the 'sentence' to the 'text' and its 'context', and from 'grammar' to 'discourse';

[22] Delete racist, imposed and hatred terms such as "Galla".

- From the ‘sign’ to the way people use semiotic ‘resources’ both to produce communicative artefacts and events and to interpret them;
- From fragmentation of the semiotic modes, for instance, into the ‘semiotics of the image’, the ‘semiotics of music’, and so on, to comparing and contrasting semiotic modes, exploring what they have in common as well as how they differ, and investigating how they can be integrated in multimodal artefacts and events.

Methods and the semiotic resources

For this analysis both archival and field data are collected. In 2012 visits were made to the some of the popular (in literature) ancient rock painting sites in Hararqee (Laga Oda, Goda Agawa, Ganda Biiftu, etc.; comprehensive list of Ethiopian rock painting sites is presented by Bravo 2007). Also, field visits were made to less known (in literature) ancient to medieval era painting sites (e.g., Goda Rorris, Huursoo, Goda K’arree Ǧalɖeessa, Goda Ummataa, Goda Daassa, etc). Huge visual data (still and motion) of paintings and engravings were collected, only very few of which are used in this paper. During the data collection, it was found out that sometimes visual data captured earlier by other scholars, for instance, Cervicek (1971) and Cervicek and Braukamper (1975) were preferably clearer due to wear-off or other factors. Yet, from the same popular sites, some previously unrevealed or undetected motifs were also collected. Another category of archival data for this analysis is the ‘scholastic’ research literature on Oromo social epistemology. However, since the Qaallu Institutionas well as its sub-themes is used as a means rather than end by itself—hence is capitalization upon social semiotic and linguistic aspects--there is an inevitable risk of undermining this/these, otherwise, complex philosophical notion(s).

Besides, two old men expert in Oromo social epistemology, are used as informants, namely Taaddasaa Birbirsoo Mootii, 87, from Wallagga, Western Oromia (Ethiopia) and Said Soddom Muummee, 85, from Hararqee Eastern Oromia (Ethiopia). Mootii, a Catholic Priest, was one of the informants and colleagues of Father Lambert Bartels (Bartels 1983, 1977, 1975) at Addo Catholic Mission Church, Wallaga Dembi Dollo town. However, Bartels only referred to Mootii as “one priest”. Muummee, is not only well seasoned wiseman, but he still celebrates and identifies himself as *Waaqeeffata*—believer, observer and practitioner of the pre-Christian Oromo religion founded on Waaqa, the Black Sky-God. Both Mootii and Muummee play the role of ‘critical friends’: they assist with the objectification needed for the all the way through the data collection and analysis as observers, descriptors, interpreters and explanators of not only the semiotic resource but also as validators, re-interpretors and re-contextualizers of pre-interpretations (the author’s and other researchers’ on Oromo). Sometimes, they also sing the ancient pastoral songs and act out the symbolic actions of during ancient Gada-Qaallu rituals, bring back to memory and enfolding them in the archaic expressions.

Analysis and Discussion

Qaallu Institution, cosmogony and genesis of hierarchy

Above, under Introduction section**,** a remark was made on the mythical-social origin of the Qaallu Institution and its relation with genesis and cow-milk. Onomasiologically *Qaallu* comes from the gerundive *qułu* (*qul'qullu*, intensive) 'pure, holy, sacred, blameless; being black, pretty, neat', pointing to the color and quality of *Waaqa* (see Bartels 1983; Hassen 1990 for detail). Due to rhotacization the expression Waaqa quɻačča/ɢurračča 'Waaqa the dark/black one' is the common metonymic reference. But, the metonymy/modification is not just semantic/conceptual but also ontic in that that *the modifier* quɻačča *that* which is "in its original state" (Megerssa 1993: 8), possibly from qara '(to) grain, eye, edge, fruit, be sharp[23]; first(ly), early' or the root qâ '(be) orifice, have opening'.

The Booran Oromo have still kept the Qaallu Institution 'unspoiled' and, thus, their world view is worth quoting:

> The Booran view of cosmology, ecology and ontology is one of a flow of life emanating from God. For them, the benignancy of divinity is expressed in rain and other conditions necessary for pastoralism. The stream of life flows through the sprouting grass and the mineral waters [hoora] of the wells, into the fecund wombs and generous udders of the cows [*ɢurrˀú*]. The milk from the latter then promotes human satisfaction and fertility (Dahl and Megerssa 1990: 26).

As recorded by Lambert Bartels and others, *Waaqa* 'Devine, God, Sky' symbolizes *Abbá*, Patriarchic-side of the cosmos or Father or Husband "who goes away" while, *Daččee* 'Earth' symbolizes, the Matriarchic-side, Mother or Wife who "is always with us" (Bartels 1983: 108-111) and "originally, Heaven and Earth were standing one next to the other on equal terms" (Haberland 1963: 563 quoted in Bartels 1983: 111). Rooted in this antique worldview, an unfortunate Oromo father/mother has to but say *élmee Koo ana ǧalaa du'e*, literally 'my offspring/child died from under/underside me' while an unfortunate child would say *abbo/ayyoo koo ana'irraa du'e* 'my dear dad/mum died from above/over me'. Some lines from a praise song for a hero illustrate caressing and kissing the belly of his mother (Cerulli 1922: 48):

An observation of the Laga Oda pictures (see Fig.1A) consistently illuminates another interesting analogy--bulls are consistently drawn above the cows. In Oromo worldview, a

[23] Qara is used as in the expression *qara adu* or *qara biftu, '*eye of the sun'.

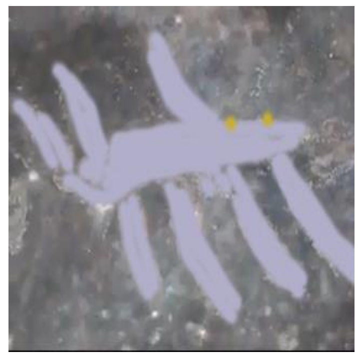
bull represent *ßoo* 'sacred domain of the male' (vocative form of *bâ* 'man, subject, being, masculine 4th person pronoun'), while a cow (*saa, sa'a*) represent *çâé, îssi* **'**sacred domain of the female' also 'feminine 4th person pronoun' **(**Kassam 1999:494)**.**[24] Lambert Bartels, writes "When they bless, they [the Oromo] say: *gurrači garaa ǧ'abbii siif ha kenu* 'May the dark one [God] with hail under his abdomen give you all (good things)' (Bartels 1983:90-91).[25] *Korma* 'buffalo-bull' is a symbol of manliness (yet, 'manliness' for Oromo is 'oromoness (masculine)') combined with virility and temperance (*korma*) and, hence, "every [Oromo] man is a bull" (Bartels 1983:146).[26] More importantly, the giant bull designated *angafa*, *hancaffa* (also 'first-born (son)') is a symbol of *angaftitti* "seniority of moieties: stratification and imbalance" (Legesse 2000:134); "he is carrier of "Boraanness" to a higher degree[=baron]" (Dahl 1996: 172), for Booran is the first-born (*angafa*, from *aɢa,* aƙa 'grand-parents, commencers; heaven') or Horroo is the primogenitor (*horroo,* from *hor* 'to vege, sprout, proliferate') of the Oromo nation.

[24] This is quite different from the biological male-female division. For instance, both "the *gadaammojjii* [who] are preparing to exit the cycle of social time [and] the *dabballee* [who] are entering it…[are] groups of men are considered to belong to the sacred domain of the female (*issi*) and are referred to by the female pronoun" (Kassam 1999: 494) though they are male.

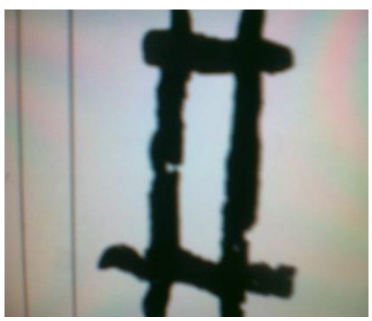
[25] Here, Bartels was not interested in the unusual play on word, though he discussed this 'sound-meaning' parallelism stylistics elsewhere. *Gurrači garaa ǧ'abbii* is, for lack expression, a polysemantic metonymic witticism: 'Sky-God, the one with *č'abbi* 'hail, ice, snow' and dark belly (=heavy cloud); 'God whose stomach [=heart] is tough (*ǧ'abbii*)'; 'God, under whose belly is there a bullock (*ǧ'abbii*)'.

[26] *Korma* also designates 'male or ram of all *Capra* varieties' and 'male of fowl (domestic and non-domestic)'. The underlying notion is *ħôr* 'vege, proliferate, (re)produce, copulate, pierce' and/or *rom*ˀ*a, romma* 'rage (sexuality)'.


A (Laga Oda, trace) B (from Porc Epic or Baallii)

C (from Goda Allele) D (from Laga Oda, trace)




E (Goda Aban Sofii) F (Laga Oda, trace)

Figure 1:

For the same reason, the line of descents marked by the most seniors or ancient moieties is coded or symbolized by *hariera* 'spinal column' or *horroo* 'vertebrae' of the bull (see Fig.1C and F; usually Oromo lexemes for animal and human body parts, etc., vary). So polysemous a word, the first (or extended) meaning of *hariera, hariira* is 'hierarchy, queue, seam, line, suture', *haaria, hariyaa* means 'co-relative generations-based age-mates', and *horroo* means 'mineral spring water; those who are sprouted' (Tutschek 1844: 98, 110; Stegman 2011:95). The primogenitors of the Oromo nations settled, according to Hararqee Oromo, in an unverified country near a big river or spring water called Mormor or Hooro Ẃalaßu (See Gidada 2006; Bartels 1983; BATO/Bureau of Oromia Culture and Tourism

1998). They set the first *ßala* ‘split, separation, moiety’ (from *baḫ* ‘to flame, impel, fly; to split, have bilateral symmetry’) or *Ẃalaßu* ‘freedom, bail, spring’, which grew into *baḻbaḻa* ‘sub-sub-sub-etc…-lineages or -moieties’ (also means ‘door, gate’; the reduplication showing ontic repetitiveness). They also set *lamii*, literally ‘citizens’ (accusative of *lama* ‘two’), but social-philosophically “the primary pair, among several pairs of binary oppositions…which are ‘the creative communion between oppositions, the fertile unity of contrasts’” (Baxteret al 1996: 21). See Fig.1 E.

Accordingly, the left hand and right hand of the bovine always represent, in rituals, the “sub-sections of the phratry” (Kassam 2005:105). That is, as the tradition sustains, when the ancient matrilineal-patrilineal moieties sowed, dissevered (*fač’á*) from the original East (*Boora, Òboro*), the *Booreetúma* (designating matrilineality, feminine soul) took or went towards the left hand side, while the Hoorroo (also for the rare /Ħ/ and /β/ interchange, βooroo, designating patrilineality, masculine soul) took the right hand side. Both correspond, respectively, to the directions of sunrise and sunset, which configure in the way house is constructed: *qâ* or *k’â ɾaa*[27] ‘the front door’ (literally ‘Inception or Inception of Moving-Sun) always faces the East, while the back wall (*Horoo*) faces the West (also *Horoo* means ‘Horus, evening twilight’).[28] This still governs the praxis that the backwall “is the place of the marriage negotiations and of the first sexual intercourse of sons and their bride [i.e., behind the stage]” (Bartels 1983:296).

The second concept is, *Ḿoo’a* the ritual or holiday of the ancient primogenitors, which is observed by their contemporary Families (Sabaa 2006:258). This concept that coheres both the primogenitors and the contemporary generations (third, second and first) is symbolized by mo’ó, mo’oo literally ‘both side of loin/lumbar’ (seeFig.1B) but socially ‘moieties’ and/or *k’omo* ‘ribs’ which also means ‘belongingness to common race, consanguinity’ (see Fig.1D). From the same concept dissimilarizes the Oromo concept of *Ḿootumma* ‘Kingdom’ (or the Biblical Kingdom of God) which Shongolo (1996) explicates etymologically:

> [*Ḿootumma* comes] from *moo’a*, autobenefactive: *moo’ď/ţ*, is a cattle image. For example, *Kormi sun him moo’a*, “that bull is in heat” and *sa’a sun iti moo’a* ‘he is mounting that cow’. With reference to human beings, the implication is not necessarily sexual, but can denote superiority or dominance in general. *An moo’a*, *an mooti* is a formula of self praise by a new Abba Gada during his inauguration (Shongolo 1996: 273).

[27] Also called *ìffa*, *fue* ‘arrow, beam, shine; sling’ (Krapf 1844: 3, 33) or *badaa* ‘front room; hearth’ (Stegman 2011:23). Hearth is a symbol of “nuclear family” or “mother-child household” (Legesse 1973:39).

[28] Hooroo and Boora*/Òboro* are interchangeably used for back wall and front wall possibly because, for Oromo time or spatiotemporality is circular (Bartels 1983).

Holiday of the Cattle

It is no surprise that the Qaallu Institution has had a special cosmological symbolism and Law of the Bovine as well as Holiday of the Cattle/Bovine, *Ǧaarrii Looni*[29] (Haaji-Aadam 2010; Legesse 1973:96; Dahl and Megerssa 1990). On *Ǧaarrii Loonii,* cattle pen are renovated and embellished, and festivities and dances with praise songs to cattle was chanted (for more on this, see Bartels 1975; Wako 2011; Kassam 2005). An excerpt from the poetic praise song to cows 'talks' about them with admiration of their body parts (See also Bartels 1975:911):

Chorus: *Ahee-ee*
Soloist: *Yá saa, yá saa*—o cattle, o cattle!
saa Humbikooti--cattle of my Humbiland,
Saa eessa ǧibbu?--What part of cattle is useless?
Saa qeensa qičču--Our cattle with soft hoofs,
koṯṯeen šínii ta'e—from their hoofs, we make coffee-cups[30]
gogaan wallu ta'a—from their skins, we make *wallu* leather cloth
gaafi wanč'a ta'a, -- from their horns, we make *wáṉč'a* large milk/beer cup
fa l̯ʔana ta'a!—as well as spoons! [See Fig.2A, B, C, D]
Chorus: *Ahee-ee*

The festivity, dancing praise-song (faarsa, afaaruu) on the *Ǧaarrii (*also *Adʼeeṭee) Loonii (Ǧaarrii* is a temporal/time divinity concept, while *Adʼeeṭee is fertility divinity concept)* involve bringing out/holding *horooroo* pastoral-stick (y-shaped, symbol of sprouting) and *afarsa/afarfatu* 'a special broom (pastoral)', *a symbol respect and* affectionate caressing (see Fig.3D). Cervicek (1971:124 Fig.10) wonders about the unexplained but recurrent "oval representations… painted black [and] white-dotted" and consistently painted "below" the cow udder (see Fig.3B). This can be compared with *wáṉč'a* drinking horn-cup or *č'óč'oo, č'iič'oo* milking (horn-)cup (see Fig.2D). On Irreečča, Ḫûrreeça ritual of Thanking Waaqa Black Sky-God, a line of the doxology mentions, among others, "*Waaqa č'iič'oo gurraattii*" 'God of the dark *č'iič'oo* milking-cup' (Sabaa 2006:312). The deadjectival *č'óč'orree* means 'white-dotted (black background); turkey or similar white dotted bird', while *Waaṉč'ee* is a proper name for white-dotted cow.

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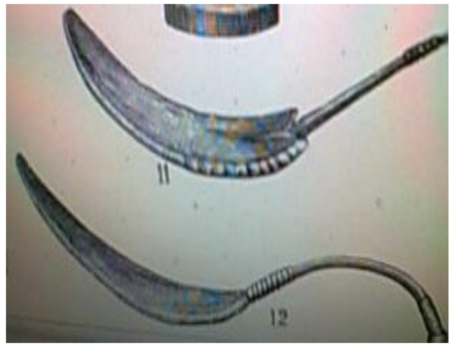
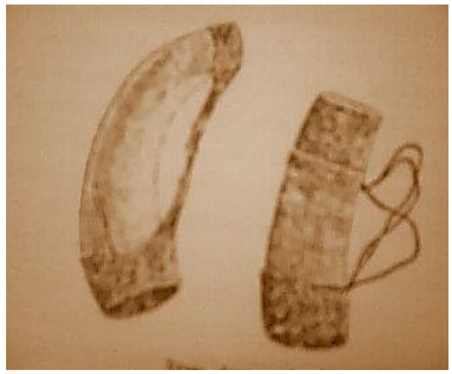
[29] There are many Oromo words for the English 'cattle', none of which is not equivalent to it: *looni, looṉ* refers to 'cattle' but as a herd or when they are grazing; *hórí* includes 'cattle' but also is emphatic of the notion that they are part of all the invaluable and 'amicable' assets fulfilling our 'manness'; *saa, sa'a, sawa, saya* refers to 'cattle', but usually to 'a cow' or 'cows'; *bêelāḍa* (bao-lee-ooṭa) refers to cattle but with the notion that they are among 'the tamed kingdom' but those graze going away from home (excludes e.g., cats).

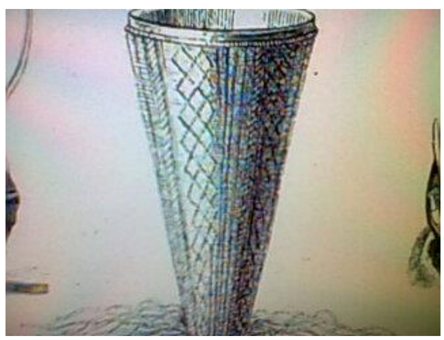
[30] Motifs of coffee-cups and *ǧabaná, ǧûppanā* 'coffee pot' (invariable from *ǧûppa* 'pipe', see Fig.1D), a symbol of cow's udder spitting milk; see Wako 2011:77) and coffee-cups are known in Laga Harro or Sok'a Ǧibičča (literally, 'Bull Engraving') in Boorana, Southern Ethiopia (Bravo 2007:219).

A (Laga Oda spoon-like paint) B (*faɭˀana* ‘horn-spoon’)

C (Laga Oda spoon-like picture) D (*wáɳč’a* horn-cup)

D (*ǧabana ‘coffee pot, image of udder)* E (*t’óffoo* horn-chalice)

Figure 2:

Qaallu, cradle land and eco-theology concept

In Oromo social epistemology, holy spirits reside also in sacred realities, the mountain hills, river beds, pasture lands, evergreen trees. For they are considered as symbol of absolute ‘purity’ (*qul’qullu*), these are areas for ritual and religious performances. Thus, the word *qaallu* (also *qoolloo*) refers to such important place for rituals of immortalizing ancestors, blessing the newborn, initiating the full-man, praying for fertility and rain, and praising the gracious God and so forth. The sacred land of spirituality must be mountain foot (*goda*, also means 'cavity', one of the words that recurrently forms toponymy of rock painting sites, besides *odaa khalloo or qaallu*, and *laga*[31]) where there must be, naturally, *laga* 'lagoon, river' (also means 'language, discourse, larynx, vocal cord'), *č'affee* 'marshy area with green grasses' (symbol of the parliamentary assembly), *χa ɭoo* 'pasture land', and the evergreen *oɖaa*, the sacred giant *Ficus sycamorus*. *Oɖaa* serves not only as "a depiction of a political power", but "is also a centre of social and economic activities" and "symbolizes the entire corpus of their activities, history, culture and tradition" (Gutamaa 1997:14). O*ɖaa* tree varieties have 'milk' (latex); their large shade is used not only as a meeting 'hall' for communicative action and hammering out *oɗuu* 'proclamations' of Gada Law amendments (from *õɖa* 'to be inspirited, to pulsate; to inform, utter'), but also as a temple (*gadaa*) as well as graveyard. It's 'milk' is proportionate with *ő**t̲t̲**a* 'amniotic fluid', the primeval fluid.[32]

Five Qaallu centres are known in Booran sub-moiety: (1) *Qaallu* Odiituu, (2) *Qaallu* Karrayyuu, (3) *Qaallu* Matťarii, (4) Q*aallu* Karaar, (5) *Qaallu* Kuukuu, (10) Q*aallu* Arusii (Nicolas 2010). These centers serve politically as headquarters of (con-) federal states and simultaneously are (sub) clan names. These names are codes and decoders of not only genealogical and landscapes, but also of ancient (sub)-moieties and settlement patterns. Since they are cyclical, based on the principles of Gada System's name-giving principle (*moggaassa*, from *mogga* 'literally 'name, mock, namesake, detour'), they are widespread across Oromia and resistant to change. Werner (1915:2) observed that in Booran Oromo, "every clan has its own mark for cattle, usually a brand (*ɢuʋa* [*guƀá*] which is the name of the instrument used, is an iron spike fixed into a wooden handle)", a fact which is significated in other parts of Oromia with different signifiers, for instance, pattern of settlement, which is determined by a *korma karbaẓaa* 'bull that bulldozes jungles' or *korma qallaččaa* 'kindling bull' (Gidada 2006: 99-100) or bull's anatomy (BATO 1998). For instance, quoting Makko Billii, the ancient Gada System law maker, the Wallaga Oromo recite their settlement pattern metaphorizing it with the anatomy of Korma 'the virile buffalo-bull', symbol of macho man: *Sibuun garaača. Haruu č'inaacha, Leeqaan dirra kormmaati* 'The *Sibuu [Sabboo]* clan is the stomach, the *Haruu [Hooroo]* is the ribs, and *Leeqaa* is the hip of the bull' (see also BATO 1998:164).[33]

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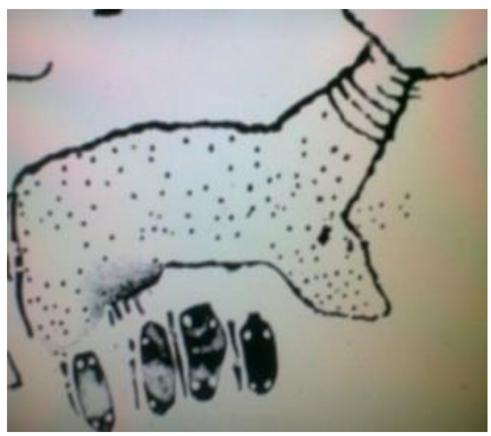
[31] Toponyms provide essential archaeoethnological data and archaeosemiotic evidence especially when they are metasemiotic language.

[32] Corrupted in form and deteriorated in meaning (especially by second and foreign language writers) are the senior and ancient clan of "Wata", "Wota" or "Wawat", appropriately Ót̲t̲aa, Óɖaa clan of the Booran Oromo in Southern Oromia (Ethiopia).

[33] Baxter (1979:71) understood that in Oromo culture "big game hunting for trophies [was] considered as a pursuit that fostered "manly" attributes; successful hunter was, like a good warrior or a prolific father, *d'iira* "masculine" or "virile", *ʤaba* "tough" or *korma* "bull"".

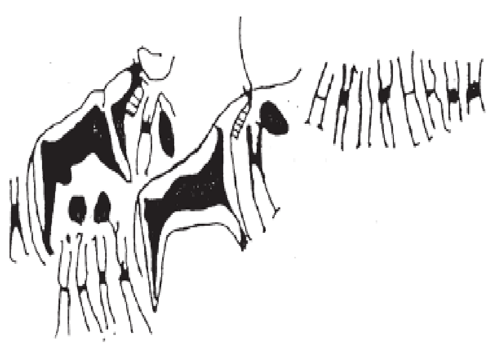
Qallačča bull as a kindler is related to *qallačča* “a white patch between the horns of a cow running back down the two sides of the neck; a charm” (Foot 1913:33; Compare with See Fig.3 A, B, D). It is the symbol of a Qaallu’s *qallačča,* here meaning, an inherited--from ancestors--spiritual and (intellectual) grace, sublimity or power. This is quite related to book’a ‘(a black) cow or bull or ram that has a white mark upon the forehead’ (Tutschek 1844:135-136). Interchanging term/concept (with possible difference of background color) with *book’a* are *qaarré (qállačča,* particulative by rhotacization) and ballačč’oó (particulative-adjectival from ball’) all whose root bear the semantic ‘(to) ignite, agate, kindle’ (compared with Fig.3C). This natural phenomenon to have blaze or white spot on the head is considered as a good omen. *Adda isá book’aa k’aba* ‘his forehead has a blaze’ is an idiom appropriately meaning the person has the natural capacity, inherited from ancestors, to prophesize, foreknow. For this reason, “white-headedness” or wearing white turban round the head is a symbol of (passage to) seasoned manhood, seniority class or superordinate moiety (Kassam 1999). As usual, there is “intimate link…between form, content and concrete situation in life” (Sumner 1996:17-18).

A (from Laga Oda, trace)



B (Laga Oda, trace)

C (Laga Oda, trace)



D (from Ganda Biiftu)

FIGURE 3:

Qallačča as a mysterious metal

Q*allačča*[34] is a polysemantic word in Qaallu Institution. One instantiation of this complex concept is that it is a mysterious sacred material culture worn on the forehead by Qaallu (Fig.4 B). For some ethnologists/anthropologists, it is a "white metal horn which is worn on the forehead" and is "horn-symbolism" (Bartels 1983: 146). For others it is just a 'white metal horn' which is a symbol of fertility or just is "phallic ornament" (Haberland 1963:51 quoted in Bartels 1983:146). These argumentations share the stem *qaɾa* 'horn (sharp and tall); graining fruit, granulate, shoot' and/or, by rhotics (rhotacization-lambadization dissipation[35]) the metaphoric designation in Oromo doxology for God namely, *Ģa łčã* 'that Witnesses/Engages' the Servant-man (*Garbičča*[36]) accompanying him in long travels and admitting him home safely (*ufkala*, *őfχala*)' (from *ɡa ła* 'to come home; to provide provisions for the road') or simply *Ģa łčã* designates 'God's Providence' (see also Tutschek 1844:57; Foot 1913:21).[37] Some flesh need to be added to both concepts next.

Amborn (2009: 401) might be wrong when he completely rejects the "phallisphication" of *qallačča* by "some anthropologists". The very Oromo word for 'sex (intercourse)', namely *sáɭa* also designates 'horn, oryx', from which comes, by rhotics, *qaɾɳî* 'sex, characteristics' (- *ɳî* is invariable marker') and *qaɾa(-mutťee)* 'horny, clitoris'. Michel Foucault, the great social philosopher of the 20th century, has taught us that there is no reason why sexuality, politics (power), embodied-power (saaɭa, 'awe, esteem, honor') and metaphysics (religion, myth) cannot be interrelated by origin or ultimate goal. Yet, he is right that *qallačča* is also a symbol of "socio-religious mediator which is able to bundle positive and negative "cosmic" (for want of a better word) energies" and rather "symbolizes a link between the human and the supernatural world; its function is to open up this connection between different spheres." Knutsson (1967:88-90 quoted in Bartels

[34]Various orthographies are known for the initial velaro-gutturals /q/, /k/, /ɡ/, /χ/ alternate or interchange. In this paper the orthography *qallačča* is adopted unless in direct quotation. Here, *q* is backed, post-velar or laryngeal, semi-ejective or implosive different from *k'* , palato-velar ejective.

[35]Werner (1914b: 263) is the only scholar who, before linguists discovered rhotics, suspected that the "word *gada* (cerebral "d" and "l" are often confused by outsiders) might have originated the name *Galla*". This dissipative phonological change is true of all the retroflex rhotic sounds /l/ , /r/, /ɖ/, /ɳ/.

[36] *Garbičča* also *gapričča* (metathesis) is a particulative-accussative from *gaƀra* or *garba* whose first meaning is the black gigantic African buffalo (also *gaprča*, *gaffarʂa* particulative-absolutive). Through metonymic change, the semantic first extended to human as 'servant, hard worker, tough man' and finally deteriorated (recently and especially by second and foreign language writers) to 'slave, vassal'. From the earlier semantic comes the hypocoristic-appreciative (marked by –ee) *gabree*, *gabâree* 'farmer (tough and rich)'. Victims of this semantic deterioration are the senior (both in genealogy and social status) are the tough and ancient Oromo clan of Gabra/Garba/Gabaro (see many of the book chapters edited by Baxter and Triulzi 1996).

[37] *Ufkala*, also spelled *Ofkala* or *Afkala* by historians, are "Oromo merchant class" or "the intrepid Oromo traders…engaged in around-the-year brisk trade" known since early medieval times (Hassen 1990: 89, 98). The word is composite of *uf*, *őf* 'self, selves' and *kala* 'construct, support, protect' or corruption of *gaɮa* 'come home, return (safely)'.

1983:145) describes *qallačča* as “a conically formed ‘lump’ of black iron…brought from the heaven by the lightening.” Both informants, Mootii and Moommee (personal communication, July 10, 2012) claim that the first *qallačča* was dropped from the sky with meteorites (*qorça*) or lightening (*bakakka*), iterating the ‘historical materialism’ narrated to them by their predecessors. Plowman (1918:114), who took a sketch of *qallačča* (Fig.4 C), described it as “emblem” of the *Qaallu* “Chief Priest”. Plowman fleshes out the components of *qallačča*: (1) “seven bosses superimposed on a raised rim running round the emblem”[38]; (2) “upright portion made of polished lead”; (3) “circular base of white polished shell-like substance resembling ivory”; (4) “leather straps for fastening emblem to forehead of weaver” (Plowman 1918:114). This mysterious cultural object is multifunctional. Taaddasa Birbirsso Mootii, informant and,in the expression of the locals, ‘a man who has sipped mouthful’ of Oromo traditional wisdom explains:

> During the time of Gada System, government by the people’s justice, the Waaqeeffataa used to pour out milk of black cow on *Dibayyuu* ritual and discovered/got their *qallačča* [truth and abundance]. For it is a sacred object, *qallačča* never moved [transported, communicated] without blood—sacrificial blood of bulls. It must be smeared on the forehead [See Fig.6B on the forehead]. How can urine/semen without water, child without blood, and milk without udder/teats be discovered [gotten]? In the aftermath of lengthy drought, they used to take *qallačča* to depression/ford and hill-top to pray with one stomach [unanimously] to God with *Qaallu* the Spiritual Father. Immediately, *qallačča* [God’s riposte] reconciled streaming milk from the sky [rains] (Interview, September, 27, 2012)

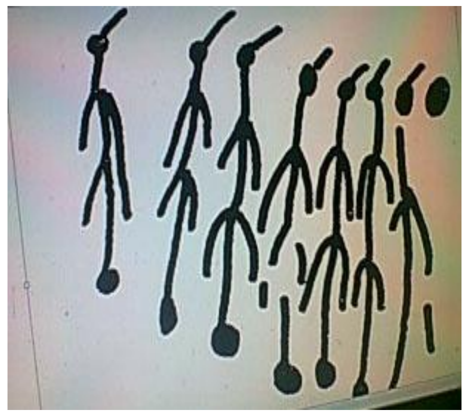
Note that from Laga Oda Cave, archaeologists (Brandt 1984:177) have found “‘sickle sheen’ gloss and polish”, which helped archaeologists to recover “possible indications of intensive harvesting of wild grasses as early as 15, 000 B. P.”; “one awl”, “one endscraper” and “one curved-backed flake” all “dated 1560 B.C.”; and, “a few microliths that show evidence of mastic adhering close to the backed edges” which “strongly suggests” that by “1560 B.C…stone tools were being used (probably as components of knives and sickles).”

[38] As Plowman and others (e.g., Werner 1914b: 272) discuss the number 7 and all the ‘true’ numbers 1-10 and decadals 20-100 code mythical concepts. We cannot treat this complex concept here.

A (Laga Oda, trace)

B (Qallačča

C (Plowman 1918)



D (Goda K’arree Ǧalḍeessa)

FIGURE 4

Qallačča, Bokkuu and initiation to Gada class

Baxter (1979:73, 80) calls it “phallic” or “ritual paraphernalia”, which is worn on the head “by men at crucial stage in the *gaada* [*gadaa*] cycle of rituals”. Muummee (personal communication, August 30, 2012) makes distinction between two types of *qallačča*: *qallačča qarača* (the soft, acuminous *qallačča*), which is worn by the elderly Qaallu or Abba Gadaa; and *qallačča korma* (the virile man/bull *qallačča*), worn by macho man. Viterbo (1892) defines “*kallaéccia”, qallačča* as ‘disciple, pupil’, which cuts parallel with the anthropologist Baxter (1979: 82-84) who states that, in Oromo Gada System, a young man’s grown tuft (*ɡuuɗuu;* see Fig.4 D) is “associated symbolically with an erect penis” and discourses that he is “*guutu diira*”, which means a “successful warrior”, the one who has reached a class of “member of political adulthood”, for he has “become responsible for the nation”. [39] At this age, Baxter adds, “each of its members puts up a phallic *Kalaacha*”, a “symbol of firm but responsible manliness.” The feminine counterpart to *ɡuuɗuu* hairstyle is “*ɡuḍeya*” (Werner 1914: 141), *guṭṭiya* (literally ‘go-away bird’ or its ‘tonsure’) or *qarré* ‘tonsure’ (literally, ‘kite’ or similar bird of prey) (Bartels 1983:262), while of the masculine *qallačča* head-gear is the feminine *qárma* (literally ‘sharpened, civilized’). In Gada System, this age-class is called *Gaammee Gúḍ’ɡuḍá* (reduplication *ɡuḍá* ‘big’) or ‘Senior *Gamme* III’, the age at which the boys elect their six leaders to practice political leadership (Legesse 2006:124-125).

Hassen (1990:15) discusses that *bokkuu* has “two meanings”.[40] One is “the wooden scepter kept by the Abba Gada in his belt during all the assembly meetings”, an “emblem of authority…the independence of a tribe, and…a symbol of unity, common law and common government” (Fig.5 A and B). De Salviac describes it “has the shape of a voluminous aspergillum (a container with a handle that is used for sprinkling holy water) or of a mace of gold of the speaker of the English parliament, but in iron and at the early beginning in hard wood” (De Salviac 2005 [1901]: 216). Legesse (2006:104) describes it as “a specially curved baton”, which shows that there are two types in use. The second meaning of *bokkuu* is, “it refers to the keeper of the *bokkuu*—Abba Bokkuu” (Hassen 1990:15), or in plural *Warra Bokkuu* “people of the scepter” (Legesse 2006: 104).

A (Laga Oda, trace) B (Laga Oda, trace)

FIGURE 5

Hence, after serving for full eight year, Abba Bokkuu must celebrate *Bokkuu Walira Fuud’a* (literally to exchange the scepter *bokkuu*), a Gada system concept that refers to two socio-political “events as a single act of “exchange”” (Legesse 1973:81): (1) the event of power “take over ceremony”, i.e., the symbolic act of “the incoming class” and (2) the

[39] An excellent example of metonymic-homophonic complex, *guuṭuu ḍ’iiraa* or *guuḍuu ḍ’iiraa* comes from *guuṭuu* ‘full, virile, virgin; roof, tuft (hair)’ (from *gúḍa* ‘to become full, big enough; to fill a hole’) and *ḍ’iiraa* ‘male, boy, son; slit sting’.

[40] Some of the orthographies are *bokkuu, bokku, boku, bukú, boqo, boqoo, boco, boqu*, etc. While it is clear that the confusion lies in the interchanging guttural consonants and the related back vowels, here the geminated guttural ‘kk’ and the longer final vowel ‘uu’ are preferred hence the orthography *bokkuu*.

event of power "handover ceremony", i.e., the symbolic act of "the outgoing class". This power-exchange ceremony is also called *Baalli Walira Fud'a* "Power Exchange" or "transfer of ostrich feathers" (Legesse 1973:81-82; 2006:125). Here, *baalli* refers to not only 'power, authority, responsibility' (Stegman 2011:5, 68), but also 'ostrich feather' and 'twig (leaved)', both of which are cultural symbolic objects used on the day of *Baalli*—the power transfer—a day which by default was the first day of New Year (Foot 1913:5).

De Salviac (2005 [1901]: 216) witnessed "the power is transferred to the successor by remittance of the scepter or *bokkuu.*" After power exchange ceremony, the 'neophyte' Abba Bokkuu: "falls in his knees and raising in his hands the scepter towards the sky, he exclaims, with a majestic and soft voice: *Yaa Waaq, Yaa Waaq* [Behold! O, God!] Be on my side…make me rule over the *Doorii*[41]…over the *Qaallu*…make me form the morals of the youth!!!..." (De Salviac 2005 [1901]: 213;See Fig.5B taken from Cervicek 1971 Fig. 44). This kind of 'speech' is called *laba* (*lablaba, laƀaba*, frequentative, emphatic), literally, 'shout, proclaim(ation),publish/publication, decree (of Gada Law)', but socially, a ceremonial, such as Baalli, speech, "highly stylized, but occasionally powerful, defense speeches eulogizing their own ancestors, their gada class, their *gogessa*[42], and the house of the K'allu [Qaallu]" (Legesse 1973: 215). An excerpt from Lallaba text goes "…May the bulls multiply, may the streams swell. I took *balli* and served faithfully [as Abba Gada] . I have not fallen short of what custom requires. I am strong. I am wise. Our family has produced thirteen Abba Gada…" (Legesse, ibid.).Then, the new Abba Bokkuu/Gada takes possession of the seat and "immolates a sacrifice and recites prayers to obtain the assistance of On-High in the government of his people….The entire tribe assembled there, out of breath from emotion and from faith" (De Salviac 2005 [1901]: 212).

Cervicek (1971:130) described Fig.5 B: "An anthropomorphic figure, H-shaped. Painted in graphite grey. The two bag-like representations above the hands are upwards weathered and lighter, therefore it is not clear if they belong to the foregoing picture." Above, it was raised that two symmetrical acts/concepts are enfolded "as a single act [or word] of "exchange"" is performed by exchanging the *Bokkuu* scepter during *Baalli* ceremony (Legesse 1973:81). That is, when the scepter is the one with *bokkuu* 'knobs' on each edge, it suffices to enfold it '*Bokkuu Baalli'* since the symmetricality principle of the act of reciprocal remittance or power exchange is as adequately abstracted in the phrase as in the iconicity of the balanced *bokkuu*. Besides, the *horooroo* stick with a knob (*bokkuu*) on one

[41] Here, *Doorii* and *Qaallu* refer to the 'edifice, tradition' trickling down (*q'urura*) since ancients (*ɖuri*, *ɖurɖuri,* intensive).
[42] Too complex a term, gogessa is described by Legesse (1973: 189): "The term includes the living as well as the dead gada classes and corresponds to the opposite sectors of the gada cycle."

side and a v-/y-shape (*baalli*)[43] on the other side is a semagram and semotactic for the same concept of symmetricality principle, i.e., Bokkuu Baalli.[44]

Qallačča, Qaallu and Bovines: A Gada system egalitarian jigsaw motif

In this last section of this analysis, it is so vital to consider the symbolic significance of what an old man skilled in Oromo social epistemology (oral history) says in a book published by Oromia Cultural and Tourism Bureau () almost a decade and half ago:

> The *Qaallu* did this. For the daughter/girl of *Ǧillee* [eponymous clan name] he took a heifer; for the daughter/girl of *Elellee* [eponymous clan name[45]] he also took a heifer. Then, for the *Elellee* girl he erected the heifer of *Elellee* in such a way that her (the heifer's) head is faced upwards. For the *Ǧillee* girl, he erected the heifer of *Ǧillee* in such a way that her (the heifer's) head is faced downwards. The girl of *Ǧillee* took *siiqqee* stick and hit the Mormor River; then, the Mormor River split into two… (BATO 1998: 75;translation added).

This story offers us a tremendously important insight. It corresponds with the amazing critical observation and re-interpretation of the informant Muummee (personal conversation, Semptember 21, 2012). Muummee rotated 90^{o}CW Cervicek's (1971) Laga Oda Figure 47 (or Fig.6 A) which is observed as in Fig.6 B after rotating.

A (Laga Oda, trace) B (Laga Oda, trace)

FIGURE 6

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[43] *Horooroo* and *ɗ’aŋqee* sticks (both y-shaped and designed from sacred trees like *harooressa*, *waddeessa*) are "symbols of material life" , held on pilgrimages to the cradle lands and immortalize Hooroo 'Primogenitor(s)', the founder(s) of the Oromo nation (Megerssa and Megerssa 1988: 36-37; Braukämper 2002: 141).

[44] It is good to mention note that many of the toponyms of the ancient rock paintings sites of Hararqee collocates with the qualifying *Baalli* and Qaalluu (or corrupted form of the vowels). This is important for consideration of metasemiotic language analysis (see Bravo 2007 for complete list of the toponyms of the sites).

[45] Note that one of the rock paintings sites of Hararqee is Goda Elellee/Allele in Č'alanqo (Bravo 2007). The qualifier *goda* refers to 'mountain foot' or it is corrupted from *gada* 'temple'; the Ethiopian Orthodox Church adopted this corrupting it as *gadaam*.

In this motif, the Qaallu , with his *qallačča* headgear, is at the centre. It is possible to observe one heifer above the Qaallu (perhaps *Ǧillee* heifer) her head inverted, serving as *qallačča* headgear, and behind him to the right handside, two heifers (cattle, one headless), both of whose heads are faced downwards but in between them and the *qallačča* cattle is one anthropomorphic motif, unlike on the lefthand where there are many, possibly a chorus in praise of the sublime white spotted cow (*aɖɖ'oolee*)[46] and of the reverenced Qaallu. Also a heifer (cow?) whose head is faced upwards (possibly *Elellee* heifer) can be seen from the motif. As usual, it is likely also that this style is as much for social-epistemological as is it for grammatical-semotactical reason. The downward-faced heifer or *Ǧillee* (apparently from hypocoristic-diminutive from *ǧiɭa* 'ritual ceremony, pilgrimage to Qaallu cradle lands'), which is equivalent to *qallačča* headgear of the Qaallu anthropomorphic, is a signification of the semantic of *gaɦa* 'to safely travel away and come home (or *ɑaɦma* 'the Sacred Temple of Qaallu')' by the help of the *Qallačča* the providence of God. Thus, the collocation forming *gaɦa-gaɦča* gives the polysemous metonymic senses: (1) to invert, make upside down, (2) one who causes safe home-come i.e., *Qallačča*. The same 'play on word' is true of *Elellee*: (1) reduplication (emphasis) of *ēɦ, éla* 'spring up; well (water)', and (2) *őɦ* literally 'go up; upwards; spare the day peacefully, prevail'. "*Őɦa*!" is a farewell formula for 'Good day!' (literally 'Be upward! Be above! Prevail!').

Yet, the most interesting aspect lies beyond the lexico-syntactic or semotactic motives. Carefully observed, the head of the Qaallu motif and that of the foreparts of the downwards (*gaɗi*) facing *Ǧillee* heifer merge, which makes the latter headless (*gaɗ'ooma, literally 'one who has become gaɖa official*) [47] a representation of the political term/concept koɳtooma 'sovereign, self-reliant'.[48] Legesse (1973:63) described similar Gada structure/system:

[46] Aɖɖ'oolee is a name for 'white spotted cow' (from áɗ'olee, ĥodolee 'spots, spotted ', a plural caritive-genitive from aɖɖí'white', aɖɖó 'whitish'); here, it is a double entendre representation of Aɗ'olee 'Baroness, Feminine Royalty' or Aduɮaa 'senior councilors' (see Viterbo 1893:4; Legesse 1973: 63-64; Stegman 2011: 18, 80). Also, Ancient Egyptian and Meroe always associated (leopard) spots with royalty (see Clyde Winters, Genesis and the Children of Kush. http://www.egyptsearch.com/forums/ultimatebb.cgi?ubb=get_topic;f=8;t=007102).

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[47] Cervicek (1971:132) writes in footnote, quoting the influential scholar Eric Haberland, "even nowadays toy figures of humped cattle without heads are modelled of clay and dung by the Borana [Oromo] (Haberland: 1963a, PI. 28/6)." A hornless cattle is called qúɖ'oo, adjectival of *quɖ'a, qooɖa* 'divide, *k'uťa* 'to cut off, truncate' or *qiťa* 'make/be leveled, co-equal' (see also Tutschek 1844:37, 46).

[48] See also Stegman (2011:73). The usual pattern in Oromo language is, when the retroflex liquid /ɳ/ appears as an epenthetic sound the implosive /ɗ/ turns to /t/ affecting the surrounding vocalic sounds, hence, possibly: *gaɗ'ooma→ koɳtooma*.

> The highest office is that of the Abba Gada Arbora.[49] He is described as the *adula fiťe* or the apical councilor *(fiťe*=apex, pinnacle, top). The next two seniority positions are held by the councilors known as Abba Gada *kontoma.* These two officers always come from two specific clans from the two submoieties of the Gona moiety. The three senior officers of the council are collectively known as *gada saden* (the gada triumvirate). The remaining three councilors are simply *adula hayyu* (senior councilors).

The *Elellee* heifer, apparently with only one horn but full *bok'uu* 'nape' (*pun on Bokkuu scepter, symbol of power*), appears to be another jigsaw making a thorax (gûɗeˡča) of the Qaallu, possibly because in the "*Barietuma*" Gada System, the Qaallu are "central", i.e., "occupy a special position, and their members act as "witnesses" (*Galech*) on the occasion of weddings or other important transaction" (Werner 1915:17, 1914a: 140; See also Legesse 2006: 104, 182, for "Gada Triumvirate System").

Pertaining to the "seven bosses" of the *qallačča* (Plowman 1918:114)) is possibly equivalent to Cervicek's (1971:192) description of this same motif: "Seven animal representations, painting of a symbol (centre) and pictures of H-shaped anthropomorphic figures…Painted in graphite grey, the big cattle picture a little darker, the smaller one beneath it in *caput mortuum* red." While we can consider, following Dr. Gemetchu Megerssa, anthropology professor, that the seven bosses might stand for the seven holes of human body (above the neck) which still stand for some mythical concepts we cannot discuss here, it is also possible to consider the (related) socio-political structure of the democratic Gada System. They might stand for what Legesse (1973: 82, 107) calls "*torban baalli*" "the seven assistants" of Abba Gada in "power" (his in-powerness makes him Abba Bokkuu, 'Proprietor/Holder of the Bokkuu Scepter'). Long before Legesse's critical and erudite study of Gada System, Phillipson (1916:180) wrote:

> The petty chiefs act in conjunction with the king. These are, however, appointed by election of officers called *Toib* [*To*ʳ*b*] or *Toibi* (= seven councilors or ministers). These are men of standing and character…. They are governed by, and work in unison with, the head. These officers are appointed by the king, and each of the seven has an alternative, so that the number is unbroken. Their office is to sit in council with the king, hear cases, and administer justice…the *Toibi* stands in the order elected: 1, 2, and c.

These seven high ranking officials (*agaoɗa*) are purposely represented by forepart of bovine body (*agooda*), because this is the strongest and most powerful part. *Ól,* literally

[49]Gada Arbora is either corruption of Gadaa Boora or is related to the symbolic meaning of arbora 'armband (prestigious)' or as in the phrase olla arbora that "refer to the original cluster of huts, the part of the camp consisting of the families of the *adula [adullaa]* councilors" (Legesse 1973: 69).

‘up, upwards, upper’ is a metaphoric expression for those “On-High in the government of his [Abba Bokkuu] people” (De Salviac 2005 [1901]: 212). Cervicek (1971:130) is accurate when he theorized “anthropomorphic representations do not seem to have been painted for their own sake but in connection with the cattle and symbolic representations only.” Nor is the headless cattle drawn for the sake of fun or ‘scholastic’ pastime, but, without doubt, is intended to capture what Legesse (1973: 63) describes “Borana version of ‘government by committee’”, called *gadaa mura* (from *mura* ‘cut (into equal seams); decide, judge, sentence’), but a paronomasia for the aforementioned system of Gada Arbora/Boora: “in spite of the fact that they were ordered by seniority, they were a community of equals and shared the same amount of decision-making power”(Legesse 1973: 63). In other words, it is stylized painting intended to texture the notions of seniority-cum-equality simultaneously, in *caput mortuum*.

Conclusion and implications

The aim of this paper was to use the ancient Gada-Qaallu Institutions of the Oromo and its two sub-themes—*qallačča* and *bokkuu* --as a general sensitizing, analytical device in order to understand and explain the underlying social epistemological, semiotical and rhetorical structures about ancient rock paintings of Hararqee in Eastern Ethiopia. Both field data from archaeological sites and archival data are used. The broader and deeper approach to social semiotics was adopted as a guiding theoretical framework.

The results reveal both substantive and methodological insights. Methodologically, the results suggest the importance, as social semiotic device of the unique Oromo social semiotical rhetorics, which combines into a single communicative structure, four features of social semiosis: homophonic (identical sound structures), homosemic (synonymic structure), homosememic (semantically polysemous, etymologically ancient, phonologically harmonic, and hence is characteristically poetic, irrespective of whether the style is verse or prose), homomorphic (i.e., ontologically/causally systematizing the cognitive faculty, e.g., *korma* as ‘a virile bull’ and *korma* as ‘a macho man’, and hence metonymically symbolic). Again, for lack of expression, it is referred to as ‘metaplasmic witticism’—a socially intended project to systematize the Jakobsonian semiotic triangle—the signifier (the visual or phonemic substance of the word); the signified (the concept or image represented by the visual or phonemic sequence/the word); and the referent (the pre-linguistic object or real world of the social or natural). By more systematized way—in contrast to unsystematized one of unwrapping the world and wrapping it with related words, Oromos believe, both the word and the world are “disposed to help memory” (De Salviac 2005 [1901]:285). This emanates from antique social epistemological praxis captured in the epistemic adages: *wal-fakkaattuun wal-barbaaddi* ‘the similar/look-alike want/inquire one/each (an-)other’; *miʔa wal-fakkatu wal-bira fannisu* ‘it is those look-alike/similar entities/things that (they) put/generate together’, and so forth. As such, the usual Western dualism (separating the world and word, the indigenous mind/people from their world/works) or arbitrarization of the semiotic triangle is a categorical mistake.

Substantively, the results show the separation of the people from their native land, symptomatic of the Eurocentric dualism, is and has never been useful for advancing human knowledge. Firstly, there must had been Peircean (Sanders Peirce) ‘community of inquirers’ or Habermasean (Jurgen Habermas) ‘communicative actors’ working for the advancement of scientific knowledge. This amazing widely distributed yet with shared linguistic-semiotic-epistemological structures could not have happened without ‘community of inquirers’.The very Hararqee Oromo clan-names or ethynonyms--as usual eponymous—are as metasemiotic evidence are the toponyms, i.e., they mean together ‘Community of Inquirers’—for instance, Warra D’aya ‘Community of Mimesis/Beaters/Reckoners (calendar)’, Afran Qaɦɦoo/Qaɻɻoo ‘The Quadruplet Wisemen; The Four Men of Reading/Writing’, Warra Hubana ‘The Community of Inquirers/Knowledge’.[50] Quite contrary to what the mainstream Eurocentric historians and archaeologists tell us, the results of this study show, without doubt, Oromo social epistemology, cultural history, social semiosis and unique rhetorical organization.

Another important implication of the findings of this study is that the faulty literary/linguistics theory of ‘punning for punning’s sake’ or ‘metaphor for metaphor’s sake’, which dismisses social semiotic intentionality, implausible to accept. In this paper, we have gotten a glimpse of the fact that the ancient wisemen never chose at their own will, but, it was real generative mechanism that required systematization or linking of the ‘word’ and the ‘world’. Particularly, in Oromo, arbitrarization does not work or it may work to some degree today but never or less in the antiquity; it might be true of some languages. For an Oromo, there is no difference between making a respectful speech (*seeda*) and erecting an obelisk (*siidá*) on *soodduu ɖ’abaaɗ’a* ritual of paying homage to the departed Abba Gada, for it is a ritual/expression that involves “all the objects and substances that are placed at the graveside and all the actions that are performed by the family in remembrance of the deceased parent” (Baxter and Kassam 2005:1). Language and languaging are complex phenomena/structures intricately related to the emergence and life praxis (of tens/hundreds of thousands of years) of Homo sapiens sapiens, yet related never arbitrarily.

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[50] The Oromo words for ‘wisemen’ or ‘men of reading’ such as *qaro*, *qoro* ‘wise man/men, noble’ (also means ‘raven, black hawk’ from *qara’a* ‘sharp, sharpen, inquire, read, delineate, sculpture, do grammar’) and *qafá* ‘wise person’ (from deverbial *qaffa*, *ɠáfa* ‘to ask; horn, day’) are popular also in Ancient Meroitic-Egyptian texts (for the Meoe-Egyptian lexemes see Aubin 2003; Rowan 2006).

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Indigenous Institutions in Pastoral and Agro-pastoral Conflict Management Systems: The Case of the Afar, Issa Somali, and Ittu Oromo ethnic groups in Eastern Ethiopia

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Abstract: *This study considered the role of customary institutions in traditional conflict resolution methods. Violent conflict in a culturally diversified community like Ethiopia is common. Conflict arises due to a complex set of variables coming together and reinforcing each other at multiple levels and at critical stages of a country or region's development. In short, the causes of conflict in the study area are the competition over the scarcity of resources, population pressure, and cultural differences, among others. Local conflicts in pastoral areas in Eastern Ethiopia have been common phenomena since time immemorial. Such conflicts are characterized by competition over grazing land and water resources which are directly or indirectly linked to livestock raiding and looting. Furthermore, it was intensified with declining pastoralism and the type of state responses. The scarcity of resources is leading to unsustainable pressure on vital resources such as pasture land and water thus increasing levels of violent competition and tension between local communities. Violent conflicts have been gradually intensified with the introduction of automatic weapons in the hands of pastoralists and agro-pastoralists due to the larger inter-state, regional and national conflicts. In this regard, Meiso area of eastern Ethiopia is generally considered as a bone of contention for long periods. In recent times, violent conflict between pastoral Hawiya and Issa Somalis and the different Oromo clans in the area has emerged as a result of the emergence of boundary disputes between the new Somali and Oromo regional states. The involvement of various rebel groups and local elites has intensified the violence and animosities along ethnic lines.*

Key words*: Indigenous institutions, conflict, Meiso, eastern Ethiopia*

Justification and Rationale

Inhabiting the lion share of pastoral and agro pastoral communities, borderlands of Eastern Africa have been repetitively plagued with violent and intermittent conflicts that recently tend to escalate to such an extent that governments seem to be unable to contain properly. Available evidences suggest that conflict in these areas often overlap with extreme food insecurity and other socio-economic problems. Men are most often the ones who are enrolled and therefore killed or injured during conflicts. Women, however, are the main victims of war. This is either directly as fatalities and casualties or indirectly through the breakdown of family and community structures and engaged in to new roles such as the sole provider to the family. Some factors that contribute to the worsening of pastoral situations include their wide dispersal, climatic and ecological conditions, state neglect, and development plans that have excluded them, seizure of their land, land tenure laws, and national borders that restrict their freedom of movement, (Kandagor, 2005).

In Ethiopia, pastoralists have been invariably victimized by most of the above listed factors. Affected by serious and recurrent famines and drought conditions, their situation has been deteriorating as their capacity to cope with the changing climatic conditions is seriously endangered. In most cases this contributes to the ever increasing ethnic tensions and conflicts among the many pastoral groups in the country. In this regard the violent conflicts that frequently erupted among the Afar, Issa and Ittu Oromo groups in and around Meiso area provide a good environment of inquiry. Among these ethnic/clan groups, conflict over the ever dwindling natural resources such as grazing land and water has been central in their strained and often violent relationships. Apart from the many environmental vagaries, conflicts among these pastoral groups are believed to be many and diverse. Some of these manifestations include nationalism, inter ethnic conflict (e.g. Afar-Issa conflict), competition for power among political parties, and on some occasions, inter-clan conflict over resources. Here conflict is increasing both in terms of frequency and armed severity (Beyene 2007). Many of the conflicts have resulted in widespread death incidences as well as displacement of people and livestock in the area often contributing to the vulnerability of the inhabitants and deterioration of well being. Adeytu is one of the contested locations where the Issa and Afar are fighting over resources. Large numbers of people and animals from both sides are gathering in Adeytu and this might lead to further conflict. (Abraham, 2002) Culturally different ethnic conflicts are widely common in Ethiopia in particular and Horn of Africa in general.

This study proposed that understanding the major causes, actors involved and the over all impacts of pastoral conflicts is paramount to the ongoing efforts in mediating and managing all these undesired events. It is also believed that instability in the communities concerned is caused by lack of or ineffectiveness of mechanisms to communicate and redress grievances peacefully. If conflicts are to be dealt with effectively, more effort will be needed in strengthening the capacity of the community in general and women in particular to develop institutional mechanisms involved in conflict management practices. The fact that pastoral conflicts can only be effectively managed with the strong involvement and enhanced roles of women in traditional conflict resolution mechanisms that contribute to its minimal impact on women and emphasis will also be made on customary institutions in order to address people's problems from the grass roots level is central to this argument.

Objective of the Study

The major objective of this study is to conduct an in-depth analysis on the causes of conflicts, actors involved and the role of indigenous conflict management institutions among the Afar, Issa Somali and Ittu Oromo in eastern Ethiopia. The specific objectives of this study are:

- to identify the underlying causes and trigger factors of conflicts between these ethnic/clan groups,
- to assess the role of indigenous conflict management institutions in intra and inter ethnic conflicts in the study area,
- to assess the contributing factors that hinder the proper functioning of the pastoral customary institutions in resolving and managing conflicts, and
- to examine the mechanisms by which the government, NGOs and other stakeholders can strengthen and incorporate indigenous with modern conflict management institutions among the concerned pastoral groups.

Materials and Methods

Description of the Study area and the study population

The proposed research was carried out in Eastern Ethiopia where the distinct ethnic groups namely the Afar, Issa and Ittu Oromo predominantly live together. The Issa and Ittu ethnic groups belong to the Somali and Oromia Regional States of Ethiopia, respectively. The research also look in to the causes, actors involved and the role of indigenous social institutions in conflict management and resolution among these groups of people. The Issa ethnic groups inhabited Shinille zone of Somali region and borders Djibouti and Somaliland in the north and east respectively; Jijiga zone in the southeast, and Oromia and Afar regions in the south and west respectively. This zone is part of the arid and semi-arid lowlands, north of the Hararghe highlands. A few mountains and shrubs can be seen along the mid-highland areas of Oromia region. The dominant clan group in the zone is the nomadic Issa, Gurgura, Gedabursi and Hawiya clan groups are also the agro-pastoral residents in the zone. Five of the six woreda-towns are located along the Djibouti-Addis Ababa railway line. Some villages of Afdem and Meiso woredas are situated slightly off the main Awash-Mille road. All these ethnic groups who are bordering and competing with each other for scarce resources are the major contenders in the study area. The persistence conflicts among them make the study area the most conflict prone and volatile area in all the three regions.

Sources of Data, sampling techniques and the Method of Data collection

This study employed both primary and secondary data collection methodology. Qualitative data were gathered through semi-structured interviews with key informants, case studies, focus group discussions, observations and informal discussions. An in-depth interview with key informants was employed in order to have thick description of events. A systematic examination of relevant documents both published and unpublished was also be used as secondary data sources. Key informants and focus group discussants were selected purposively based on their sex, age, level of education and awareness/knowledge about their culture, society and environment from all the three clan/ethnic groups. Parts are evaluated in the context of the whole system (i.e. holistic approach). The number of key informants (flexible in size and type) and focus group discussions were adjusted after factors and conditions become clear and directive while the study is in operation.

Data Processing and Analysis

With regard to data analysis, the proposed research was analyzed based on the theoretical and methodological principles of interpretation. To this effect, descriptive and conflict analysis techniques were employed for the description, interpretation and analysis of qualitative data.

Result and Discussion

This section tried to assess the overall nature of conflict scenarios in the study area which is characterized as intra- and inter-ethnic conflicts over the use and control of natural resources as well as the conflict due to the territorial expansionary moves done by different but contending ethnic groups, the causes of conflicts in the study area which is multi dimensional, complex and dynamic in nature that requires a deep understanding of the conflict situation in all intervention and development endeavors, the dynamic nature of conflicts in the study area, the roles of the various indigenous institutions in managing and resolving conflicts, how the different institutions are organized/structured, functioned, their enforcement mechanisms, and how compensations during conflict resolution process are practiced by such institutions.

The Nature of Conflicts in the Study Area

Regardless of the significant importance of understanding the causes and dynamics of conflicts in the study area, for effective mitigation and resolution mechanisms which have important policy implications for peace building activities, the problem seems lack attention. Both intra- and inter-ethnic conflicts over the use and control of natural resources as well as territorial expansionary moves are everyday business in the dry lands of Ethiopia in general and in the study area in particular. There is high incidence of violent conflict among the different pastoral ethnic groups found in the study area. This conflict has resulted in high distractions in livelihoods of the pastoral and agro-pastoral communities and their lives from time to time. Furthermore, the conflict in the area is characterized by multiple interests and causes among the pastoral and agro-pastoral groups which resulted in massive displacement of people from their original settlement. A case in point is the Oromo who displaced from Bike of Somali region and settled in Meiso, and the Somali who displaced from Bordede and Meiso of Oromia region and settled in Mullu and a new settlement site named Hardim. This displacement and resettlement of people is due to the ethnic based conflicts over the control of certain territories and its subsequent referendum which took place in 2004 among the contested areas between Somali and Oromia regional states. The conflict has caused precarious living conditions in the area and resulted in huge socio-economic disruptions and lose of human lives.

The conflict has changed its nature from time to time and the introduction of modern weaponry in the conflicts arena made the conflicts more devastating than the earlier forms of traditional confrontations. The conflict has also got new shapes and dimensions with the introduction of ethnic based federal arrangements in Ethiopia in 1991 particularly among the pastoral and agro-pastoral communities of eastern Ethiopia. Pastoralism as a livelihood mechanism by its nature requires mobility as an adaptation to the arid and semi-arid range lands of the region as well as an alternative strategy to maximize their productivity. When their mobility is restricted it could be a cause for conflicts. The conflict between Ittu/Alla vs Issa, Ittu/Alla vs Hawiya, Issa vs Afar and Ittu/Alla vs Afar pastoral groups are some of the notable conflicts found in the study area from the different inter clan/ethnic conflicts and there is frequent incidence of conflict between these groups especially between the Issa vs Afar and Issa vs Ittu/Alla Oromo ethnic groups.

Furthermore, FGD participants of the Mullu Meiso Woreda community elders (May 25/2012) clearly outlined the major actors of conflict involved and the main sources of conflicts in the study area. The primary actors involved in the conflict are the Issa clan Vs Hawiya clan of Somali, the Issa clan of Somali Vs Afar, the Issa clan Vs the different Oromo clans. There are also secondary and tertiary actors of conflicts like governmental and non-governmental organizations, the neighboring states, the Diaspora community, the different libration fronts/resistant groups in the region, etc. They also added that the primary sources of conflicts in the study area are the competition on pasture land, water points, cattle raiding, heroism, and among others.

The Potential Causes of Pastoral Conflicts in the Study Area

This study tried to assess the various causes of pastoral and agro-pastoral conflicts in the study area. The causes of conflicts in the study area are multi dimensional, complex and dynamic in nature. Such complex and dynamic causes of pastoral and agro-pastoral conflicts requires a deep understanding of the conflict situation in all intervention and development endeavors. There is no single cause of conflict that can address the variety of superseding variables that take part in practical conflict situations. These variables include cultural, historical, political, and economic motivations of the various parties involved in the conflict. Real world conflict situations are often further complicated by the actions of secondary conflict parties expressing their interests through the primary contenders or actors (Adan and Pkalya, 2005).

The current literature speaks that different authors have suggested different hypothetical variables that are potential causes of pastoral conflicts. According to Mahmoud (2006), for instance there are wide ranges of factors which trigger conflicts at local and regional levels. His empirical finding in Southern Ethiopia and Northern Kenya pinpoint that factors like a policy of ethnic based regionalization, ethnic politics at the national level; state implemented ethnic based boundaries and the like are major causes of conflicts among feuding groups in southern and eastern Ethiopia, who have laid claims on crucial range resources in certain pockets and on disputed boundaries which have a strategic economic/political interests. Similarly, several ethnic groups in the study area have engaged in at least one or more ethnic/clan groups' conflict in relation to land and water disputes, disputes on custom posts, territorial expansionary moves over the year, etc. This is due to the absence of clearly demarcated regional, zonal, district and kebele level boundaries among the contested pastoral and agro-pastoral areas of eastern Ethiopia.

Furthermore, this study revealed that some of the most important variables as most important causing factors for conflicts in this region are competition over pasture land, water points, boundary disputes, livestock raiding, heroism, banditry and its sudden killings and the like.

A similar study conducted by Beyene (2007) in Mieso district of Eastern Ethiopia also confirmed that factors like customary norms, power asymmetry, resource scarcity and livestock raids are causes of conflicts in the area. Besides, Mahmoud (2006) outlined some of the major hypothesis in the anthropological study of conflict management. These are competition for scarce resources, frequent internal conflict in societies with strong fraternal groups, emphasis transforming disagreement in to violent action, enemy stereotype, marginalization of a society, uncontrolled proliferation of weapons are found to be the causes of conflicts in the study conducted in Somalia, Ethiopia and Kenya border line.

Furthermore, some scholars are also stressing on livestock raiding as major causal factor to conflicts in most pastoral areas of Africa. For example, Blench (1996) indicated that in the research that have been done, inter group conflict between pastoralists has been interpreted as competition for pasture. However, he clearly indicated that chronic insecurity from livestock raiding has the effect in some areas determining herders from exploiting pasture that are not easily defensible.

Moreover, resource scarcity and the subsequent competition is also a causal factor to conflict is strongly highlighted and explained by FDG participants in Meiso district. The rapid environmental degradation, an alarming rate of population pressure, unequal distribution of power and the lack of good governance, and changing consumption pattern exacerbates resource competition and in turn exacerbate natural resource scarcity. Homer-Dixon (1994, 1995, and 2003) indicated that environmental scarcity will contribute to the occurrence of violent conflicts. Drought conditions can trigger and escalate conflicts over scarce resources. During severe shortage of rainfall in pastoral areas, the groups residing in the area try to spread over more land, while at the same time, neighboring groups increasingly do the same (Stiles, 1992). According to the empirical research finding done in Sudan it is indicated that when land becomes more scarcer and under increasing pressure, the various stakeholders will claim over it and therefore, underpinning a history of conflict in relation to land and access to natural resources. Despite the huge land size in Sudan, scarcity of the range lands creates for primary production systems has become increasingly felt and perceived by resource users (Taha, 2007).

In the study area there are various development projects or interventions that are also considered as causes of conflicts. However, not all development intervention activities are considered as causes of conflicts. But those development interventions which are not conflict sensitive might instigate or trigger the existing or new conflicts in the area. For example, a road from Bordede to Gelemso town and also another new road that links Serkama and the surrounding kebeles to Dire Dawa city behind Hurso military camp which are constructed by the Oromia regional state in collaboration with the local people trigger the already existing conflicts between Somali and Oromo clans in the region. Another Indian investor in Meiso at Bordede area in Jatroffa plant was also harassed or threatened by the clan conflicts and finally forced to withdraw from his investment in the area. Besides, another investor in Bordede who tried to construct Oil Company was also considered as a threat to the livelihoods of the local pastoralists so that he was threatened by the local people (FDG participants on May 22, 2013, Meiso district).

Conflict Dynamics in the Region

This study revealed that the nature of conflicts in the area is very much dynamic and changing its nature from time to time. Both the existing ethnic/clan groups who are competing each other on several crucial issues in the region (the Afar, the Issa, the Hawiya, the Ittu, the Alla, the Nolle) are Cushitic speaking pastoralist groups that have formed more flexible strategic alliance with one another and also with other groups differently at different times throughout their history. They have a similar religious practice called Islamic religion and more or less similar socio-cultural and economic practices. The majority of them are pastoralists although there are agro-pastoralists in the region. They were placed under one administrative unit/region in one regime and different in another regime in Ethiopian past history. For example, during the Imperial regime these contested areas was classified and administered in to two. These were the Adal and Gara Guracha Awraja for the Afar and the different Oromo clans living in the region and another one was the Issa and Gurgura Awraja for the different Somali clans. During the Derge regime all the three ethnic groups their sub-clans (the Somali, Oromo and Afar in the area) were administered and named as Issa, Adal and Gara Guracha Awraja where they were unanimously administered. Gara Guracha belongs to Oromo, Adal for Afar and Issa for the Issa clan. Oromos were not named /called by their name rather by the name of the mountain i.e. Gara Guracha which means literally black mountain/hill while Issa and Adal were named by their names. FGD participants stated that they raised the issue to be named by their name Oromo (FGD with Meiso district community elders, May 24/2012). However, after the introduction of ethnic based federalism in 1991 when EPRDF took power, they were/are separated in to three regional states and administered by their respective regions namely the Afar regional state, the Oromia regional state and the Somali regional state.

It is a known fact that pastoral and agro-pastoral conflicts in the region were practiced since time immemorial. Community elders pointed out that there were pastoral and agro-pastoral conflicts (inter/intra ethnic/clan) on the competition of pasture lands and water points during the Derge and Imperial regimes and even before. However, the level and intensity of conflicts at that time were less than today's conflicts. The recent conflicts get new shapes with the introduction of ethnic based regional boundaries. They further added that apart from the cultural/social and economic motives of conflicts in the region, there is an increasing influence of politics (both regional and national) that the primary actors of conflicts are competing for territorial expansion and claiming over disputed borders. In such cases conflict has been changing in its nature over time from a simple confrontation by using traditional weapons to the use of modern and more sophisticated weapons which ultimately increased the devastating nature of conflicts. It is believed that most of the states in the horn are considered to be fragile states and of which some of them are stateless societies. As a result of these the region is considered as the most conflict prone region in which there are easy proliferation and circulation of modern firearms. Traditionally, the pastoralists practiced cattle rustling using spears and bows, but now the weapon of today's choice is the AK-47. The relative ease of acquisition and low cost of these illegal guns enable the pastoral communities to guarantee a sustained market (Mkutu 2001). The East African weekly newspaper estimates that there are between 150,000 and 200,000 firearms in the Karamoja region of Uganda alone. While the exact number of small arms in the hands of pastoral communities is difficult to assess, it is clear that the threat posed by them is enormous (Goldsmith 2006).

Some scholars also stressed that there is also a fear that the region would be a potential home for terrorists that aggravates for the unstable conditions of most states in the region. The various actors involved in the conflict (the Diaspora, the neighboring regional states, individuals/rebel groups who have an interest and stake in the region like secession policy, and also the different state interventions in the region have different implications for the conflicts. This can be verified as true by different authors like Dejene and Ame (2002) in Southern Ethiopia indicated that the pastoral conflict is changing its nature and devastating effect increased from time to time. As to the study conducted in 1990s, the frequency and magnitude of conflict has increased. As proved, in 2000 three major conflicts occurred between major rival pastoral groups (Borena versus Gari, Merihan versus Digidia, and Degioodia versus Borena). These conflicts resulted in the death of hundreds of people and combined with severe drought, they resulted in dislocation leading to the formation of internal displace camps.

Such a similar phenomenon is also happened in the study area. In the 2004 referendum which took place between Oromia and Somali regional states among the disputed districts and kebeles, there are the formation of new settlement areas/camps at Hardim and Meiso. In the new Meiso settlement area, the people who are settled are those Oromo clans who were displaced from Bike and Afdem following the victory of the Somalis in that referendum. The same is true for the Somalis who settled in a new camp at Hardim following the victory of the Oromo at Bordede which is today the most volatile area and a cause for the recent clash between the Oromo and Afar against the Somali.

The pragmatic research finding done in Afar tries to reveal that the nature of conflict changed in the ecology, socio-economic and political arenas. In the past, the Afar leads a predominantly nomadic life in which livestock husbandry was the dominant source of their economic subsistence. This form of economic performance dictated a particular social organization within the Afar and it shaped their relation and neighboring ethnic groups particularly with the Tigrayan highlanders (Kelemework, 2006) and also with the Ittu, Issa and Kerreyu pastoralists.

The Roles of Indigenous Institutions in Conflict Resolution Mechanisms

Indigenous institutions, according to the definition, are informal institutions. They include local cultural forms of organization, for example locally elected, appointed, or hereditary leaders and elders. They are customary rules and regulations as well as indigenous practices and knowledge regulating the access to resources. All of these have been recently heralded as a valuable resource through which appropriate and sustainable development can be achieved (Watson, 2001). As evidence done in Kenya indicated that lasting conflict resolution can only be achieved by the parties themselves, based on strengthened local institutional capability (including customary institutions and local civil society organizations), and key local individuals. However, government and outside agencies have an essential role to play in creating the external conditions for such local settlements, and in supporting local institution capability (Adan and Pkalya, 2005).

Furthermore, case study showed that people in the Horn of Africa have time tested and effective indigenous mechanism to stream, prevent, mitigate, manage, resolve conflicts, and to draw the attention of the government of the horn countries to stream line and use these indigenous mechanisms to make the region more stable and peaceful. Indigenous mechanisms are time tested and effective to handle conflict which arise in the horn region, had it not been for these mechanisms, things would have gone and have been exacerbated and gone out of the government's control and been developed to a full scale of war between the neighboring state. When compared with the non indigenous mechanism for the prevention and resolution of conflicts, they are less complex, save time and give chances to parties in conflict to actively participate to solve their own problems and to handle their affairs in relatively more acceptable way to them (Assefa, 2001).

Governance Structure of the Gumma System of the Oromo in Meiso area

The governing system of the Gumma has a highrarchical structure in its governing principles and administrations. Each position has its own duties and responsibilities which are directly accountable to the immediate next top position. For example, the Abba Gada is the head of the Gumma system who hold the top position of the traditional Gumma governance system. The next position is the Bokku (s) who is/are equated in modern governance system as a minister(s) who has different duties and responsibilities in the community. It is also named as Damina in Arabic word. Next to the Bokku is the Kondale Karra who is responsible for the fair distribution and contribution of the compensations contributed from members of each clan during conflict resolution. The next most important position is the Jejebi Gossa which is the lowest position in the Gumma governing structure. Jejebi Gossa is normally a soldier (s) who is/are responsible to enforce the decisions made by the council of elders in the Gumma administration. They are responsible to collect cattle for compensation, punish the culprit or whip or any other order at grass root level in kebeles or small level administrative units.

Genealogical Structure of the Meiso area Oromo clans

Barentu Oromo has five sons, namely Merrewa, Tumuga, Karrayo (Uttulo), Humbena and Qello. Merrewa has one son, i.e Ittu. Ittu has four sons, namely Gallan, Manna Babo, Manna Ittu and Khurra. Qello has four sons which is publicly known as Afranqello (the four sons of qello), namely Dagga Qello, Alla Qello, Babelle Qello and Obbera Qello. Babelle Qello now again has three sons, namely Hawiya, Gidille and Gundup. However, there is a controversy that Hawiya belongs to one of the Somali clans.

The Procedure of Gumma System and its Enforcement Mechanisms

In the procedure of the Oromo Gumma system, there is the intervention of a third independent party from another clan as a mediator between the disputed parties/clans. Until the case is handled, the offender will hide him/her self somewhere else, his clan elders tried to negotiate with the deceased clan. The offender clan pays some amount of money for the deceased clan for the funeral ceremony together with 3 meters of cloth, one ox, and few kilos of maize for the funeral ceremony. This is named as *kefenafi kefera (named in Amharic as Eniba madirekia*) and *Immimetti* (previously 50 cattle and now 15 cattle) were given for the deceased close relatives (mother, father and sisters only). Then, a larger and wider appointment for dispute resolution at clan level will be organized. The offender clan makes a group called *seglen* to collect cattle for compensation from their own clan members. Then, the culprit will be assigned to look after those cattle until the *seglen* members finished their duty. Until then, he is excluded from any activity, for instance not to perform sexual mate with his wife, prohibited to eat together with others (excluded), get in to the house at backyards, not cut his nail short, not cut his hair short, not allowed to wash his body, etc.

These are all signs of punishment for the culprit. Then after the *seglen* finished the preparation, a large temporary hat (*dass*) will be prepared as a large whole for the resolution ceremony. At this juncture one ox will be slaughtered for this ceremony. Then, it will be divided in to two equal parts, one for the offender and the other for the offended clan. Then, each of them distributed it to their members. The left front leg of the ox will not be eaten. The mediator obscure the cattle prepared for compensation about their status. The culprit who looks after the cattle for compensations at the nearby kraal will be tied with *difen qill* at his right hand and allowed to come to the audience from the kraal. Then, he will be allowed to beg to make him free from all of these sanctions. The brother of the deceased and the culprit tied together by the *meditcha* (rope like made of leather) and came together in front of the audience. Community elders and religious leaders will bless them to become unit as one and brothers to each other. The rope symbolizes to end their enmity and unit together for peace and development. The deceased mother will lash butter on the hair of the belligerents so as to get rid of evil spirit from their womb or mind and begun as relatives and not allowed to intermarry among themselves.

The culprit then went to a hill. Here his eye brow will be cut, the qill will be broken down, his nail cut, he will change his clothe with a new one, he will be blessed, those utensils who used during his confession time will be broken and buried in that hill. Then, he will be allowed to join the community. This seclusion process may last for about one to three months and more, i.e one month during summer as cattle are near their village and three months during winter as cattle are far from their homestead. Except for the first 15 cattle, the remaining cattle for compensation will be distributed to clan members. If one clan brings a food named pourage, it will be considered as one cattle as a contribution for compensation. These all Gumma system is functional only in Oromo clan conflicts. Elders said that they didn’t have such systems for cases of inter-ethnic conflicts. This system works for conflicts between Oromo clans and Hawiya clan, but doesn’t work for conflicts between Oromo vs Issa and Oromo vs Afar conflicts. The only way of addressing the latter types of conflicts is through the intervention of the modern system of conflict resolution, i.e through the intervention of the federal army which is almost ineffective and not timely as the community elders pointed out.

Compensation System for Different Types of Offenses in the Gumma System

The Oromo clans in the study area have its own rule of governance for various maladjustments and happenings particularly with conflict and conflict resolution practices. Compensation or blood money also called Gumma is one of the best strategies in indigenous institutions of conflict resolution mechanisms. In the study area there are strict rules and regulations for every kind of offenses with regard to compensation mechanisms. Some of the compensations for offenses are as follows: First, if killing of an individual happens in the form of sudden killings, the amount of compensations given to the deceased family is 100 cattle. If the killing of an individual is in the form of purposive killings, the amount of compensations will increased to 150 cattle. Second, the amount of compensations for the offense of an amputation of any of the body parts has its own specific rules and regulations by the Gumma customary law.

A. Arms amputation: - If the left hand is amputated, the amount of compensation given to the offended one is 16 cattle and if the right hand is amputated, 15 cattle will be given (one more cattle is added for the left hand amputation because the left hand is considered as more important than the right one because of its role in reproduction/love making and defense mechanisms).

B. Legs amputation: – Leg in the community is represented as baria (male) and bariaytu (female). If the left leg is amputated, the number of compensations given to the offended one is 16 cattle, 2 oxen and 1 mule; while if it is the right leg, the compensation will be 15 cattle, 2 oxen and 1 mule. Here 2 oxen are given for the injured for farming purpose and 1 mule for transportation as his leg is injured.

C. Eyes amputation: – In this case 19 cattle for each eyes or sometimes it is equated with a gift of few cattle and a virgin girl to look after and guide him as a wife and a form of gift (compensation). If they (the offended party) are unable to pay the decided amount of cattle, there are enforcement mechanisms for such rule of law which is named as social exclusion or enforcement from any social affairs in their own respective clans. If the man refuses her to accept as a gift like her, her clan also regrets and asks why he refuses her, i.e the question of clan identity/recognition. Compensation for women is generally smaller than men for such cases and a man who creates the problem on her will be forced to marry her. If someone insults a woman/girl as blind or any other injury related insults, he will be punished seriously.

D. Similarly, if the husband breaks one tooth of his wife, he will not be punished. But, if I he insults her in connection to her teeth, he will pay five cattle. In Oromo culture rape cases is very serious. FGD participants stressed that let alone rape cases if someone harassed a woman/girl verbally, he will be punished seriously. Several years ago, girls were not being harassed and dared by men/boys rather they were respected. In connection to their compensation 100 cattle will be given for killings, 50 cattle for rape cases, some one's wife rape involuntarily is 5 cattle and voluntarily is 1 cattle for the husband. Voluntary and involuntary rape cases are identified on the style of their sleeping whether it is by force or on peaceful means. For rape cases the compensation various from case to case. For virgin girls is 5 cattle, non virgin girls is 3 cattle.

Fourth, if someone killed somebody while he is on offensive acts, there will not be Gumma ceremony for that. This is justified that any one has the right to defend himself/his family from any external enemy. Finally, for looting cases if some loot one cattle, he will be forced to return back one additional cattle.

Genealogical Structure of the Somali clans

Genealogically, the Somali are generally divided in to three major clans, namely the Dire, Erer and Darod clans. Dire clan again has seven sub-clans namely Issa, Gedebursi, Gure-Gerire, Gurgura, Issaq, Gerri, and Gatsu. Erer has only one sub-clan that is Hawiya. Here there is a controversy that the Oromo claimed Hawiya as one of their sub-clans. However, the Hawiya identified themselves as one of the various Somali clans. Again Darod has three sub-clans, namely Mejerten, Ogaden and Jidwaq. Hawiya has four sub families, namely Amerti, Fejew, Remedona and Galjeal. The four sub families have four sultans. For each sultan they have three Abeyal (elders). There are peace committees from each sub clans. They seek for solutions but if it is beyond their capacity, they will hand over to the government. Customary institutions were very strong in the previous times, but gradually replaced by modern ones.

Structure of the Issa/Hawiya customary institution – Xeer

There are five basic positions in the governing structure of the Issa/Hawiya customary institution named Xeer. These are Ugaz at the top, Sultan, Nebdon and Abbaworoch. Each position has its own duties and responsibilities. **Ugaz** is the most top position the Issa/Hawiya Xeer system. The position is considered as a king of Issa/Hawiya Somali clan. Currently, Ugaz Ali is head of the Issa and Hawiya Somali clans. **Sultan** is the second position next to Ugaz. Sultan is a position given to judges for conflict resolution, compensation process, find the offender and punish with appropriate measures according to their agreed principles. **Nebedon** is the third position next to the sultan in the hierarchy of the Xeer of Issa/Hawiya clans. Nebedon are peace seekers/keepers and information gatherers,who are responsible for negotiations of family disputes, practicing marriage arrangements and/or practices among the community, collecting compensations during conflict resolutions practices, etc **Abbaworoch** position is the last in the hierarchy of the Xeer. Abbaworoch are mostly composed of village elders, religious leaders, and some clan representatives, who work together with the Nebedon.

Compensation Mechanisms of the Hawiya/Issa clan

Compensation mechanisms in the Hawiya and Issa clans are named as Mugg/Boqol. Some of the procedures, types and amounts of compensations in Hawiya/Issa clan is as follows: Rape cases – There will be 1,000 birr or 5 cattle by their Xeer and then additionally the offender will be punished by the modern law. If the rape case is happened on married woman, the amount of compensation is 3 cattle. Murder: - If the murder is a deliberate action, the amount of compensation is 100 camels for men and 50 camels for women. By their culture, the amount of compensations given for women is less by half than that of men. If the murder is accidental, the amount of compensation is about 60-70 camels for men and 30 camels for women. Wound cases: – If the wound is on the left eye of an individual, the amount of compensation is 16 camels plus a girl as a gift because he will not get wife. If it is the right eye, the compensation is 15 camels plus a girl.

Left body parts (eye, arm, leg, testicle, etc) which are considered as more important for love making and reproduction exceeds in the amount of compensations than the right side of the body parts by one camel. In the process of resolving murder related conflict cases one camel will be slaughtered which is named as *Ahan* means promise not to take revenge killings until the case is settled following the formal well established cultural procedures. This is followed by the submission of kefen (cloth) and kefera (maize) plus 2000 birr including kchat, sugar, etc for burial ceremony. The offender then urged to cut off his hair showing his sadness about his wrong action. His close relatives will not allow to be armed with their traditional knife, modern fire arms, shoe and other decorations during the conflict resolution process. Then, they decided a 2-3 month period for resolution and collection of compensation of camels based on the customary institutions, i.e. their xeer. The family of the murderer should hand over the gun in which the deceased was killed during the funeral ceremony. Within the 15 days, there is the submission of the so called *immimitte (means something to compensate the sorrowness of the deceased relatives)* composed of 15 camel to the deceased family. These camels should be contributed from the murderers' family only excluding other members of the clan.

This xeera is also acceptable both by Hawiya and Oromo conflicts. However, according to the community elders Hawiya and Issa clans have lost their communally shared customary governance system. There is no compensation for murderer; it is only a camel that will be slaughtered to create relative/temporary peace. It is reported by the oromo clans that Issa have access to modern fire arms than any other rivals in the area, so that there is power asymmetry between Issa Vs Hawiya and Issa Vs Oromo clans. Elders added that Issa have support from Djibouti government as well as voluntary individuals.

The Woreda level peace committee together with that of neighboring woerdas peace committee are closely work together to address peace and conflict issues. The peace committee members may be sultan or any other community elders' who work together closely to the modern system of administration /governance system. This shows that indigenous institutions are gradually replaced or took over by modern ones. Women have not direct role in customary institutions unlike that of modern ones. However, they have an indirect role by consulting their husband, father, and brothers on critical decisions during conflict resolutions.

Summary, Conclusions, and Recommendations

Summary and Conclusions

This research testifies that both intra- and inter-ethnic conflicts over the use and control of natural resources as well as territorial expansionary moves are everyday business in the dry lands of Ethiopia in general and in the study area in particular. There is high incidence of violent conflict among the different pastoral ethnic groups found in the study area. This conflict has resulted in high distractions in livelihoods of the pastoral and agro-pastoral communities and their lives from time to time. The conflict has dynamic nature with the introduction of modern automatic weapons in the hands of pastoralists which made the conflict arenas more devastating than the earlier forms of traditional confrontations. The conflict has also got new shapes and dimensions with the introduction of ethnic based federal arrangements in Ethiopia in 1991 particularly among the pastoral and agro-pastoral communities of eastern Ethiopia. This is because pastoralism as a livelihood mechanism by its nature requires mobility as an adaptation strategy to the arid and semi-arid range lands of the region as well as an alternative strategy to maximize their productivity. When their mobility is restricted it could be a cause for conflicts.

The causes of conflicts in the study area are multi dimensional, complex, and dynamic in nature. There is no single cause of conflict that can address the variety of superseding variables that take part in practical conflict situations. These variables include cultural, historical, political, and economic motivations of the various parties involved in the conflict. This study revealed that some of the most important variables as most important causing factors for conflicts in this region are competition over pasture land, water points, boundary disputes, livestock raiding, heroism, banditry and its sudden killings and the like.

This study revealed that the nature of conflicts in the area is very much dynamic and changing its nature from time to time. Both the existing ethnic/clan groups who are competing each other on several crucial issues in the region (the Afar, the Issa, the Hawiya, the Ittu, the Alla, the Nolle) are Cushitic speaking pastoralist groups that have formed more flexible strategic alliance with one another and also with other groups differently at different times throughout their history. They were placed under one administrative unit/region in one regime and different in another regime in Ethiopian past history. For example, during the Imperial regime these contested areas was classified and administered in to two. These were the Adal and Gara Guracha Awraja for the Afar and the different Oromo clans living in the region and another one was the Issa and Gurgura Awraja for the different Somali clans. During the Derge regime all the three ethnic groups and their sub-clans (the Somali, Oromo and Afar in the area) were administered and named as Issa, Adal and Gara Guracha Awraja where they were unanimously administered. Gara Guracha belongs to Oromo, Adal for Afar, and Issa for the Issa clan.

When compared with the non indigenous mechanism for the prevention and resolution of conflicts, they are less complex, save time and give chances to parties in conflict to actively participate to solve their own problems and to handle their affairs in relatively more acceptable way to them. One of the indigenous institutions responsible in addressing conflict issues in the study area particularly to the various Oromo clans is the Gumma system. The governing system of the Gumma has a highrarchical structure in its governing principles and administrations. Each position has its own duties and responsibilities which are directly accountable to the immediate next top position. In the procedure of the Oromo Gumma system, there is the intervention of a third independent party from another clan as a mediator between the disputed parties/clans.

Recommendations

Based on the above result and discussions, the following are major recommendations forwarded by both the community elders and the researchers:

- There should be a strong political commitment to promote peaceful coexistence and cooperation at all levels since the local and regional political bodies lack the necessary power and less responsible for the problem and less committed for finding long term solutions. Departments at zonal and regional level should implement what they have planned on paper to the ground on the issues of peace, conflict, and development.

- There should be the beginning of revitalization of customary institutions, but it is not fully implemented and functional. This revitalization process should be encouraged at grass root level. The government should assign appropriate budget for the continuous dialogue of community elders at grass root level for promoting a culture of peace, respect, and tolerance. Besides, there should be an appropriate budget for the peace committee of clan elders so as to make their agreement towards peace more effective.

- Harmonization of traditional vs modern governance administration systems is an urgent need and due attention should be given to customary institutions which are closer to the community and more effective in resolving societal problems.

- The roles of culture and tourism which is currently minimal in the study area should be promoted and encouraged that will play an important role in peace building process in different ways. Festivals, awareness creation workshops, promotion of the culture of peace and peaceful co-existence, etc should be promoted and developed by the ministry. There should be awareness creation trainings, workshops, seminars on the nexus between conflict, peace, and development to the pastoral and agro-pastoral communities in the study area. There should be a wide range of deliberation and discussion forums at grass root /community level on peace and conflict issues on continuous bases.

- Livelihood diversification or transformation i.e. from pure pastoralism to agro-pastoralism or from pastoral production system to agro-pastoral form of production system is strongly desired since the mobile nature of cattle and camel herders for long distances during drought seasons creates conflict.

- Women should be represented in all forms of conflict resolution mechanisms. Women’s issues/concerns should be addressed both in traditional and modern systems of governance. This is because they are the most victims of violent forms of conflicts in the area.

- As there is dispute over the issue of land tax collection on disputed border PAs and custom posts, there should be awareness creation workshops about the concept of federalism and federal system of administration. Clear demarcations of the disputed boundaries and PAs that always aggravate conflicts are also the first priority agenda of both the regional and federal governments.

- Development of basic infrastructures like water points for drinking, educational services particularly adult education, health posts, access to road, appropriate budget allocation, water pond development, promotion of irrigation agriculture, etc should be the government's prior agenda and should gain an urgent response.

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Primary Schooling Vis-à-vis Food Insecurity in Pastoralist Communities of MiesoDistrict: The Double Jeopardy

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Abstract: *The purpose of this study was to describe the interdependence between primary schooling and food insecurity among pastoralist communities of Mieso District, West Hararghe Zone, and East Ethiopia. The study employed descriptive qualitative research design through such instrumentations as focus group discussion, key informant interview, observation and document review. Parents, students, Parent-Teacher Association (PTA), school principals, supervisors, aradda heads, education, health, and pastoralist office personnel, Development Agents (DA) and health extension workers were participants of the research. Data from these sources were triangulated, organized, tabulated and analyzed through theme and explanation building. Thus, the finding of the study shows enrollment, completion rate, and gender disparity remains heightened. There also seems high dropout and frequent absenteeism. Primary school children are; either absent or dropout for varying reasons among which child labour, as a coping strategy for food insecurity was at forefront. Prevalent food insecurity and serious water scarcity appear to bedevil primary schooling. In order to achieve UPE by 2015, improving the school attendance of the pastoral children in Mieso context is an imperative, which in turn calls for improving the food security situation and access to safe drinking water. Unless these issues are ameliorated, embracing pastoral communities of Mieso district in universal primary education by 2015 seems going off track.*

Key words: *pastoralists, primary schooling, food insecurity, Mieso, Oromia, Ethiopia*

INTRODUCTION

Background

Located approximately between 3° 14' N latitude and 33° 48'E longitude in the Horn of Africa, Ethiopia is the second most populous country next to Nigeria. Growing rapidly at an average annual rate of 2.58 percent, the current size of population is projected to have escalated to well over 80 million. Even though, there reported (World Bank, 2005) sizable population to have been urbanized, the country claimed to have remained the least in terms urbanization in Africa. According to the 2007 Ethiopian census report, about 84 percent of the total population was rural dweller whereas urban population constitutes the remaining about 16 percent only. The country's economy mainly depends on rain-fed agriculture that makes the country vulnerable to climate related shocks, which in turn threatens food security. Even though there have been substantial progresses, the country is still among the poorest nations in the world with such low human development Index (HDI) of 0.396, below the average calculated for Sub-Saharan Africa 0.475, ranking 173 out of 187 countries of comparable data for the year 2012 (UNDP, 2013).

Ethiopia is one of the most disaster prone countries, incessantly affected by a multitude of catastrophes with increasing frequency (UNDAF, 2011). Devastating and recurrent droughts, coupled with rapid population growth and land degradation have put the country under serious food insecurity (UNICEF, 2012). This specifically, believed to erect a severe setback in lowlands and pastoralist areas where annual rainfall is below 700mm. As a result, low standard of living, poor health condition, and high illiteracy rate are the thorniest tribulations affecting the life of the people in general; and strikingly impinge on pastoralists' life in particular; which in turn believed to have jeopardized the education system. Despite the fact that education is taken on by government as a key strategy for poverty alleviation, the provision of education for all citizens still seems long way off. According to UNESCO (2012) education for all report, for instance, Ethiopia is among the low Education for all Development Index 0.622, ranked 116th out of 120 countries for the year 2010.

Though the country is currently making inroads towards achieving universal primary education (UPE) by 2015, it appears to be much more demanding. Enrollment, dropout and completion rate are also turn out to be another predicament undermining the endeavor to universalize primary education. World Bank (2012) reports that the net enrollment rate (NER) to primary schooling is increased from 79% to 85% at an annual growth rate of 1.9% that is less than the population growth rate; and grade 8 completions remain low at 49.4%. Most importantly, the current education system that follows eight years of primary education is explicitly vexing, as it demands more than offering five years of primary schooling. This dilemma could be more exigent for agro-pastoralists and pastoralists as their educational participation lags far behind others (Pact Ethiopia, 2008; Ziyn, 2012). There were about three million out-of-school children needing special attention (ESDP VI, 2010), of which most are bound to be female, rural, poor and vulnerable (UNICEF, 2012). Though strong emphasis placed on reaching such marginalized sections of the society to boost up their participation in Education Sector Development Plan (ESDP) IV, years have elapsed to put it fully into practice.

Statement of the problem

Enshrined in the 1948 Universal Declaration of Human Right by United Nations, in article 26:1as: 'Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages. Elementary education shall be compulsory', access to quality primary schooling has long been accepted as a basic human right. Thus, it was underscored that denying the child the right to primary education would tantamount to handicapping him/her for life; as life exclusive of such skills as numeracy and literacy would turn out to be anomalous at best (UNESCO, 2006). More on this point, UNESCO (2010) emphasize that such repudiation violates basic human right and would undercut economic growth and poverty reduction as it wastes a precious national resource and potential driving forces. Irrespective of such acclaim, however, problem of universalizing primary education is strongly persevered that some regions are going off track. Estimation by UNESCO (2010) shows 56 million children could remain out of school by year 2015, with 28 million children dropping out each year. Similarly, according to UNESCO (2012) trend analysis suggests that the rate of advance towards universal primary education goals has shown declining trend in recent years, which could escalate the number. The number of out – of – schoolchildren, in sub-Saharan Africa has increased by 1.6 million between 2008 and 2010, for instance.

Children around the world are obligated to remain out of school for diverging reasons, among which poor health and nutrition are barriers between children in poor communities and their educational potential (Jukes, et. al, 2008). In UNESCO (2010, 2011), the issue of malnutrition and child health is also clearly accentuated as one of most glaring problem to achieve Education for All as children who suffer malnutrition tend to start school at later age and drop out early prior to completion of primary schooling. Further, Siegler, et al. (2006: 308) caution, "chronic inadequate diet early in life can disrupt brain development, and missing meals on a given day can impair intellectual functioning on that day". Jukes et al. (2008) also underscored that hungry or poorly nourished children have impaired cognitive abilities and are less attentive in class. Put it differently, food security, and hence proper nutrition is a prerequisite for the right to education to be realized (Raimbault, 1979). Similarly, a study by Tefera et. Al, (2012) shows adolescent and household food insecurity is positively associated with school absenteeism and a lower educational attainment.

Hunger and malnutrition are direct outcomes of food insecurity (UNDP, 2012), which in turn results from such complicated factors as drought, land degradation, population growth among others. According to APRM (2011), drought is the prime cause of food insecurity in Ethiopia. Ethiopia is known to be the most food insecure, and famine-trademarked for over years. According to Tenna (2012), Ethiopia reportedly experienced about 54 natural disasters between 1974 and 2003, the 1983-5 famine episode being the worst ever the country had experienced.

The country is one of the most disaster prone areas in East Africa, with frequent drought affecting millions of People. Accordingly, most parts of the country, specifically the lowland areas are drought prone areas, with all parts of Afar and Somali regions, are classified as high drought-risk areas whereas parts of East and West Hararghe are categorized as medium drought-risk areas (UNICEF, 2012).

Predicated on this, food insecurity and malnutrition could be heightened for pastoralists where depletion of resources and water scarcity seems so immense. Malnutrition among child remains an acute and widespread challenge in Ethiopia (Save the Children, 2012), more so in arid and semiarid or pastoralist areas (Rajkumar, 2012). In Ethiopia, pastoral areas are one of the most drought prone regions facing chronic food deficiencies where erratic and poor rainfall impinges on pastoralists through shortfall of fodder and water (Mekonnen, 2011). In similar vein, FAO/WFP (2012) reports the number of people in need of relief assistance in 2011 had heaved to 4.6 million due to poor rainfall, which affected mostly the agro-pastoral, and pastoral areas. Consequently, about 329,500 children were admitted to therapeutic feeding; that could have a bearing on primary schooling. According to FAO (2005), the persistence of hunger and malnutrition are one of the prime reasons attributed for impeding the inroad to universal primary education.

In pastoral areas, social services like: infrastructure, safe drinking water, and education are disappointingly developed (Pastoralist Forum Ethiopia, 2002). Pastoralists are the most marginalized social group in terms of economy, politics, and educational provision among other things (See, Ayalew, 2001; Hogg, 1997), explicitly in the acquisition of education (Ziyn, 2004 & 2012). Following this, Pact Ethiopia (2008) asserts enrollment in education is the lowest among pastoralists in Ethiopia. Disappointingly, from those who enrolled, only few complete the first eight years of schooling and high dropout rate (MoE, 2011), as a result of which they have lagged far behind others (ESDP IV, 2010).

Of many such pastoral groups, the East – Central pastoral communities comprise Oromo, Somali, and Afar are groups of pastoralists inhabited West Hararghe Zone. Of many West Hararghe districts, the current study focuses on Mieso, most part of which is known for its minimum annual rainfall and inveterate drought, hence chronic food insecurity that suffered the 2011 drought. OCHA (2011) report reveals at least 58,000 school dropouts and more than 280 school closures in Somali and Oromia regions during same year. Correspondingly, the problem continued to exist in 2012 as the rain failed for two consecutive seasons in West Harerghe Zone that resulted in failed crop, reduced livestock, scarcity of pasture and water (FEWSNET, 2013).

Objective of the research

The general objective of this research was to assess the impact of drought induced food insecurity in universalizing primary schooling in pastoral communities of Mieso district. In specific, the research addresses the following objectives.

- Examine how the progress towards universal primary education is affected by drought induced food insecurity in pastoral communities of Mieso District.
- Figure out how drought induced food insecurity impacts school attendance in pastoral communities of Mieso context.
- Identify what the interplay between primary school attendance and food insecurity looks like in pastoral communities of Mieso District.

LITERATURE REVIEW: THEORETICAL CONSIDERATION

Universal primary education

Ethiopia is signatory to Education for All (EFA) and Millennium Development Goal 2(MDG 2). MDG 2 states 'Ensuring that by 2015 all children, particularly girls, children in difficult circumstances and those belonging to ethnic minorities, have access to and complete free and compulsory primary education of good quality'; where quality universal primary education is conceptualized as entering school at an appropriate age, and progressing through the system and completing a full cycle (UNESCO, 2010). The definition of primary education also varies from country to country (UNESCO, 2007), mainly based on the years required for basic literacy and numeracy attainment though it comprises the first four or five years of schooling.

Catering for 7 to 14 age groups, in the 1994 Education Policy of Ethiopia, however, primary education comprises the first eight years of schooling in two cycles: first cycle (grades 1-4) and second cycle (grades 5-8) (MoE, 2012). Stated in the Education and Training Policy; 'Primary education will be of eight years duration, offering basic and general primary education to prepare students for further general education and training'(TGE, 1994:14). Primary education is, thus, the most decisive turning point where foundation for further education can be laid.

Concordant with above global commitment, Ethiopia has developed successive Education Sector Development Plans (ESDPs), and currently implementing ESDP IV, a five year Program Action Plan (2010/2011 – 2014/2015). Prioritized in ESDP IV is, 'to improve access to quality primary education in order to make sure that all children, youngsters and adults acquire the competencies, skills, values and attitudes enabling them to participate fully in social, economic and political development of Ethiopia'. Irrespective of such ambitious objective, nonetheless, *ensuring access to quality primary education for all children* seems easier said than done. Though there has been improvement in access, many children still do not complete the first cycle of primary school, and repetition and dropout rates remain high throughout the whole cycle (ESDP IV, 2010). The most challenging aspect of UPE is thus from all primary school age cohorts, some remain out of school; of those who do come, most of them leave prior to completing the mandatory level of schooling for required literacy and numeracy level. Even if the issue was well accentuated in ESDP IV, little has been improved during the last three years of implementation.

Of course, there have been improvements in enrollment in Ethiopian primary schools as shown in *Educational Abstract 2012*. However, from those who enrolled only 74.1% survive to grade 5; whereas completion rate to grade 8 is 52.1% which is well below the rate computed for sub-Saharan Africa; that is 62%. Counted alongside the Sub-Saharan African countries, whether Ethiopia is to meet the MDG goal of UPE or not; is subjected to critical scrutiny though some argue the country is well on truck (UNDAF, 2011). Despite substantial progresses, gender gap have also remained a serious challenge, where girls were more likely to have never attended school, and about 43% of poor rural females aged 7 to 16 have never been to school in 2011(UNESCO, 2012).

Even though vast gap between the enrolment rates in first cycle, and second cycle was a primary focus of ESDP IV, the gap still persists. GER was 122.6 for first cycle and 65.6 for second cycle, which indicates low primary school completion rate regardless of expected 100% cohort completion rate for a country to achieve UPE (UNESCO, 2012). Another important point is the gap between GER and NER, which shows 122.6%, for 1st cycle including Alternative Basic Education (ABE), and 65.6% for second cycle, whereas NER for primary cycle shows 92.2%, and for second cycle 48.1%. Strongly associated with low enrollment to the second cycle, this has important ramification for UPE, as when children come late or over-aged, there is high possibility for them to drop early (UNESCO, 2012). As indicated in MoE (2012), the average annual growth rate of enrolment increased nationally by 4.5% for primary school during the academic year 2011/2012. NER is 85.4 with sharp regional disparities: as high as 100.3 and 108.1 respectively for Benishangul-Gumuz and Gambella, and as low as 35.5%for some regions like Afar.

Most importantly, with only five more years to go, there were about three million primary school-age children left out of school in Ethiopian context as of 2010 (ESDP IV, 2010). In this view, most children from pastoral communities could remain out of school by 2015 unless utmost effort is exerted during the coming two years. To this effect, Ethiopian government committed to develop special support programs for the emerging regions so as to tone down a steep and swift pupil dropout rates (ESDP, 2010). Though it has been well accentuated in 1994 education policy to offer special financial assistance to those who have been deprived of educational opportunities, and to take steps to raise the educational participation of deprived regions (TGE: 1994); pastoralist groups remained underserved, and lag far behind others (see ESDP IV, 2010; Pact Ethiopia, 2008; Ziyn, 2012).

While concluding the existing Sub-Saharan Africa circumstances of pastoralists (UNESCO 2010), underscores that pastoralist children are extremely disadvantaged in terms of educational provision. If Universal Primary Education is to be achieved by 2015, thus, including pastoralist children is a matter of overarching significance. Providing all pastoral children with eight years primary education is, however, the most challenging and demanding assignment facing the government of Ethiopia, which may oftentimes, gets exacerbated by food insecurity as pastoral areas are inundated by drought induced food insecurity and widespread destitution.

Food security situation in pastoral areas

Last decade has entertained increased frequency in droughts occurrences (Venton et al., 2012), though the 2011 East African drought that affected about 13 million populations was the worst ever crises in 60 years (Save the Children, 2012). As such, this drought episode affected most parts of Ethiopia because of which rainfall was either delayed or failed completely with agro-pastoralists and pastoralists in the south and south-east being the worst affected (FAO/WFP, 2012). Inundated by environmental degradation and shrinkage of the traditional pastoral territory, coupled with climatic change, put the area under chronic food insecurity, which made most pastoralists dependent of relief support (Mekonnen, 2011). They are among chronically food insecure households in Ethiopian context (Workineh, 2008). Similarly, FAO/WFP (2012) asserted that pastoral areas generally are deficit in crop production where rising food prices has amplified food insecurity and vulnerability, with the main hunger season lasting from December to February/March. Pastoralists are, for instance, the hardest hit segments of population during the 2011 drought that affected about 13 million people across East Africa (Save the Children, 2011).

Comprising many pastoralist groups, Oromia is one of the most affected regions in terms of food insecurity, specifically in West and East Hararghe zones (OCHA, 2011). Similarly, FAO (2012) indicated East and West Harerghe zones are among worst affected agro-pastoral and pastoral lowlands due to the late onset, early withdrawal, and poor performance of the 2011-hagayya rains. The situation in East and West Hararghe Zones still seems hard-hitting as there was below normal rain during 2012 rainy season too. According to FEWSNET (2013), in East and West Hararghe and surrounding areas, the performance of June to September rains was especially erratic and poorly distributed that crop has failed and would put poor households in these areas under crisis during January to at least June 2013.

A note must be made at this point that the prevailing food insecurity situation had seriously jeopardized the schooling of children in the drought stricken areas. Regarding this, OCHA (2011) referring to Education Cluster, indicated that 1.8 million children of an estimated 2.3 million children aged 5 – 17 years were not attending school. Similarly, over 300 schools, Alternative Basic Education facilities closures, and over 87,000 dropouts in Somali, Oromia and Afar Regions, was reported during 2011 drought. Thus, the bearing that food insecurity could have on education, explicitly primary school children appears to be pervasive. More theoretical clarification on this point; specifically the interplay between education and food insecurity, is in order.

The interplay between education and food insecurity

Apparently, poor food insecure households can never prioritize education as existence precedes education. It is equally unwise to expect the hungry or famished family to send their children to school, nor expect starving children to make a benefit out of schooling. Food insecurity results in hunger and malnutrition, which in turn brings about health problem and impair proper cognitive functioning (Del Rosso, 1999). Obviously, the importance of good nutrition and health is unquestionable for overall development of child (Rodriguez-Salina et al., 2008). Even to the extent that missing one time meal may inflict adverse impact to cognitive development that would acutely bedevil school learning (Del Rosso, 1999; Siegler, et al., 2006). The issue appears more worrisome for primary school children in an attempt to universalize primary education. Commenting on the adverse impact of food insecurity, UNDP (2012) asserts food insecurity debilitates society by increasing mortality, disease and disability that would result in absenteeism and poor education which could last generations.

Malnutrition and hunger increases the risk of disease and early death (UNDP, 2013), reduce learning achievement of children (Birdsall et al., 2005), and impair children's performance (FAO, 2005). With enduring effect, it creates vicious circle in that malnourished poor mother would give birth to low-birth weight babies whose chance of getting school on time, and taking advantage of schooling would be much constricted. This in turn perpetuates poverty circle, as less educated ones possibly remain poor and food insecure that the cycle starts all over again (Sanchez, et.al.2005). Put it differently, food insecurity and, hence, malnutrition implies a less productive people, and less capable to create opportunities to gradually break the cycles of both poverty and hunger in a sustainable way (UNDP, 2012).

If a household skips a meal for days or reduces food intake for prolonged time, then comes malnutrition. Hunger and malnutrition believed to pose adverse impact on schooling of children. From this, it follows that in chronically food insecure parts of Ethiopia, school learning could be constrained. Manifested through such indicators as stunting low height-for-age, wasting (low weight-for-height) anemia and iodine deficiency, malnutrition impair cognitive ability and reduce children's capacity to learn (FAO 2005, Rajkumar et al. 2012). Poor nutritional status of children and women has been a serious problem in Ethiopia for many years (CSA, 2012). As a result, stunting and wasting of children under five are common public health problems. According to the latest Demographic and Health Survey (DHS) data, 29% of Ethiopian children are underweight and 9% are severely underweight, about 45% are stunted and 10% are wasted; and 3 percent are severely wasted. Similarly, 44 percent of children under age five are stunted, and 21 percent of children are severely stunted (CSA, 2012).

Research design and method

In this study, descriptive case study research design was employed. According to Hancock and Algozzine, (2006) it is a design where an attempt is made to present a complete description of a phenomenon within its context. Data for case study comes from myriad of sources; including document review, observation, interview, and focus group discussion. In this light, Yin (2002) has figured out six such sources of data: "documentation, archival records, interviews, direct observation, participant observation, and physical artifacts" (pp. 83). Of these, interview, focus group discussion, observation and document review were used as major data collection instruments.

In so doing, observations of school environment and classroom situation were effectuated in some selected schools. Focus group discussions with parents, Parent-Teacher Association (PTA), supervisors, school directors and teachers, Development Agents (DA), *aradda* managers (*abba Ganda*) have been executed. In the mean time, documents have been reviewed from schools, Mieso District Education Office, Mieso District Pastoral Office, Mieso District Water Mineral, and Energy office and Mieso District Health Office. In the same way, few anthropometric data was accessed from some Health post. Besides, interview with school principals, DA, health extension workers, students, supervisors, and head teachers have been conducted. In so doing, field note taking, photographing, and recordings have been effectuated. Data from these instruments was classified, organized and tabulated. Analysis was made qualitatively through explanation and theme building.

Site selection was criterion-based following information obtained from the district officials. Subsumed under Mieso District are 46 *Aradda/kebele*s, of which 23 are totally pastoralists while the remaining 22 are either semi pastoralists or agro-pastoralists. As the research focuses on pastoralists, pastoralist PAs and primary schools within six Cluster Resource Centers (CRC): *Mieso, Asebot, Dhaga Daku, Annanno, Bordodde, Gololcha* and *Waltane* were sampled purposively based on such criteria as serious food insecurity, water scarcity, pastoralist preponderated, little or no farming at all. Furthermore, as these PAs are easily accessible, and are where children from different ethnic groups conflate, they were taken up as research site.

RESULTS AND DISCUSSIONS

Primary schooling in Mieso context

According to UNESCO (2007), two indicators are most important to determine the school attendance: enrolment the children who have registered with a school and net attendance: the number of children who are actually going to school. Accordingly, to shade a light on what primary schooling in Mieso context looks like, such indicators as enrolment rate, absenteeism, dropout, and completion rates will be presented hereinafter.

Primary school enrollment

Enrolment shows the number of children registered for schooling in a given academic year. Overall primary school enrolment rate shows high achievement at national as well as regional level as indicated somewhere. According to the zonal education office, same works true for West Hararghe, that is, 82.36% for grade 1 – 8 for 2012/2013, though there is a slump from what it was during 2011/2012 academic year that was 90.4%. Correspondingly, official data from Mieso District Education bureau shows an improvement in Gross enrolment rate (GER) during the last two years, 66% and 70.8% for 2010/11, and 2011/12 respectively, but falloff to 65% during 2012/13 academic year. However, net enrolment rate (NER) remained unsatisfactory at the rate of 53% in 2010/11, 57.27% during 2011/12, and 55% for 2012/13.

Comparison between cycles shows noticeable discrepancy in terms of NER that is 73%, 85.6%, and 93% for 1st cycle, and 24.2%, 22%, and 19% for 2nd cycle during school year 2010/11, 2011/12, and 2012/13 respectively. Evidenced here is improvement for the 1st cycle, but a declining trend in NER for second cycle for the last three successive academic years, which would tell us the low primary completion rate. Similarly, one possible conjecture that can be made from the difference between GER and NER is that over aged children are coming to school, which case is congruent with data from other sources. Besides, noteworthy gender gap noted from the latest 2012/13 data from Mieso District with GER 74% and 56%, and NER 57% and 14% respectively for boys and girls.

The aforementioned official data show the number of children registered through campaigning, which might have been over reported. Procedurally, enrollment or registration starts late in August each year through house-to-house campaign where all unschooled primary school age (7 years old) and beyond who have never been to school, and dropouts would be registered. For most parents, however, getting registered their children at home, and sending them actually to school mean different things that would result in inconsistency between official student statistics and actual school attendance. From this, it follows that not all those who registered would be sent to school as parents were not properly convinced about children education, or need them around for their labour. As registration is hardly ever based on the willingness of the parents but the government, it is not a fostered; but forced one. Even though there has been capital punishment put in place for parents; either for not sending or pulling out them from school, there were out-of-schoolchildren at every household. Even, from those whom parents want them attend the school, many seem apathetic that they come one or two months later after the school has commenced. This would play a devastating role in education quality coupled with coming late to class, class-forfeit, absenteeism, and early dropout.

School absenteeism

In Mieso context there is relaxed school rule and regulation to entice, and to encourage the students stay in the school. Consequently, there were cases where students who had never shown up for two or so months, yet could be seated for the final exam. As a result, many are completing primary education without acquiring the required literacy and numeracy skill. According to some teachers[51], it is quite common to find primary school complete unable to write his/her name properly. Even though children absent from school for such diverging reasons as tending animals, helping parents during harvest time, collecting fuel wood or charcoaling, *khat (Catha edulis)* processing, gravel production, and fetch water; they also engage themselves in petty trade and menial jobs during market day. For instance, at Gumbi Primary School, only 33 out of 204 schoolchildren were attending class, whereas about 361 truants were reported at *Gololcha* Primary school. [52] The number is so much alarming during market days as noted at schools like *Bordodde*.

[51] Interview with teachers, supervisors and school principals at Gumbi, Balo, Asebot, Gololcha, Brdoddee, Fayo, Hese Mandhera, Mieso, Waltane, Kurfa Sawa, and Qiqilftu indicates that school regulation is relaxed to entice, and to encourage more pastoral children to stay in school.

[52] Classroom observation was effected at Bordodde as of 6 December 2012, and Gumbi and Gololcha as of

Table 1: Market day Absenteeism in the Afternoon Shift

Grade	Number of students	No of Presents	No of Absentees
5th	76	14	62
6th	64	17	47
7th	55	8	47
8th	33	15	18

Source: Bordodde school personal observation

In Mieso context, the most glaring cause of school absenteeism seems attending market, as presented in *table – 1* above. Well over 75% schoolchildren were absent during this particular day. Market day is referred to as *Ida Miskiinaa* literally *Poor's Eid,* to mean poor's festivity. Put it differently, during market day many students never attend school, in most schools in Mieso district as household food consumption is always depends on market, which in turn determines the amount of money they would earn. Their food expense for the days to follow, and school expenditure is totally depends on the earning they would make during the market day doing menial jobs which case jeopardizes their school attendance, even beyond market days. To participate in petty trades or menial works themselves (from town), or let their parents to attend (from suburb and rural) by minding sibling, either tending cattle or look after young, children in Mieso habitually absent from school. And when they are absent for long school days, they eventually dropped out, often never to come back.

School dropout

Taken as an indicator of school attendance, dropout shows the number of students who leave out the school before completing certain cycle or achieving the required skill, or knowledge commensurate with that level. It also shows "the percentage of those students who discontinue their learning from a given grade compared to the previous year's total enrolment in the same grade" (MoE & UNICEF, 2012: 33). Dropout rate is high in Ethiopian school system that challenges universalizing primary schooling. MoE (2012) report reveals that about 25.0% of pupils enrolled in grade 1, in 2010/11 have left school before reaching grade two in 2011/12. The fact is that children continue to drop out as they advance to the next grade. Dropout, thus, seems the prime factor standing against universalizing primary schooling in rural areas in general, and in pastoralist areas in specific. In Mieso context, for instance, primary school student population shows that the number of students decrease as the grade level increases and is higher than the average computed at national level. The following table presents the existing student statistics at two sample schools.

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12 March 2013, and the school attendance was discouraging.

Table 2: Students enrolled in 2012/13 to Ananno and Dhaga Daku Primary School

Grade		1st	2nd	3rd	4th	5th	6th	7th	8th
No of Students	Ananno	80	74	68	44	36	17	14	12
	Dhaga Daku	63	55	34	22	32	29	24	24

Source: Ananno Primary School, and Dhaga Daku Primary School, 2012

What is clear from the above *table – 2* is that as students move on to the next class, there is a cutback in the number of students. In fact, even if this is the actual official figure provided from the school, the reality on the ground appears different. For instance, during classroom observation at Ananno[53], as few as four 8th grade, and seven 4th and 5th grade students combined in one class were observed. From this, it can be estimated that how many students complete grade 4 and how many would persist to the second cycle. In this connection, a note has to be taken that only 345 students were at school out of 577 estimated primary school age populations, which translates into 222 (38%) out-of-school children in *Ananno* context. To better have a fuller picture of primary school dropout rate and survival rate in Mieso Pastoralist children context; it seems of paramount significance to present *Dhaga Daku* Primary School student statistics as follows.

Table 3: Dhaga Daku Primary School 2012/2013 Student Statistics

School Year	Gend	Grade Levels							
		1st	**2nd**	**3rd**	**4**	**5**	**6**	**7**	**8**
2004/0	Boys	81							
	Girls	10C							
	Total	**181**							
2005/0	Boys	56	56						
	Girls	40	34						
	Total	**96**	**90**						
2006/0	Boys	35	47	45					
	Girls	24	26	23					

[53] During classroom observation at Annanno on 4 December 2013, few schoolchildren were observed attending lesson in the classroom.

	Total	**59**	**73**	**58**					
2007/0	Boys	23	30	42	3				
	Girls	22	20	26	2				
	Total	**45**	**50**	**68**	**5**				
2008/0	Boys	31	25	28	3	3			
	Girls	11	20	20	1	1			
	Total	**42**	**45**	**48**	**5**	**4**			
2009/1	Boys	25	25	21	3	2	3		
	Girls	21	15	14	2	2	1		
	Total	**46**	**40**	**35**	**5**	**4**	**4**		
2010/1	Boys	42	19	16	1	3	2	2	
	Girls	29	16	17	1	1	1	9	
	Total	**71**	**35**	**33**	**3**	**5**	**3**	**3**	
2011/1	Boys	37	25	14	1	2	2	1	1
	Girls	34	15	11	1	1	9	1	9
	Total	**71**	**40**	**25**	**2**	**3**	**3**	**2**	**2**
2012/1	Boys	30	35	20	9	1	2	1	1
	Girls	33	20	14	1	1	7	6	7
	Total	**63**	**55**	**34**	**2**	**3**	**2**	**2**	**2**

Source: Dhaga Daku Primary School, 2012/2013

Conspicuously, what can be concluded from the table – 3 above is that less than 50% of children enrolled were able to complete the first cycle and less than 15 percent will endure to the end. As the school commenced in 2004/05, the total number of children enrolled was 181, of which only 45 (24.9%) were able to complete 4th grade and enrolled to 5th grade during academic year 2008/09. The number has shown sharp decline over years and only 26 (less than 15%) out of this cohort were able to complete the first eight years of schooling. Surprisingly, out of 100 girls enrolled to 1st grade in 2004/05; only 20 of them reached 4th grade; and only 9 of them able to complete 8th grade. This would point to that education attendance in Mieso: high dropout rate, low completion rate, and huge gap in gender. When compared to 52.1% completion rate to grade 8; and 16.3% dropout rate for grade 1 – 8 computed at national level (MoE, 2012), it could spotlight where the pastoralists stand in terms of universalizing primary education.

The shrinkage of their number as they move up the ladder is so worrisome in some schools, as students never push further beyond grade 4; and leave school prior to acquiring the required skills. No single children, for instance, from *Goda Challe*, *Dhaddacha Gurracha*, and *Buri Arba* first cycle schools could able to proceed to the second cycle this academic year[54]. The situation is even more horrendous in schools like *Balo*. Much disappointing as it may, the school opened second cycle at *Balo* some years back where one more additional next class has to commence each academic year. Accordingly, 7th grade was launched last academic year, and 8th grade should have opened as of September 2012. Sadly, let alone opening 8th grade, even 7th grade that already had inaugurated in September 2011 itself was shut down a year later due to the thinning number of students[55]. In short, completion rate seems a disturbing problem in pastoral communities of Mieso district. As the age increases, it is obvious that children are much needed by their parents to cope up with the food insecurity issues through such mechanism as petty trade, work on farm or mind siblings while parents are out for *khat* retailing, fuel wood and charcoaling, sand or gravel production, petty trading among others.

Food insecurity situation

Several areas are facing severe food insecurity in Ethiopia including East and West Hararghe Zones with the estimated 3.7 million total number of food insecure people in need of humanitarian assistance currently FAO (2013). Situated in West Hararghe Zone, Mieso District is one of drought prone district characterized by erratic minimum annual rainfall. Following this, it is identified as one of food insecure districts of West Hararghe Zone. The food security situation is worse this harvest season, as per information from focus group discussion with Development Agents (DA) and *Arada* heads[56], as the *ganna* (2012) rain come in late August, and stopped early September that resulted in crop failure. Expounding the issue in more details, FEWSNET (2013) indicates, as a result of delay in the onset of the 2012 *afrasa* rain, short-cycle crops wilted and long-cycle were not sown timely which followed by unusually early withdrawal resulted in reduced yields.

[54] During interview with supervisors at Bordodde, Gololcha, and Waltane CRCs, they noted that beyond 4th grade most children – specifically girls, never proceed to the 2nd cycle and dropout.

[55] At Balo Primary School, an interview held with school principal and head teachers as of 12 March 2013, reveals closure of 7th grade as of September 2012.

[56] As per the information from focus group discussion at Huse Mandhera, and Dagaa Daku and Annanno as of 3-4 December 2012, crop has entirely failed this harvest season, and hence there was extreme worry.

Similarly, data from informants and discussants shows that there was extreme worry in having something to eat during months to come[57]. Skipping meal and consuming low cost food was common among most households. As per data from some health posts and discussion with PTA, most families have not enough food or income to properly feed their children. According to some health extension workers, malnutrition and poor health were widespread among Mieso district community. At Kurfa Sawa Health Post, for instance, there were about 72 underweight, out of which 22 were moderate and four of them severely malnourished[58]. Though appears under reported, Mieso District under-5 age Screening of Acute Malnutrition for November 2012 shows only 129 children with moderate, while 43 with severe acute malnutrition. Similarly, according to West Hararghe Zone Health Office, nutritional screening conducted as of August 2012, shows 21, 262 children with medium acute malnutrition, and 4, 102 serious acute malnutrition. Further, the April 2013 screening reveals 23, 530 with medium acute malnutrition, and 1,665 children with serious acute malnutrition. In food insecure areas, thus, where nutritional and health status of children is low, it can bear negative impact on educational achievement and contributing to the dropout rate (UN report, 2012).

If there is food insecurity, and, hence malnutrition and poor health, school learning would be constrained. UNESCO (2012) underscores malnutrition constrains progress towards the Education for All goals by hindering cognitive development and the capacity to learn. Further, while commenting on the effect of malnutrition and poor health on school learning, Del Roso (1999: 5) explicates, “Weak health and poor nutrition among school-age children diminish their cognitive development either through physiological changes or by reducing their ability to participate in learning experiences - or both”. From this, it follows that food insecurity in Mieso district is plugging pastoral children to make a benefit out school learning.

These two-year drought periods appear to have devastated the life of many Mieso pastoralists. For instance, in semi-pastoralist PAs like Hametti, Huse Mandhera, Kurfa Sawa, and Asebot where some sort of small-scale cultivation is possible, crop has entirely failed, fodder was depleted, and water points were utterly dried up[59]. According to the discussants, they have much worry in that they have not enough to eat or to feed their children. Asked if they can afford nutritious meals for their children, one mother replied:

> *We wish we could. With our current capacity, it is unthinkable to feed our children nutritious food; though we have been trained on how to feed balanced diet, and urged to do so. Let alone feeding balanced diet, affording twice a day*

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[57] On focus group discussion held with parents at Hammetti on 6 March 2013, key informant interview at Huse Mandhera on 3 December 2012, Dhaga Daku 4 December 2012, Fayo, on 11 June 2012 revealed that many households have extreme worry in having something to eat during months to follow.

[58] During an interview session with health extension workers at Kurfa Sawa health post as of 5 December 2012, 4 serious, and 22, medium acute malnutrition reported, but reported as 1 serious acute malnutrition, and 25 medium acute malnutrition; by Mieso Zone Health Office.

[59] During farm observation at Hammetti Mata Deyma as of 12 March 2013, shocking crop failure noticed.

has become most challenging for us. We feed them suummoo (boiled cereals), shuuroo (porridge), and sorghum bread. This by itself is not found in abundance. So, we feed them twice and sometimes thrice a day. You see, young children cannot tolerate hunger, they demand meal repeatedly. Nevertheless, when you fail to provide them you feel desperate.[60]

It is contended that for children to have all rounded development, the issue of food security and hence nutrition and health are matters of profound importance. Nonetheless, many children around the world are experiencing hunger. Owing to poverty, low food production, mothers' lack of education, poor water, sanitation and health facilities, and climatic shocks, developing countries experience high level of underweight preschool children as they cannot afford food of sufficient quantity or quality to meet their nutritional requirements (Sanchez,et.al.2005). In this view, in Mieso district many parents made clear that there are times when children go to school without breakfast. Sending children to school without breakfast has so many damaging aspects. Similarly, during focus group discussion with PTA, teachers, and students[61], it has been indicated that children oftentimes come to school without breakfast, and skipping meal is common.

Apparently, the food intake of pastoralists is highly dependent on milk and milk products. Nonetheless, it is not obtainable to the required quantity during long dry season. During time of drought, however, milk obtained in small amount is never be used for home consumption, rather exchanged for low cost food item, most parents struggle to sustain their children's life. According to the discussants[62], most parents are supposed to milk early in the morning, go to shopping, and exchange it for low cost flour to get the breakfast ready for their children. Schoolchildren sometimes, have to wait long for breakfast, missing the first two or three classes for the day. In case the mother is unable to come back promptly and meal could not get ready on time; it is most likely for the children to go to school without meal; or to totally absent from the school. This in turn challenges the benefit a child has to get from schooling. To curb such schooling ills and evils, there are school-feeding program in few schools in the district, but not as much as necessary.

School feeding

School feeding is a program meant to support schoolchildren in food insecure areas like pastoralists. It is believed to have a positive contribution in enticing more children to school, explicitly girls. Beyond boosting up enrolment and retention, school feeding is also believed to enhance school learning by ameliorating hunger and malnutrition. In light of this, there was a plan to assist 1,185

[60] Focus group discussion held with parents at Hammetti on 6 March 2013 shows appalling water scarcity.

[61] According to focus group discussion was held with PTA and students at Fayo (11 June 2012), at Mieso (12 June 2012), at Asebot (13 March 2013), at Annanno and Dhaga Daku (4 December 2012), at Borddodde (6 March 2013/2012) many parents oftentimes send their children to school without breakfast.

[62] Focus group discussion at Kurfa Sawa, December 5, 2012 and at Waltane on 14 March 2013 shows milk is oftentimes exchanged for low cost food item to sustain life.

schools across six regions: Afar, Amhara, Oromia, SNNPR, Somali and Tigray, targeting primary school children during academic year 2012. Accordingly, 688,500 beneficiaries were planned for 2012 through on-site feeding and take-home rations (FAO, 2012), out of which 649,000 schoolchildren in food-scarce areas were provided with a daily hot meal during same year (WFP in Ethiopia, 2012).

Though school feeding is implemented in pastoral areas to boost up the enrolment and retention, very little steps were taken by the government or NGOs in arranging school-feeding programs to tackle this prevailing problem in most schools. In context of Mieso District, for instance, out of 59 primary schools in only 8 that school-feeding program is currently functional. School attendance, motivation and performance of learners are said to be relatively good at the schools where the program is operational. Nevertheless, some school directors say, it could not be produced the aspired-for result in terms of magnetizing pastoralist children. Out of the eight, only one school has water supply that children are asked to bring cooking water. As water is so in short supply in the area and bringing it is a must-do activity, students opt to abandon school whenever they fail to get water. Thus, it is contributing massively its own share to increasing absenteeism and dropout, though meant to lure more children to school. To have a closer look at how school feeding is boosting enrolment and mitigated school dropout, juxtaposing *Huse Mnadhera* Primary School, where school feeding is operational, and *Bordodde* Primary school; where school feeding is relinquished five years before; seems of paramount important to have a better view of the issue.

Table 4:*2011/12 EC School Dropouts at Huse Mandhera and Bordodde Primary Schools*

Grade	*Huse Mandhera*							*Bordodde*						
	Enrollment			**Dropout**			**%**	**Enrollment**			**Dropout**			**%**
	Boys	**Girls**	**Total**	**Boys**	**Girls**	**Total**		**Boys**	**Girls**	**Total**	**Boys**	**Girls**	**Total**	
1st	104	58	262	22	11	33	**12.59**	91	76	167	11	16	27	**16.17**
2nd	66	41	107	5	-	5	**4.67**	52	37	89	3	2	7	**7.86**
3rd	27	19	46	3	-	3	**6.52**	46	59	106	11	8	19	**17.92**
4th	17	19	36	2	1	3	**8.33**	27	18	45	7	2	9	**20.0**
5th	43	11	54	5	1	6	**11.11**	56	36	92	15	7	22	**23.91**
6th	40	10	50	4	2	6	**12.0**	49	26	75	12	6	18	**24.0**
7th	37	3	40	2	-	2	**5.0**	45	22	67	13	3	16	**23.88**

8th	26	1	27	8	-	8	**29.62**	43	18	61	2	2	4	**6.55**

Source: Huse Mandhera and Bordode primary School, 2012

As can be observed from *table-4* above, there seems better school attendance at *Huse Mandhera*, where school feeding is operational. In comparison with *Bordodde* Primary School, it shows that dropout is less and there seems high likelihood for more children to complete at least the first cycle. Nonetheless, there is no strong evidence to conclude that school feeding had fruitfully encouraged retention to the first eight years of primary schooling. Similarly, information from *Balo* Primary School reveals that relinquishment of school feeding has dropped off school attendance; the number of children at school seven years before and to date is incomparable, though supposed to improve. Their number deteriorated to 355 now, from 460 in 2006/2007 when there was school meal. It is commonplace for children to depart to the neighboring schools in search of school meal, even across regions from *Bordodde* to *Hardim*, and from *Qiqilfitu* to *Mullu*, for instance.

In similar vein, WFP in Ethiopia (2012) reported that in chronically food-insecure districts Ethiopia, school feeding promoted increased enrollment and attendance of children. That is why everywhere, parents, teachers, and students, beseech and put forth in one voice that school feeding could have a positive influence in enticing pastoral children to school, and help take advantage of education. Jointly managed by the Ministry of Education, WFP and other partners, it is a program meant to boost up children's school attendance. Accordingly, remarkable results have been produced in the year 2012 whereby attendance at participating schools reached 95% in 2012 and dropout rates fell to 7% for girls and 9% for boys (WFP in Ethiopia, 2012). However, improvements are irrefutable, in some schools observed in Mieso district; the aspired-for result is not as remarkable as this one.

Acute water scarcity

In The Dakar Framework for Action (2000), one of the strategies to achieve *Education for All* goals was creating safe, healthy, inclusive and equitably resourced educational environments among which access to adequate water and sanitation facilities was one. Yet, in Ethiopian schools, water supply and sanitation facilities are posing a great influence on the quality of education (ESDP IV, 2010). Thus, about 50% of schools were more than 1 km of travel time access to water sources is an overarching concern in Ethiopia(ibid), and only 36.9% primary schools have water supply in 2011/12 (MoE, 2012). Access to water is, thus, so much limited regardless of attempts so far made. The limited access to safe drinking water is so striking in pastoralists' context, which grew from roughly 28% in 2001/02 to an estimated 54% in 2007/08 (UNICEF,2012). Regardless of government plan to improve rural potable water supply within 1.5 KM radius from 65.8 to 98% at the end 2014/15(GTP, 2010); so far less has been delivered. In Mieso district, for instance, water coverage was only 35.76% as of 2012, but there seems a push to 40.23 with two new water sources and maintenance of the existing borehole at *Balo* PA at the beginning of 2013[63].

Water problem is much more considerable in time of drought, specifically in pastoralist areas. Even though access to safe water during a period of drought is the commonest hazard in Ethiopia, it is the most neglected aspect of food security by only focusing on analyzing access to food (Tenna, 2012). As one of pastoralist district, Mieso experiences serious water shortage. Water scarcity and water related problem is a serious predicament of schooling in many Ethiopian schools (ESDP IV, 2010). No exception is schooling in Mieso district. For instance, *Ananno* is among PA with agonizing water problem where mothers and children have to travel more than 16 KMs to get drinking water. At *Gololcha* CRC, getting water for drinking and for home consumption is demanding with *Gumbi* PA gravely affected. It was mandatory for pastoralists to journey as distant as Awash to water their animals. Similar situation also exists at *Hametti*, *Waltane*, and *Qiqiliftu*[64] where mothers supposed to move to the water point early in the morning and come back home late in the afternoon. Whenever adults depart either to fetch water or water animals, it is given that children would absent from school to mind the homestead or young siblings, which case affects their school attendance or achievement.

Water scarcity, thus, could constrain children's schooling directly or indirectly. On one hand, without water, human survival is unthinkable; neither does schooling. Without water, survival is seldom possible, explicitly plays a critical part for the brain to function well (Marcus, 2007). On the other hand, some children come late to school or absent from school, either to fetch water or to water animals. Furthermore, water scarcity can result in health related problems that would restrain school learning. According to Degnet, et al, (2011), though there seems a gradual improvement nationally in coverage of safe drinking water supply, the rate is still very low and remains a major cause of health problems in rural areas of Ethiopia. Water scarcity increases sanitation and health problems and exacerbate risk of diseases and malnutrition (APRM, 2011). While emphasizing the educational implication of water related problem MoH (2012) reported that women and children spend several hours every day fetching water that often stands in the way of their education, combined with the lack of sanitary facilities in schools that disadvantage girls.

In most of the cases, albeit water is available, waiting for long queue is mandatory to get a single drop of water where schoolchildren are supposed to stay for the whole morning or afternoon that gravely affects their school attendance and even achievement, for instance[65]. According to Degnet,

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[63] According to an interview with expert at Mieso District Water Mineral and Energy office, on June 2013, two new boreholes were dug at Waltane and Haramaro Deyma, and maintenance of the existing borehole underwent at Balo said to have improved water coverage of the district.

[64] According to interview and focus group discussion at Hammetti, Waltane, Kurfa Sawa, and Qiqiliftu, as of 12 – 13 March 2013, water scarcity is the most excruciating problem where it oftentimes results in conflict with neighbouring Somali, and usually ends up costing human life.

[65] Interview with teachers and Focus Group Discussion with PTA at *Fayo, Asebot, Kurfa Sawa, Annanno, and Dhaga Daku* primary schools show that students spend considerable time queuing for water.

et al. (2011) physical distance to the water source is one of the starkest problems of drinking water supply in Ethiopia, with an estimate of well over 50 percent of the population traveled half an hour or more every day to the nearest water source whereby women and children are victims. Costing them 1.00 to 4.00 Birr per 20 liters jerry cane, fetching water was taking them 11 hours every other day that takes 3 hours to reach the nearest water source, 4 hours waiting for long queue, and additional 4 hours to return with heavy jerry cans (CARE, 2012). This erects a hurdle for most girls' attendance and success in school as it consumes significant amount of their time (Degnet, et al. 2011).

Finding and Implication

Irrespective of substantial progresses in enrolment, in Mieso context, some children whose age is appropriate for school are not coming to school owing to diverging reasons; and of those who are coming, many dropout early. In many schools, it is commonplace to find over-aged schoolchildren, specifically in suburb and rural schools. This appears to emanate from parents' perception of appropriate school age, where children are kept at home until they grow strong enough to withstand the long distance to school; and become capable enough to resist hunger and dehydration at school. Nonetheless, when students enrolled late to school, it is contended that they dropout early prior to acquiring the required literacy and numeracy skills.

Thus, enrolment, dropout, primary completion rate, and gender disparity seems daunting primary schooling challenges in Mieso district which seem to have interlinked with food insecurity. For instance, children are not sent to school in favour of more productive works to cope up with food insecurity; and those who are at school frequently absent, or are supposed to assist their parents back home after school that consumes much of their study time. On one hand, children are much needed at home to tend or water animals, work on farm, collecting fuel wood and fetching water, minding homestead and siblings when parents are engaged in food insecurity coping mechanisms like *khat* transaction, running petty trades, gravel and sand production among others. Eventually, eschewing the business of schooling altogether, they finally dropout. On the other hand, it seems less likely for children from poor food insecure household to come to school and even when they do, they benefit less out of schooling. This has strong implication for Education for All and Universal Primary Education as food insecurity, hence, malnutrition hinders cognitive development and the capacity to learn, limits progress towards the Education for All goals (UNESCO, 2012).

In Mieso context, regardless of the hitherto steps forward, many pastoralist households appear to be food insecure and hence malnourished. It thus seems logical to argue that food insecure households can never prioritize schooling as existence precedes education. Put differently, for the poor food insecure households, it seems less likely to send their children to school. Thus, it equally appears unlikely for children from poor food insecure family to take advantage of school learning. Thus, most pastoralist children in Mieso suffer the double jeopardy of food insecurity and left out-of-schooling as Jukes et al. (2008) states, being more likely to be affected by poor health and nutrition, and being more likely to have cognitive delays or educational problems as a result, the poor suffer the Double Jeopardy.

Thus, to improve school attendance, children learning capacities and performance, accentuates FAO (2005), ameliorating hunger and malnutrition, especially among rural people who constitute the vast majority of the unschooled and hungry is massively vital. In the light of this, in Mieso context, more resilience program such as school feeding, productive safety net program, food aid, and public work need to be strengthened. For instance, school feeding seems more imperative for schools at *Gololcha*, *Ananno,* and *Bordodde* CRCs than anywhere it is operational now. Equally calling for attention is access to safe drinking water in most parts of the district, as water scarcity is the single most agonizing issue affecting schools in Mieso. Further, community sensitization on the importance of children education and significance of education for breaking the food insecurity trap also appears enormously crucial. As it stands now, universalizing primary education for pastoral communities of Mieso district by 2015 seems going off track, unless these issues are acted on.

Acknowledgement

I am greatly indebted to Haramaya University for funding, and supervising this research from its very inception. I am also grateful for students, parents, teachers, principals, PTA members, DA and Health Extension workers, supervisors, and experts who took part in this research. My appreciation also goes to officers at West Hararghe Zone and Mieso District Education office, and Health office. Specifically, Lensa Gerba, Naol Engida and Mohammed Abdurrahman deserve special thanks for your conviviality, and cooperation. My friend, Hambissa Ensermu, I owe you much for your invaluable constructive comments, and incessant encouragement. Colleagues and friends, Getaneh Bekele, Emana Beyene, and others, thank you for your comment and suggestion.

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Unearthing Harla's Past Civilization: Tracing Its Historical-Archaeological Imprints

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Abstract: *This paper tries to uncover the presence in the Harar plateau of the Harla people before the introduction of Islam into the region. This can be related to the practice of traditional religious beliefs until their conversion to Islam probably around beginning of 10th century. Between 13th and 16th centuries they had developed advanced stone building technology, and practiced agriculture using terracing and irrigation works. The presence of seals, pots and shreds reveal that Harla people had organized state and had authority over the surrounding region. The ruins of buildings extending through Harar-Chercher Jijiga to Somaliland as evidenced by immense oral traditions and some sources attested to the existence of Harla people in the region. The presences of home utensils in Harla sites also show that the Harla had organized community who settled permanently and practiced agriculture. The existence of coins in Arabs as well as in China indicates their trade relation with the Muslim Middle East as far as India and China. Their close relation with the Harari and Argobba can be discerned from their architectural building styles which resemble each other. The Hararis and the Afars are strongly claimed that the Harla belong to their groups. Regarding the disappearance of Harla into historical anonymity, there are several versions. Notwithstanding, however, the name Harla exists among the Somali and the Afars referring to certain clans, this probably showing their dispersal and integration into these peoples. With the settlement of the Barentu Oromo most of* *the Harlas seems to have been assimilated by the Oromo. Drought, famine and wars must have also been at the root of the cause reducing their demography and ultimately leading to their dispersion and absorption by other neighboring groups.*

***Key words**: Civilization, historical-archaeological, unearthing, Imprints*

Introduction

Historically, the region which is normally named Harar plateau has at no time constituted homogenous political entity. Currently, the region of Eastern Ethiopia hosts four neighboring national regional states: Afar, Somali, Oromia (East and West Hararghe), Harari, and Dire Dawa Administrative Council.The physical landscape of eastern Ethiopia can be divided into hot and arid climatic conditions settled by the Afar and Somali pastoralists. The Oromo settled areas which include the largest geographic area that runs east-west direction ranging from hot lowlands to wet highland, where agriculture is highly practiced (Emiru Haile Sellassie, 2001:94-98). According to the Ethiopian Central Statistical Authority in 2008 the total population of Eastern Ethiopia was 10,995,191. According to this report, more than eighty ethnic groups are found in Eastern Ethiopia together with foreign nationals. Since the region is a vital outlet to the outside world, both legal and illegal trade configuration must have created a good opportunities for new comers into the region from elsewhere in Ethiopia. (FDRE, Population and Housing Census Report, 2008:21, 59-83)

In the medieval period of Ethiopian history there were a fierce conflict between the Muslim state and the Christian highland kingdom over control of the lucrative trade route leading to Zeila and Berbera, This ultimately led to the war of Ahmed 'Gragn' in the 16th century. (Trimingham, 1953:65-90; Tadesse Tamirat1972:115-154). According to Sihab al-Din the Harla people were one of those forces who fought the Christian kingdom by sending its contingents from its six different tribes. Another major development during this time was the Oromo population movement which brought the Barentu Oromo to the region of Hararge. The first Oromo-Harari contact was in 1559 after Amir Nur who succeeded Ahmed Gragn. The Barentu Oromo settled in Harar-Chercher plateau and the Semitic Harla-Harari gradually dwindled to small number due to a combination of factors like- assimilation, wars, drought, famine and diseases. Even Emir Nur who succeeded Ahmed Gragn was one of the victims of plagues in 1567. After 1585 the Harla people disappeared from written document as a distinct ethnic group.

Objective of the study

Most of the studies conducted on Hararghe region focus on the political, social, economic and cultural aspects of the people of Harari though studies on the early peoples like Harla, Gaturi and the Argobba are very scarce. Both expatriates and nationals have produced much works on Harar city and its peoples. These studies give heavy weight to the Harari and deals not so much about the earliest existing populations. The only exception is the anthropological works of Professor Ulrich Braukämper, who devotes his work to the autochthonous populations like Harla, Gaturi and Argobba. But his work on the Harla lacks comprehensiveness. This study is an effort to fill in some of the historical knowledge gaps that intrigued fuller understanding of the earliest existing population in Harar-Chercher plateau although I do not claim that this study is exhaustive and complete.

Generally the study has the following objectives:

- To discuss their origin, and their relations with the Argobba and the Harari
- To explore some of the Harla sites, and their civilization in terms of their stone buildings and agricultural technology, and different material culture
- To trace some Harla sites and interpret those material culture or remains
- To discuss about the geographical extent of Harla sites
- To discuss how the Harla as a people vanished into historical anonymity
- To briefly explain the role of Harla people in the sphere of agriculture and trade and their relations with Far East country like China.

Methodology and source

Since historical and archaeological methodologies require exhaustive investigation of source materials, primary and secondary sources, published and unpublished documents, books, articles, journals, oral tradition and as well as intensive archaeological survey and observation of buildings and ruins of stones related Harla people the researchers take serious attention in this regard. Particularly, some secondary sources from the Institute of Ethiopian Studies and Kennedy Memorial Libraries are of a paramount importance in the reconstruction of Harla’s past. Field observation of Harla sites and the architectural styles of the buildings, and different material remains were investigated and interpreted based on the nature of their designs and function or purposes. Oral traditions gathered from different regions of Hararge are of a good help in terms of Harla’s settlement areas, their extraordinary performances, their huge physical appearance, about their practice of mixed farming and trade. Most of the traditions told by the people are shrouded in mystery but a close look at the tradition reveal about their way of life.

Harla people, their Origin, Religion and Relations with other ethnic groups

This work is based on archeological observations, historical sources and folktales which attested to the existence of Harla people in medieval period in the east and southeastern part of the present-day Ethiopia. According to sources at our disposal, the Harla were one of the earliest existing populations who dwelt on the northern escarpment of the Chercher and Harar mountains. Like the Argobbas they were one of the earliest Muslim peoples of Ethiopia who mastered stone buildings technology which have marked the region with cities of several traces of stones that extend from Awashand Jijiga to Somaliland.[1] Before venturing into their appearance in written documents as the people who lived in the regions of Harar-Chercher plateau let us first look at how the people of the Horn in general and Ethiopia in particular emerged.

Ethiopia and the Horn of Africa is one of the regions influenced by early Islamic cultural activities. The geographical proximity of the region to the Middle East and the presence of Pre-Islamic contacts on both sides of the Red Sea have produced a symbiotic relationship characterized by interdependence. It is well known throughout history that all cultural, economic, social and political developments that occurred in the Arabian Peninsula and Middle East had both direct and indirect impact on Ethiopia and the Horn of Africa since the remote past. The introduction of the Sabean language and writing as well as art and architecture from the Arabian Peninsula to northern Ethiopia around the first millennium BC could be cited as an example of this close interaction and relationship. Thus, what we could observe during the expansion of Islam in the seventh century and after were not a new development rather a successful fusion of old and new cultural element. Gradually, this fusion has created shared identity and values and promoted harmony and coexistence among the different communities.[2]

Abir also mentions the coming of immigrants from south Arabia to the Horn of Africa in the first millennium B.C. and their influence on the local people resulting in Semitico-Cushitic cultural blend. The numbers of immigrants from Arabian Peninsula were small though their influence on the culture, languages, and political structures of the Cushitic societies which absorbed them was deep and lasting. Other Arabian immigrants who came through Babel Mandeb and settled among the Cushites of the Harar-Chercher plateau produced the semetized culture of the Adare of Harar, the Harla cultivators and the Warjih pastoralists of the region. The latter penetrated from the Harari highlands into parts of eastern Shewa and later served as a vehicle for the expansion of south Arabian cultural influences of Islam into the area.[3]

When we come to the Harla people there are many questions that arise. Where did Harlas come originally? Did Harla people belong to Cushitic or Semitic family? Did they come from outside Ethiopia and later assimilated with the Cushitic settlers of the region? These are one of the most important questions that puzzle historians and anthropologists' alike.Sihab ad-Din who provides an eyewitness account of the 16th century eventful period told us that the Harla people are not

Somalis but they are separate and distinct group.[4] On the other hand, the Harla people also differ from Gaturi, Argobba and even the late comer Harari. The majority of Oromo ofHarar region and Chercher plateau also tell us that they are of distinct group ofpeople and were not descendants of the modern Harari though many Hararis claim their close relations with the Harla.[5] At the same time the Hararis also claim that the Harlas welcomed Sheikh Abadir and his cohorts allowing them to settle among them.[6]Of course the coming of sheikh Abadir (who is claimed by the Harari to be their descendants) from South Arabia was not uncommon in Harari tradition.[7]However, many writers discuss that the Horn of Africa was settled by Cushitic speaking peoples and their dominance in the region was also unquestionable. Nobody denies that northeast Africa including our region is the original home of Cushites and Omotic people. Both H.N. Chittick and R.I. Rotbergdiscuss that for centuries Cushitic people occupied only that part of the Horn that faces the Gulf of Aden including Hararplateau. On the other hand, the South Arabian emigrants at least from the first millennium BC by crossing the Red sea and Bab al Mendeb settled both in the northern Ethiopia and the area opposite to the Gulf of Aden including Harar and Chercher plateaus.[8] Thus the Harla people like the Habashites and Agazines in the north might have crossed to the southeast and settled among Cushitic people of Harar region and Chercher plateau. Abir writes that “Arabian immigrants who crossed the Bab al Mendeb and settled among Cushites of the Harar-Chercher plateau produced the semiticized culture of the Adare of Harar, the Harla cultivators and the Werjih pastoralists of the region.”[9] Thus, the Harla people might be the product of such a mixture of the two cultures and civilization of both Cushitic and Semitic. It seems for this reason that both the Semitic Argobba and Hararis have some similarities with Harla culture in terms of building styles, stone structures andsome field terraces.[10] With regard to the Oromo, which we will discuss later, they do not claim their descendants to be Harla.

Folktales collected from Hararghe region-both East and West Hararghe Zones, and Eastern Shewa show that the Harla people existed and lived before the arrival of Oromo, Harari, Somali and Afar people in the present-day Harar-Chercher region. Based on oral traditions, archeological evidences and historical analysis the Harla people seems to have existed before at least 10th century and established a well advanced civilization during the medieval period.[11] The first written account that mentions Harla people and their region in the 13thcentury is documented by the cleric of the Egyptian Coptic Church who was in service of the sultan of Egypt, ad-Din Baybars. The account of the correspondence between ad-Din Baybars, sultan of Egypt and YekunoAmlack, recorded by Mufaddal b. Abi’l- Fada’il, a Coptic cleric gives some information about the kingdom of Abyssinia and the Harla people. He mentions that Amhara is one of the regions of Abyssinia and it is the largest. Its lords rule over the greater part of Abyssinia such as the countries of Damut and Harla. According to this source one of the kings of Abyssinia was Yusuf ibnArsamaya who was lord of the Jidaya, Shawa and Qalhur, and their dependencies, which are all Muslim principalities.[12] Thus, it can be argued that the Harla people were one of the earliest people in Harar plateau known to have existedas one of theMuslim principalities under the vassalage of the Amhara rulers during this period.

For the second time they appeared in the chronicle of the Ethiopian Emperor Amde Seyon (r. 1314-1344). According to this source, their king entered coalition with other Muslim forces led by Salih against the Christian empire but they were eventually defeated by the Christian forces in thearea close to Dawaro. In Christian chronicle the Harla were mentioned as one of the many groups assembled by a man named Seleh or Saleh. There were many lands ruled by Muslim kings some of which were Mora, Hagara, Nagab, Zuba, Harla, Zel'a, Dawaro and others. These forces, each under their sultans are reported to have made coalition in their fight against Christian kingdom though they were reported to have been defeated by the Christian forces.[13]Again two centuries later, they appeared in the 16th century Arab Faqi in Futuh al-Habasha,*The Conquest of Habasa*, the famous chronicler of Imam Ahmed, who describes them as one of the peoples who comprised the forces of Ahmed B. Ibrahim, popularly known as Ahmed Gragn in his "jihad" war against the Christian Empire. During his war against Christian kingdom, the Harla forces took part in the campaign. Sihab al-Din mentions six Harla tribes like Zemoubarah, the Barzarah, the Yaqola, the Djasar, the Arab Takha and the Alqa who were ordered to hold the Muslim right. According to Sihab ad-Din, the Harla who were holding the Muslim right wing confronted the first, second and third ranks of the Abyssinians. Sihab ad-Din explains, the fighting between them revolved like millstone with men's head being cut off. The Abyssinians committed more forces against the Muslim right. But the Muslim survived with a remarkable endurance.The Harla tribes took part in the war together with the Somalis, the Malasay (probably sub-groups of today's Harari) and desert Arabs.[14]During the conquest, Ahmed Grang had three military units one of which was led by sultan Muhammad, the son of Imam Ahmed Gragn's maternal aunt of Harla. The other division was made up of the Somali under the command of*Garad*Mattan. The third one was made up of a people (Malasay) who used to incursions and to a thorough-going upon whom Ahmed relied. The unit that came from Harla clan of Zarba under the command of sultan Muhammad consisted of 20 knights and 300 infantries where as the tribe from HabarMaqdi with their chief *Garad* Dawit came with 50 knights and 500 foot soldiers and the tribe of Garri with their leader *Garad* Mattan came with 80 knights and 1000 foot soldiers. Other Harla clans like Zaman Bara, Barzara, Yaqula, Jasar, Arab Taka and Al-Qa also sent military contingents to Imam Ahmed.According to Sihab ad-Din the Imam urged the Harla to unite under sultan Muhammad. Furthermore,Sihab ad-Din tells us that during the fighting with the Christian highland kingdom the Harla, Malasai, Somalis and Arabs together lost nearly five thousand Muslim combatants.[15]From Sihab ad-Din'swork one can conclude that the Harla principality was highly organized and had also chiefs or sultans and the sultans as we saw above were responsible to Imam Ahmed. Moreover, one can safely also conclude that the Harla principality was a Muslim principality with its sultans which from the beginning of the war sided with the Imam and one of the three major groups who provided military contingent to Imam Ahmed.

Regarding Ahmad ibrahim, Merid explains that he was born sometimes in 1506 or 1507. Although there is no clear evidence to show that he was either a Harla or a Somali, his father seems to have been connected with the chiefs of Harla. Ibrahim was *garad*of one of the small emirates, probably Sim, between Harar and Dawaro, andhad takenpart in many incursions into Fatagar and Shawa. Owing to his political position orhis loyalty to Mahfuz, Ibrahim was able to arrange for his son anadvantageous marriage with Batia Del Wambara. According to Merid, Ibrahim's sister was the mother of Muhammad, chief of the Zerba clan of the Harla. But the lady in question need not have been of Harla origin.[16]

The last written account attested to their existence as distinctive ethnic group in the region was around 1585A.D. After this period, however, it seems that they might have encountered the same fate as the ancient states of south east Ethiopia and disappeared into historical obscurity.Notwithstanding, however, Braukämper discusses thatbetween the 14th and 16th centuries the Harla people had developed advanced civilization having urban centers and built stone architecture. The Harla were identified as the oldest people who used to live in Harar plateau.[17]The history of Harla according to folk tradition goes back to the time prior to the introduction of Islam to Ethiopia.[18]

The relation of the Arabs with the Ethiopian highlands on the one hand, and with the eastern part of Ethiopia, particularly Harar, on the other existed before the emergence of Islam. Obviously like many people in the eastern part of Ethiopia the people in Harar region followed their traditional beliefs before the introduction of Islam.[19]The people of Harla might have practiced their own traditional religion before the introduction of Islam. But the arrival of Ismail Djaberti must have something to do with the conversion of Harla people to Islam probably in ca. 10th/11th century as the tradition related them with Ismail Djaberti in the sphere of Islam religion. In relation to the integration of some primordial thoughts of the cult of saints with Islam Emile Foucher explains suchreligious sense which he believes is sprung from the pre-Islamic practices of the Harla people.[20]

There is a strong tradition in the Harari community about the successive arrivals of Muslim *ulama* and *ashrafs* from Arabia in the 10th and 11th centuries. Skeikh Umar al-Rida(Aw Abadir) is believed to have come from Arabia through Saad al-Din Gate(Zeyla) with 405 sheikhs. He is reported to have converted various unidentified tribal groups and ruled from Harar over the surrounding communities.[21]

At the time when Abadir(Umar al-Rida), the legendary ancestor of the Harari, arrived in the 13th century he is reported to have been welcomed by the Harla, the Gaturi and the Argobba (Muslim people who came from the Shoan escarpment of the central Ethiopian highland by about 1200). When he reached there with his cohorts of 405 *shaikhs* the native people he found there, the Harla, Gaturi and Argobba, were already Islamized. In this case Abadir was not the first missionary of Islam but he and his followers came to strengthen the institutional framework of religion.[22]My informant Abdulnasir underlines that the Harlas welcomed Abadir and his followers at the site of today's Lange town and later they allowed them to have their permanent seat at today's site of Harar city.[23]According to the biography of emir Haboba, before the coming of Abadir, Haboba is report to have fought with the pagans and converted them forcefully to Islam.[24] Regarding the introduction of Islam to Harar, sources at our hand reveal that the Harla and the Gaturi were already embraced Islam.[25] Though sources at our hand speculate as to when they espoused Islam, the inscriptions found at Harla sites indicates, "Kulu min Alaiha Fan." Meaning, 'all those who live in this world shall die or disappear' quoted from Qur'an. This inscription written on the grave may probably indicate a famous Harla religious man or head. The Gaturi on the other hand, are believed to have come from Hadramaut (Yemen) in the late 7th century.[26] Braukämper underscores that sheikh Abadir was not the first man to teach Islam as the Harla and Gaturi were already accepted Islam earlier. Today, Sheikh Abadir and his companions were highly celebrated for strengthening and disseminating Islam to different regions rather than as pioneers in introducing Islam to the region.[27] Our informant Ali also told us that the inscriptions on stones at Harla site bears"Allaoukber,"[28] and others, and this attests to their embracing of Islam. The fact that the Harlas were followers of traditional beliefscan be discerned from some elements of pre-Islamic thought and practices being integrated, as can be observed, from the cult of Muslimsaintswhich continued to play a pivotal role in deepening and strengthening one's religious feelings.[29]

At Harar, one believes that this religious sense sprung from the pre-Islamic religion practiced by the Harla people before they were converted to Islam most probably by Ismael Djaberti. This was well understood by Harari Islam when its missionaries set forth to Islamicise the south and the west of Ethiopia. These "Asmadina", as they were called, were natives of the "quarter" of the Shoagate. They crossed the" AsmadinBer" (our present ShoaBer) to go and spread Islam to the region as far as the "kingdoms beyond the Gibe."[30]

Folk traditions and some written sourcesreveal the presence of or existence of Harla once in the region, though it is hard to get authentic information about their historical fate after the 16th century. Nowadays, the people do not exist. Notwithstanding, however, oral tradition has it that the Harlas were a physically giant, milk drinking and sedentary pastoralists possessing a highly developed agriculture with urban center and stone architecture.[31]There are several folk traditions about their disappearance into historical obscurity. One version claims that the Oromo people destroyed the Harla people. This does not seem plausible as it was not a complete physical extinction. Another folk tradition, which is commonly held among the Oromo of Afran Qallo, Ittu and Karayu claim that it was not through war that they were annihilated. Instead they were punished by the natural catastrophes and hunger sent to them by God for their wealth and arrogance and their excessive pride.[32]When one travel to rural areas of Hararge he/she would come across ruins of ancient buildings to which local people attest to Harla. It is common to find among the people of Oromo, Harari, Somali and Afar to find in their oral tradition that the Harla were a tall and gigantic race. According to the Ittu Oromos who occupied the western part of the

Harar Plateau the Harla were cultivators of land situated around Asebot town even coming from areas further south like Belbelti town and each day they were required to travel a distance of more than 200 kilometers on his two ways trip.[33] Folk traditions claim that the Harla were destroyed by the wrath of God because of their excessive pride, extravagance that they showed with milk and foodstuffs. Both the traditions among the Ittu and Afran Qallo Oromo unanimously tell that during their marriage ceremony the Harlaput breadson the path that connects the bridegroom's house with the bride's home like a carpet. The people invited for the wedding ceremony would wash their hands with milk. Out of abundance they are believed to have discharged milk to the valley to flow like rivers. They claim that such acts of obsession with extravagance have displeased God so that He sent his wrath up on the "Haralla" people.[34]

The Ittu and Karayyu Oromo claim that earth quake, volcanic eruptions and drought attacked their land. On account of this the "Haralla", the renowned race of extra ordinary length, disappeared from the surface of the earth. For example, one tradition explains that their disappearance is related to the volcanic eruption that took place around Metehara town in the remote past. The Basaqa Lake near Metehara town is said to have been created owing to the volcanic eruption which fall on multitude of the Harla people who were conducting an extravagant ceremony on the scene.[35] Though some of the traditions surrounding the Harla people are shrouded in mystery, there is no doubt that once there existed, people with advanced stone building technology and a good knowledge of irrigation works. Some latest studies show that the Harla were one of the earlier inhabitants of the land that stretches from East Shoa to Jijjiga. The scholars add that despite the tragic stories tailored and composed to fairy tales, the disappearance of Harla seems to be not total annihilation. Many scholars who treat about Harla tell that both natural catastrophe-like famine and diseases, and assimilation by the Oromos in the west and the Somalis in the west must have taken place for total disappearance of the Harla as a distinct people.[36]

According to Mohammed Hassan since 1559 the Oromo settled among the somewhat large Muslim Adare and Harla people, not only assimilating them but also influenced by them to a great extent in some facets of life. He adds that since the second half of the 16th century the Oromo who inhabited adjacent to the city among the large Adare and Harla populations were influenced by their farming technology to considerable extent. This resulted in the practice of mixed farming system which became the main means of Oromo economy during the 18th century.This shows that the Oromos not only assimilated them but also influenced by their farming system.[37]

Richard Caulk similarly emphasizes the assimilation of the Harla people by the Oromos. Heclaims that the Muslim towns west of Harar on the plateau with terraced fields were abandoned. Their populations, speaking a Semitic language akin to Harari, either took refuge in Harar or submerged by the waves of the incoming Oromo.[38]

Ahmed Zekaria, on the other hand, claims that famine and Oromo attack were responsible for the disappearance of the inhabitants in the region. According to him, immediately after the wars of Ahmed Gragn, Harar suffered the heavy burden of Oromo invasion and a famine unprecedented in its history. In this period most of the surrounding villages and regions such as Sem, Shoa, Negeb, Deker and Hargaya were destroyed by the Oromo and the merciless famine. There is an eyewitness account of the agony where cannibalism was practiced. Nur b. Mujahid, successor of Gragn, was forced to defend Harar by digging trenches and later on by building the Jugal, the circumventing wall, as a means to protect the city from the attacks of the highland Christians and encroaching Oromo.[39]

According to Sydney Waldron, the first reported appearance of the Oromo in region of Harar, which was then capital of the Adal empire, was an encounter between a gada force and amir Nur, Ahmed's successor in 1559. The consequence of this initial contact was the devastation which established a major component of these and future relations in Harari perceptions: fear of Oromo aggression. Until this time, the arable regions of the Harari highlands, extending to the east in the present range of the Barteri and Geri Somali cultivators and in the west well into the Chercher range of the Rift projections which connects Harar with the Ethiopian highlands, seem to have been occupied by a proto-Harari farming population, who like modern Harari, had close linguistic affinities with the SeltiGurage and who may have been an ethnic offshoot of that group's predecessors. The last trace, however, is the record of their decimation. Mohammad Hassen explains that by 1577 the Oromo had destroyed more than a hundred villages and besieged the city, ''until the gates were filled with corpuses.'' Amir Nur had reacted to the Oromo invasion by building the city's wall in 1567 providing a refuge for surviving farmers and the established residents, thus establishing Harar as a one city culture an immured and encapsulated society, whose survival in these early days, was precarious. The sultanate of Adal abandoned Harar and moved its capital to the Danakil oasis of Aussa in 1577.[40]

Braukämper explains that after the Semitic-speaking block had dwindled away to the small concentration of Harar town, the history of the plateau over the last 300 years was dominated by the Cushitic Oromo and Somali.[41]

It is more plausible that from the 16th century onwards, a period of great turmoil and the population movement, the Harlas were assimilated by both the Oromo and the Somali and their descendants are at times evident by their genealogies and Muslim survivals. In 1577 the sultanate of Adal made its center at oasis of Aussa, in the Afar desert. In 1647 Harar endured as an isolated independent city state and a Muslim enclave within an Oromo occupied territory. The other remnants of Harla might have moved from Harar to Aussa, where they were assimilated by the Afar.[42]Harari, Argobba, Somali and Afar could so claim to have their roots from Harla. Dr.

Philip Paulitschke mentions Rare Harle Somalis (people of Harla) in Issa region and Cerulli mentions the presence of some Harla words in the spoken Somali language in Fafan area which is located between Gursum and Jijiga.[43]

Jamaladdin Ibrahim, ascribing to the work of Sihab ad-Din underlines Sultan Mohammed, son of Ahmed Gragn's maternal aunt, who was of Harla origin and led the Harla forces. He further makes explicit that the Harlas are one of the many clans of Afar known to exist today. Claiming them to be one of the Afar clans, Jamaladdin explains Harla settlements in Aussa along the banks of the Awash River, Doka and other areas of the Afar Triangle. He indicates afew other Harla clan who settled in Aussa of Afar region parts of which were later included under the Somali region. He claims that, some Harlas being originally Afar, had settled among the Somali and were influenced by the Somalis todayspeaking a Somali language. According to Jamaladdin, in the 17th century they had been rulers of the Aussa sultanates. He discusses that the Harlas ruled the sultanate of Aussa for a brief period of time. He mentions great religious leaders like Kabir Hamza as a man from Harla group. He boldly claims those Harla who today speak Somali language as the assimilated ones whom he underscores their beingAfar in origin. He mentions some prominent leaders of Ahmed forces like Sultan Mohammed Bini Sultan Ali, and Al-Sheik AnasIbn Al-Sheik Bobah.[44] Sihab al-Din, who provides an eyewitness account during the 16thcentury, identified Harla people as neither related to the Somali nor the Afar.[45] The existence of Harla as a clan among the Afars might reveal thatsome of the Harla people might have taken refuge among the Afar when the sultanate of Adal moved its capital from Harar to the oasis of Aussa in Afar and dispersed elsewhere.Though Merid keeps silent on the interaction of Harla with either Somali or Afar he underlines that they were less Semiticized population, and this probably exhibitstheir interaction and integration with the Cushitic peoples living in the region.Merid also tells us that the Warra Maya who might have been a Maya tribe incorporated and assimilated into the Oromo as there are strong indications from the existenceof names like Hara-Maya, and Warra Maya tribes living east of the city in Biciuman district. Similar process might have led the Harla to historical anonymity.[46]According to Braukämper, the Karayyus in the previous times used to differentiate those true Oromo from those assimilated autochthons people of Harla. They named Hawassu from the place they had lived on the Awash River. The benchmark for ethnic differentiation is manifest as the assimilating groups were recently Islamized. [47]

Nowadays, the people who live in the region of Hararge trace several archeological sites of ruins of stone-built necropolis, stone pits, houses, tombs and mosques which are found here and there to the Harla people.[48]According to Tilahun Cherinet the ruins in Hararghe region are all associated with the giant Harla race who are supposed to have lived in the region in the past and their ruins are widely distributed in the region with associated legends as related by all nationalities now living in Hмехан Hararghe area.[49]However Azais and Chambard and as well as Huntingford indicate that the master builders of these huge ruins were a people akin to the Somali. But it could be difficult to establish that the Somali with a predominantly nomadic population having no unique stone architecture had built such structure. Until now there is no data to prove that the Somalis had greater cultural change for the last 400 years. Futuh al-Habasha clearly attests to the distinctive ethnic origin of the Harla. But modern tradition related the Harla to Ismail Djabarti and Darod, progenitors of the Ogaden Somali. This Ismail Djabarti, who is believed to have come from Arabian Peninsula was considered one of the most renowned pioneers of Islamization in the folk tradition of many peoples of east of the Awash River, dated to 10th or 11th century. However, this does not give adequate information to support the assumption that the Harla were of a Somali descent. At the same time there is no evidence to prove that they were of the Afar origin.[50]

A weighty argument for the ethnic interpretation is provided by the Futuh al-Habasha, which explicitly ascribes a non-Somali origin to the Harla. It is noticeable, however, that oral traditions connect the Harla with Ismail Djabarti and Darod, ancestors of the Ogaden-Somaliland their ethnic denomination is still existent among the western Issa and among a Somali-speaking group south of Harar. For Ismail Djabarti it can be stated that he does not only appear in the genealogies of the Somali but also of other Muslim peoples of Northeast Africa such as Hadiya groups in southern Ethiopia. From the contemporary peoples of the area of our concern only the Harari were culturally close to the Harla as representatives of a highly developed peasantry with centers.[51]

According to Merid Wolde Aregay, the sultanate of Harar comprised various inhabitants with "the semetized Adare seem to have lived in the highlands. The less semetized Harla occupied the southern slopes and most of the lowland Babile." Though he mentions about both the Harla and the Adare engaged mainly in agriculture and to some extent trade, he limited the settlement areas of Harla only to the Babile lowlands and the southern slopes of the Harar highlands which definitely seems implausible as there are different oral and written sources frequently confirmed and attested to Harla's existence in the Highlands of Harar and Chercher mountains.[52]According to Braukämper who conducted extensive research on Islamic history and culture, Shaikh Abadir, the ancestor of the Hararis was welcomed by Harla peoples among others.[53]This clearly depicts the presence in Hararghe highlands of the Harla people to whom many tradition attest the different ruins of buildings and mosques evident today to them than the Hararis whom traditions associate them to more recent than the Harla and thus regards them as an extension of the Harla people.

Moreover, there are some striking similarities in the technological standards and even in structural details between the ruined "Harla" sites and the architecture of Harar town. For instance, the Harari store-pits, as described by Yusuf Ahmed (1960) resemble in their form and mode of construction the so-called bolla [Biyo: meaning city]Harla, which are frequent in Chercher and still used by the present-day Oromo (.[54]

On the other hand, one tradition describes that the name Harar itself has come from Harla. It holds that it was the remnants of Harla who settled in Harar and named after them. Abadir is also accredited for naming it using calculation by assigning a number to every Arabic letter to remember the year of his coming to Harar, i.e Ha=5, Ra= 200 R= 200- total 405 Higeria, which is around 1012 A.D the year when Abadir is believed to have arrived at Harar. Other tradition also holds that the word Harar has come from Somali word, Harur, meaning Sorghum, and that the Somali used to trade with Harar probably got some sorghum and the name Harar might have been the corrupted form of Harur. On the other hand, Richard Burton holds the view that the name Harar is named after a tree, which used to grow in the heart of the city. Indeed, there is no linguistic evidence to confirm, but there is no doubt that the data suggest a Semitic Harari type at one time settled a large strip of land between the Chercher mountain and the middle Awash and the eastern escarpment in the region of Jijiga.[55]

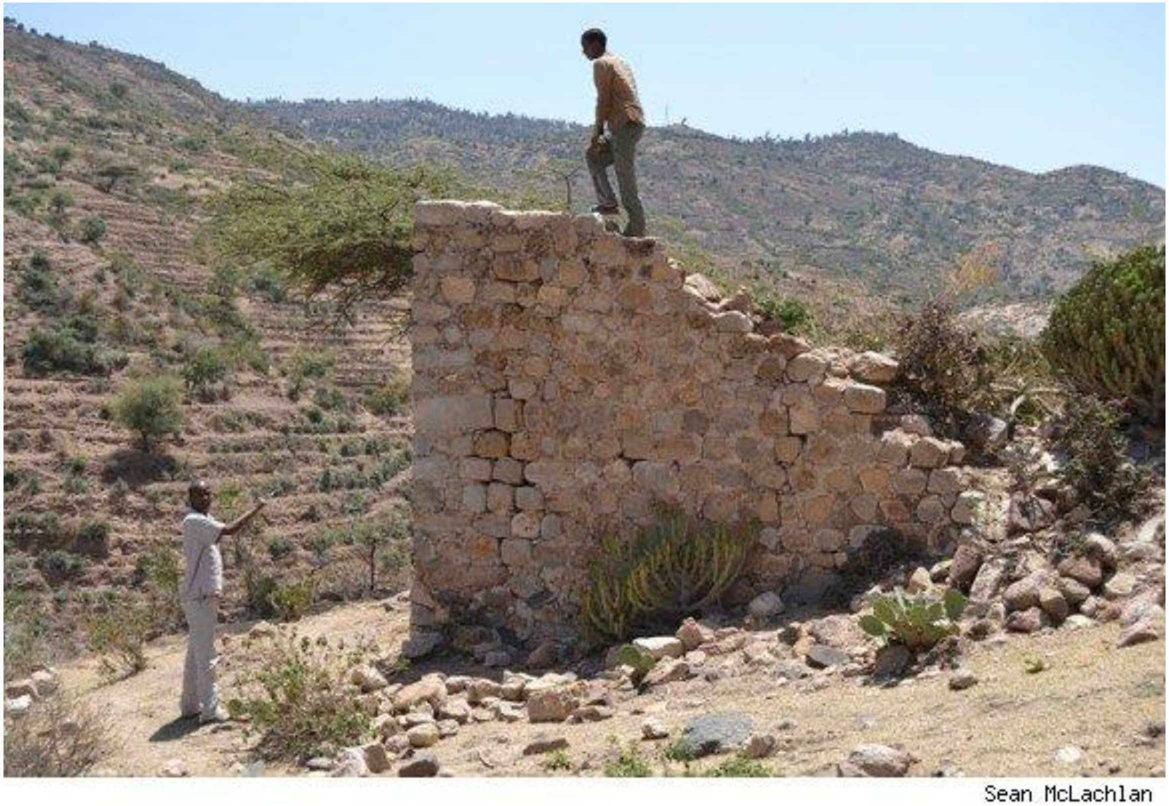
Despite the different views on the Harla people, the ruined Harla sites and the contemporary architecture of Harar city depict a remarkable resemblance in the technological styles and in structural features. According to Harari tradition, Harar is seen as the continuation of Harla people. Some scholars have expressed the view that the layout of the overcrowded town of Harar with its narrow lanes and also the walled villages of the Argobba in the Erer Valley should be interpreted as part of the same tradition as the Harla ruins. If this view is maintained, then it follows that Harar with its present over-crowded layout must have developed from a settlement, which was once very much like the present Argobba villages. But as a trade centre it would have attracted far more people than the walled town had space for; and evidently the city was not willing to enlarge the wall - perhaps because a larger wall would have been more difficult to defend.[56]

Apart from those Harla sites in Harar-Chercher plateau, oral traditions collected from the district of Metehara, East Shoa, indicate that Metehara was one of the centers of Harla civilization. The village now called Harla hosts several remains that are collected and preserved in the house of the farmers: mysterious seals, tombs, ruined mosques, objects of daily life in carved stone, etc.[57]According to oral tradition obtained from Afar elders, there are also ruins of settlement of Harla on the eastern escarpment of the Great Rift Valley along the Awash River. The Afars called their settlement places Harla Habur (Harla village). The Afar informants also indicate Hadiya Habur (village of Hadiya) probably referring to the existence once in the areas (in the past) of the Hadiya people in the region. In the areas of Metehara local tradition point to the existence of the Harla, describing them as giant people as they are described elsewhere in Hararge. The tradition underlines that the Harla people used to cultivate Sorghum and collect them in their pottery terracotta. Informants indicate the presence of their old settlements of ruins of stone buildings and piles of stones on Fentale Mountain.[58]

Historical and Archaeological Survey of the Village of today's Harla (ca.10 kilometers south of Dire Dawa)

Today, the village of Harla hosts different types of remains such as mysterious seals, tombs, ruins of Mosques, different tools carved from stone.[59] The thick walls of stone which were cemented together are still standing strong after many centuries of weathering. Some of the walls standing above a height of a man and there are a set of connections of walls, attesting that the ancient town was a bunch of closely built structures. At one place a tree grown up through a wall growing slowly and gradually cracking through the sturdy Harla cement or plasters and grew around the ancient stones, bracing them into the air as the tree grew and the stones hanging several feet above the ground (See the photograph 3 below). The ruins of towns with large stone buildings unlike anything built by the Oromo and the Somaliare found scattered from eastern Ethiopia all the way to Somaliland considered to be the remnants of Harla civilization which is much left to be uncovered.[60]

Photograph (1): Partly ruined walls



Photograph (2): A view of the landscape surrounding the ruins of building at Harla village**:** Source: Sean McLachlan, March 29, 2011.

From the above picture we can see Harla site surrounded by chains of mountains seen with terraced fields. The site is well protected and its location reveals that the town is situated strategicallyin a niche well defended from all directions. Near this ruins of mosque there are graves not far from this mosque.

Photograph (3): A tree grew and the stones hanging several feet above the ground

The two newly recovered coins from Harla sites which go back to the year 1080 and 1040 A.D, respectively are fascinating evidences obtained from the ancient town near Dire Dawa. This poses an interesting question that how coins from oriental China came there about thousand years back? The significance of these coins is that Harla may be about thousand years old or even more than that thus invalidating the previous French dating to the 15th century A.D. The coins were uncovered by the peasants who live amidst the ruins.[61]

Picture (4): First North Song Chinese coins found in the Village of Harla.

Source:*http://etio.webs.com/thenextexploration.htm*

From such partial data one can speculate that Chinese presence in East African in the distant past under the Chinese Admiral Zheng He who is said have led many fleets of ships which traversed the Indian Ocean in 1418.Zheng He had Abyssinian Myrrh, spices, and even a Giraffe traded back from his 4th, 5th, 6th and 7th expeditions. Excavations in a Harla village near Dire Dawa, in 1987, came across a Chinese coin presumably dated from the 6th century AD. This too is evident on the trade route from the highlands of Ethiopia to Somaliland. It seems that once there was extensive commercial relation between east and southern Africa, and the Chinese Empire. Archaeological reconnaissance that was recently made, stretched from Ethiopia and Somaliland, concentrated on recently highlighted towns like Harla, Gandabello, BiaWorabu and more on the Somali side, with especial focus on marine archaeology in the port of Berbera, Zeyla and across the Somali north coast which give striking survey.[62]Also we know of Harar city that while a great part of their economy was based on agriculture,their intercontinental trade contacts reached to South Arabia and India, while the East African Coast had for centuries trade contacts perhaps indirect, with China as is proved by the rich findings of Chinese porcelain. That occasionally Chinese porcelain made its way at quite an early date to Eastern Ethiopia is referred to by Wilding with regard to surface finds at Derbiga near Jigjigga. According to Wilding it was a 14th century Celadon shred from the export kilns of southern China. This is interesting insofar, since we have thus an indication that both civilization may have been, though perhaps not in direct, yet in indirect contact via what is now Somalia and East Ethiopia.[63]

Apart from trade, agriculture was the mainstay of their economic activity. Harla people also participate in the international trade. They also developed advanced civilization having urban centers and built stone architecture between the 13th and 16th centuries. They have a very advanced skill of stone masonry which they used it to build their houses, mosques and fortify their town.[64]Their agriculture consists of crop cultivation and herding. They cultivate sorghum, millet and the existence of grinding stone at Harla village attested to this. According to Oromo informants of Harla village the digging stick on which a rounded stoneis cemented and put on the top part of it as a weight in order to maximize efficiency and finish work in short period was developed and used by Harla people. Herding also constitutes the major livelihood of a substantial number of Harla societies. Various types of livestock such as cattle, camel, goat and sheep were reared by the Harla people. They also developed a good system of land conservation which involved terracing using stones and digging the soil. The terracedfields and water wells whichwe canobserve today in Harlavillage is attested to the Harla by the local people. They also dug water wells and pounds and used them as water reservoirs which they used for drinking-by both humans and their livestock. The wells and pounds which the Harla people dug during that time now even in existent.[65]

Photograph (5): Water wells found in Harla village, between Dhangago and Dire Dawa

In addition to agriculture and trade the Harla people also engaged in different craft activities such as weaving, melting mineral and iron works, knitting, pottery and processing of leather and skin. All these activities could be attested in the Harla village where ruins of stones are reused by the local peoples to build their homes and at least a few material remains of Medieval Harla people are in the hands of the farmers. They also developed a calendar in Arabic, one stone tablet with moon calendar.They developed the technique of making cement and also developed a technique of bringing big stone from distance places. They also built many mosques which of course parts of some of the walls are in existence and others are observed simply as a ruined wall. They also made a seal curved from stone slab which indicates how far the bureaucratic system of the state was advanced. Many Islamic burial places and tombs were also found there. Pieces of glasses and different ornaments like beads also in existence in Harla village. (Our observation) They constructed different types of granary and put precious materials in the womb of the soil. Thus the Harla people had a very advanced civilization at least before 16th century.

According to tradition the Harla people were enormously strong and they could perform striking achievement with strength. The tradition has it that they were three meters long and their graves long. They were considered to be long and thin sometimes three to four meters long. Presumably *the skeleton in the grave does not seem to be tall. Their graves are usually covered with a layer of ash, ostensibly from burnt offerings, the skeleton of a sacrificed cow and below that we can find a stone slab sealing the tomb. Harla skeleton are usually buried with pots putting above their head. Within the pots is black sand, necklaces of gemstones, and silver coins which are to some extent smaller than a dime. There are writing on the coins but badly minted and old and it is cumbersome to read. The style of pots, coins and jewelry resemble those of both in the mountains of Harar and in the Somali lowlands all the way to the red sea. This may reveal that the sites all belong to the same culture.*[66]

Photograph (7): *Stones and Fragments of bones, probably humans*

Photograph (8): Ruined stones reused for building houses by the surrounding farmers and the remaining are piled for future use

Intensive archaeological and historical survey has been undertaken on Harla site, situated in the western down the hill of *Dangago*adjacent to the high way road. During our survey, Mr. Ali who is well versed and acquainted with some of the material remains and sites we have observed which have a tremendous number of early structural ruins, attributing to institutional buildings, including a mosque, a seal, early ceramics such as a pot and a clay object which seems to be incense burner, a coin with Arabic inscription, and other exotic material remains made of glass, grinding stones, many other underground burials and banks which are not yet uncovered. Most movable rare objects are currently found in the hands of individual farmers.

Besides, we have seen the presence of two water well areas, along the right side of the drainage, protected with the stone built wall. In the upper part of the drainage we can observe stratigraphic layers which are also rich in the composition of fossilized bone fragments related probably to early game animals or human bones and ceramics.

As the external geological out crop indicates, the stones, used to build common residential houses and other mega buildings, according to our informant come from the nearby hill site which is approximately located at the distance of some three to five kilometers.

Photograph (9): Structural remains of one of the earlier buildings of Harla people

The present settlement of Harla, with the collection of ruins which are believed to have been probably of medieval civilization, is located some 10km from Dire Dawa along the high way road of Dhangago-Harar-Addis Ababa. Structural remains and the pattern of mega stone collections in the area, particularly, on the right side of the main road on a hilly land escape between two small wabi may suggest that Harla site was probably a well designed terraced and walled medieval urban center. On the left side burial sites have been identified. The material remains, oral and scant documentary sources reveal that Harla site found here might have emerged as an important political and commercial center or one of the many centers of the Harla emirates probably between the 13th to 16th centuries. It is believed to have maintained commercial ties with the Middle East and Far East via the port of Zeila probably in the course of the medieval periods. This can be partly proved by the presence of Chinese coins and Arabic coins which is difficult to read due to corrosion that resulted from its burial underground for long years. Through extensive archaeological and historical survey, several surface collections which have been gathered by the peasants are also observed. These comprise coins with Arabic text inscription, pieces of glasses, ornaments, ceramics, tools for knitting, and a stone moon calendar, seals etc.

Abeyaziz Mosque near Dire Dawa

The structural remain of this ruined mosque is found in Hulul Modjorural kebele, situated some 25 kilometers away from Dire Dawa city.This single towered mosque is believed to have been built around the locality probably during the medieval periodby the Harla tribe who are reported to have lived in the area. The building technology which involved were the use of massive structured cobble stones, appears to have shared similar technological attributes, illustrated in most structural remains of buildings or houses associated with the lost civilization of Harla, located in some other locality.

Beside the standing structural segments, a handful number of fragmented remains of house utensils and grinding stones are also found at the site. Such related material remains are also recovered from the major site of Harla. Generally, the material relics may indicate settlement of early people in the area and their domination of the surroundings with upper hand. We have come to observe that several ruins of stone building which are related to the Harla people by different nationalities living in Hararghe, show similar cultural links with some other Harla sites in the adjacent areas.(Our Observation)

Photograph(10): Structural remains of Abeyaziz Mosque of Harla

The archaeological artifacts, recovered from the site encompass silver coins that are slightly smaller than a dime. The coins bear inscription with Arabic text or designs on the coins but they appear too old to and poorly minted. Unearthing such numismatic material relics may help us further explore not only the nature and hallmarks of Harlas' economy based on caravan commerce, but also its external socio-economic and political ties with the outside world, particularly the Muslim Middle East.

Photograph (11): One of the early coins, from Harla village

Photograph (12): Early seal- like lithic artifact

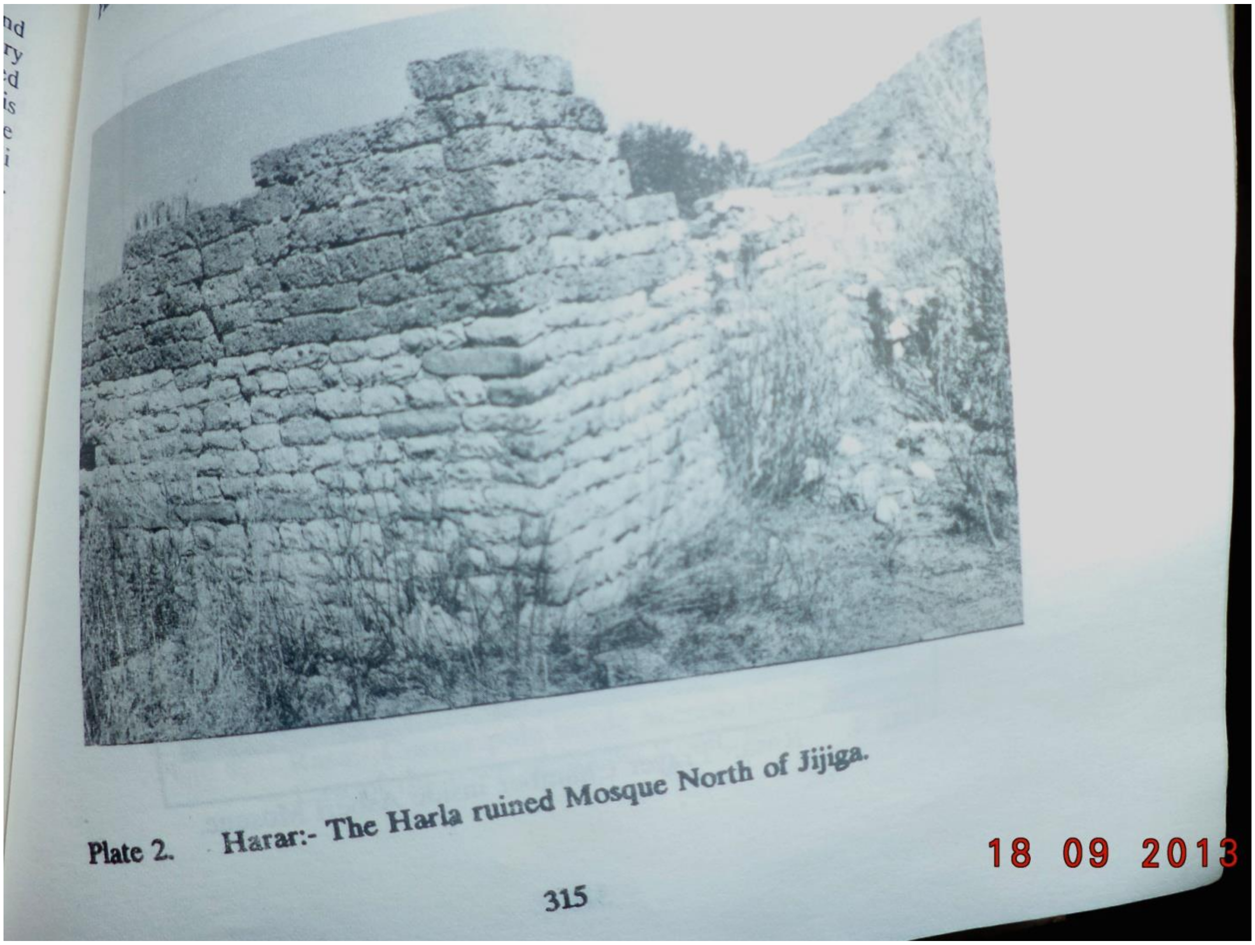
Archaeologically, the recovery of seal in the early sites like Harla is believed to have marked the presence of authority or formation of state. Such material remains tend to have profound potential to justify the early existence of state in the region. Some other archaeological artifacts from Harla site includes handful early pots which is collected by the local villagers are indicated hereunder.

Photograph (13): The early pots and potsherds, from Harla village

In archaeological inquiry and analysis, the finding of such early pots and potsherds can be attributed to the presence of settled and organized community or society in the area. Thus, the pottery artifacts may confirm the oral information and scant written accounts, pertaining to Harlas' lost civilization in general and the features of its society in particular. The external surface and shape of the pots may probably show their long age. The structure and shape of the pots may be associated with their function. Their color varies from white gray to black. In general as we overview the above material remains, the style of the pots, coins, seal and jewelry share some close related attributes.

Photograph (14): *Underground Bank, where some precious materials and tools are believed to have been buried by the Harla people*

Photograph (15): *Landscape of Harla site and terraced fields at the foot of the mountain*



Photograph (16): *Source: Cherinet Tilahun*

Harla Site at Lange

The site of Lange which is located at about 45 kilometers away from Harar found to the south of the road right next to it immediately before reaching Lange town. There is a hill top walled settlements and the area on the top is probably 900-1000square meters. The house are not well preserved though it seems that they have been built of wood and daub lay down on solid circular stone base walls with a diameter of between 5m and 8m and a height of around 1m. There are several burial chambers lined with stone on the south side of the hill. Attempts had been made by the local inhabitants to uncover the bodies in these tombs in the hope of finding treasure. Many of the tombs have been damaged in this way. It should nevertheless be possible to find an undisturbed tomb and it is certainly possible to excavate several of the other structures and recover information about the inhabitants. The few shreds collected revealed the same formal collection as those in the other Chercher sites. There was a predominance of medium size water pots and open bowls. The hilltop settlement, heavily fortified and very small seems to be a characteristic of the Chercher settlements associated with the Harla.[67]. As can be seen below the wall at Lange site has a circular base with few meters in diameters.

Photograph (17): Hill top settlement at Lange

At can be observed above, the bottom structure of the stone at Lange (immediately before entering Lange town) is too large in shape as compared to several piles of small cobble-like stones found spread over the hill. When we look into the farmland found at the bottom of the hill the farmers seem to use them in building irrigation works. According to Umar, my informant, there is another hill site found immediately to the north of Lange lake where the ruined building and parts of the wall which is still standing. Between the two hill top settlements we can see Lange Lake spread over a wide plain, though it totally dries in times of lengthy dry season. The settlement on the hills clearly reveals the strategic importance of the site for defense purposes with the valley and wide plains at the bottom suitable for both farming and pasture for their herds.(My own observation)

Photograph (18): The top of Lange hill

Photograph (19): Ruins of stones at Lange

Photograph (20): View of Lange town and the dried Lake seen from the top of the hill

Photograph (21): A partial view of the plain at the foot of the mountain

Harla Mosque at Manna Qallu (Dobba)

Despite the disappearance of Harlas as distinct people the Barentu branch of the Oromo who settled in Harar plateau since 1570s must have assimilated steadily the majority of the Semitic-speaking Harla-Harari peoples. Presumably the Harari of today are the last representative of the ancient Harla whose were either decimated by war and famine in the 16th century or gradually assimilated by the Oromo in the west and by the Somali in the east. Despite this however, Harar as a Muslim city continued to flourish and eventually made a great effort in the conversion of the Oromo to Islam. Apart from serving as attractive urban center of cultural orientation to the surrounding Oromo peasants, some small centers of sanctuaries and shrines of saints which found in the countryside were reestablished in the 19th and 20th centuries and served as centers for the expansion of Islam.[68]Like the town of Harari itself, virtually all visible shrines are constructed on top of hills. Taken in combination they constitute characteristic land marks forming a saintly topography. The material appearance of these places is highly diverse. They existed in shape of niches, trees, simple graves, rocks and the typical cupola. Some shrines have rooms, which are used for the venerations of saints (*gelma*). Many of the shrines have a mosque with small cemetery attached to it. Saintly places in the countryside in particular are erected close to enormous overhanging sycamore trees.[69]

The Harla mosque of Manna Qallu near Dobba/Chercher is an example of such centers which clearly depicted uninterrupted continuity. Following the diminishing number of Semitic-speaking group to small concentration of Harar town the history of the region over the last 300 years came to be dominated by two Cushitic speaking groups, i.e. the Oromo and the Somali.[70]

The ruined mosque of Sharif Ahmad in Manna Qallu near Dobba/Chercher is ostensibly one of the oldest places which is continued to be a place of reverence for Muslims. In 1922 Azais and Chambard visited the stone-built outer wall of the building which stands today. People living in the surroundings believe that the spirit of Sharif Ahmad living there can be invoked. At the time when Azais and Chambard visited the site the local people considered Sharif Ahmad to have been the leader of the Harla people who are said to have possessed immense wealth of foodstuffs and they proudly wasted part of it. It was believed that as a vengeance God brought to them a long-lasting drought and many of the people of Harla died in the successive famine. Ahmad is said to have had cautioned the people to take care of the endowment of nature and told them to respect *adja* (triticumdicoccum), a grain which was seen with contempt. He told the people not to ignore and disregard the breeding of sheep and goats which resist drought as compared to cattle. In doing so, it is believed, Sharif Ahmad and his family were able to cope up with famine with considerable time. As a consequence the local people in the Dobba area considered him as some kind of patron saint in times of drought. The shrines of Sharif Ahmad and the second man Imam Abd al-Rahman are located inside a rectangular stone wall some few feet to the northwest of the main entrance of the mosque. The *hadra* which is located behind the eastern wall is a place where pilgrims can make fire and stay overnight. The Oromo used to frequent to this place during September and October to pray Sharif Ahmad to support their prayers to God for a good harvest.[71]

The ruins of Harla mosque is found at DirreBalo ofDobbaworeda, particularly at GandaShani or formerly GandaNole. The place is also called MananQallu. The mosque is located on a hilltop well defended by another hill at the back of the mosque and somewhat a deep valley in the front at the foot of the hill on which the mosque stood. This location of the mosque may probably indicate that it was built on such a site for defense consideration. According to informant the mosque is dedicated to Ahimad.[72] My observation of the mosque shows that it is a large rectangular shaped building, though parts of the two sides of the wall are almost fallen. The other two sides are relatively standing better but in the absence of proper preservation there is no doubt that the remaining parts would fall the sooner or later. The inner sides of the mosque seem to be well built and cemented as can be observed from the somewhat remaining structure which stands better. The inner side inclining towards north east direction is uniquely polished oval shape-like niche which is believed to have been a place where an imam or sheik of the mosque were supposed to stand and led prayer session in that direction. Immediate to the wall of the mosque at the back we can find two graves which probably related to personalities or religious figures attached to the foundation of the mosque(Sharif Ahmad andImam Abd al-Rahman). According to my informant, there is also another Harla site, Bio Karaba, located further to northeast of Dobba town. He witnessed that the site is located on mountain top with ruins of building and piles of stones to which local people related to Harla people.[73]The following are some views of the existing structure of the Harla mosque seen from different directions.

Photograph (22): Inner side of the Mana Qallu mosque

Photograph (23): Outerside of Mana Qallu mosque facing the east

Photograph (24): Inner side of Mana Qallu mosque

Photograph (25): Innerside of the wall where imam or sheikh face this niche to lead prayer session

Photograph (26): Side view of Manna Qallu Mosque

Photograph (27): A partial view of the ruined Harla mosque, the wall in the west side

Photograph (28): Two graves (Probably men related to religious personalities: Sharif Ahmad and Imam Abd Al-Rahman) behind Mana Qallu mosque

Photograph (29): View from the East side

Harla Mosque of Sakate in Mechara (West Hararghe)

Another Harla site is located in Western Hararge Zone in HawwiGuddina district, Kombolchakebele, specifically at the place called Sakate. As can be observed the building is related to religion, mosque though the informant is not able to read the Arabic letters on a wall. Probably the area where the mosque located might be mid-temperate climate as can be observed from pieces of wood put on the top of the roof. Today the temperature of the area tends to hot climate. Near the mosque there are pools and small dams which could reveal the practice of agriculture using irrigation works. From the surface structure we can also observe abandoned terraced fields. According to my informant the chat field found now in that area is believed to have been planted by the Harla people and it is believed that no one used those chats fields today. The people are believed to be of giant race, and large body structure. According to my informant their skeleton is longwhich he claims them to be large from the fragments of bones of legs and arms. In Mechara also the tradition related their disappearance to famine and their excessive pride and waste of foodstuffs during their marriages. My informant added that their skeletons are also found in Ciro and Hanchar areas. The Harla mosque and building found in Mechara was made up of sand and big stone slab stick together and it is in existence today though the wild fire destroyed the upper portion of the mosque which was covered with wooden part and with light stones. Now the top side of the roof is open but the wall is better built and standing well. The mosque is built of big stone and the window is too long.[74]

The Harla and the Argobba

*The Harla are by and large*related with the stone built hilltop settlements of the highlands of Harar and Chercher. But some of the traditions about the Harla and the Argobba confounded the two and the tradition sometimes overlapping. The Argobba people are still living in the highland parts near Harar. They have connection with the Argobbas living in the hills just above the Danakil sites east of Shewa and South Wello massif.[75] The movement of the Argobba people to the east might be a gradual arrival through time and this perhaps corresponds with the southward expansion of the Christian empire and the end of the Shawan sultanate. The Argobbas are said to have established their eastern settlements in about 1200A.D immediately before the arrival of Abadir and they become gradually absorbed by the Oromo after 1600. The stone-built villages of the Argobbas in Bisidimo is supposed to have been built during the time when Emir NurMujahid(1551-1569) who organized the construction of the walls of Harar. In northern Arsi in ArbaGugu the Oromo related piles of stone and other archaeological ruins to the Argobba. The Karayyu and the Ittu Oromos attributed the ruined terraces on the middle Awash to the Argobba. It is important here to note that the tradition regarding the Argobba people overlaps with the Walasma dynasty and as well as confused with the Harla tradition and it is apparent that an ethnic interconnection between these groups might have previously existed.[76]

The stone built medieval settlements of eastern Ethiopia are built on heavily defended hilltops which are from 1800-2000 masl. All of the mountain sites have related features. These places are close to abundant pasture and water. They all give the appearance of terracing. Many of them are clearly associated with terracing. They have ceramic assemblages which considerably resemble each other. Ashlars were used for massive defensive walling in these places. They all use homes of wattle and daub, occasionally with stone footings. They are all small: the largest BiyoHarla covering little more than 1000m^{2}. In the Ogaden and the Haud towns,stone built Islamic sites have been observed before several times. A survey of the Ethiopian Ogaden exhibits much information on the sites. They seem to have been occupied by 14th or 15th century. Similar to the Somali site east of the Haud, the Ethiopian sites also provided fragments of celadon, Indian glasses and beads all indicating to this period. Both the highlanders and the lowland Somali speakers strongly associated these sites to the Harla. In contrast to the Danakil and the highland sites, the Ogaden and the Haud sites have no hilltop sites and there is no remarkable defensive walling. The southern sites in the lowland areas are frequently related to the Harla. The graves found in the highland places are evidently related with those found in the Ogaden sites.[77]

The following two structures of building (Asberi and Nora Mosques) which are found in north-east Shoa of the former Ifat related to Argobba show some similarities in the styles of building with the Harla and Harari and Argobba buildings in Hararghe. This may reveal close connection between these peoples in during the medieval period of Ethiopia.

Photograph (30): Asberi Mosque, north-east Shoa, probably medieval related to Argobba in former sultanate of Ifat

Photograph (31): Nora mosque, still to be dated, most probably medieval related to Argobba in the former sultanate of Ifat

The presence of these settlements in the southern Afar, Chercher and the Ogaden might be associated with the old commerce between the Ethiopian highlands and the coast. It can be assumed from the scanty sources that the Harla and the Argobba might have been involved in the long distance trade. Some of the east highland sites of the Harla though they are local fortification established to protect against attack from the lowlands, they are not widespread and not permanently fortified like that of the Afar. Nevertheless, the highland settlements of BiyoHarla and Lange seem plausible that they were permanent settlement and exactly located in place where the caravans could traverse from the Afar towards Harar.[78]

Conclusion

In the final analysis, the ruins of stone building of Harla, Argobba and Harari show a remarkable resemblance in the styles of their architectural technology. This might reveal their close socio-economic and cultural association since both oral and some written sources show the presence of Harla in the region. Their disappearance as distinct ethnic group do not led to the conclusion that either the Harari or the Argobbas have build several stone buildings found in Harar-Chercher plateau. It is obvious that the Argobbas moved to Harar in about 1200 when the southward expansion of Christian kingdom forced some groups to move to Hararge. This does not help us to conclude that all those ruins of stone buildings and cities are related to the

Argobba.Historical connection between the Harlas and the Hararis can be established since the coming of Abadir and his followers whom the Harari people considered to be their ancestors. The sources at our disposal tell us that at the time of Abadir's and his followers' arrival the Harla and the Gaturi people had already been Islamized. Though the Hararis sometimes claim the Harlas to be their ancestors, the evidence at our hand reveal the existence of the Harla people prior to the modern Hararis. The account in the 13th century by the Egyptian Coptic cleric who was in the service of the sultan of Egypt indicates the existence of Harla region and many Muslim principalities under the vassalage of Christian kingdom. From our finding we can conjecture that wars, drought, famine and assimilation must have been at work for the disappearance of the Harla people into historical anonymity. Apart from assimilation by the Oromo through their old institution of Gudifacha and Mogassa, the existence of Harla name in Somali and Afar may reveal their dispersal settlements and assimilation by these ethnic groups. At the same time some remnants of Harla might have taken refuge in the Walled city of Harar. The Hararis seem to have escaped such total assimilation by building their walls and maintaining their identity through peaceful market relations or marriage alliance with the surrounding Oromo whenever conditions allow them to do so. The existing oral tradition in Hararghe and Eastern Shoa, some available scanty sources and archaeological survey of the Harla sites in Harar-Chercher plateau tend to reveal the existence of a people called Harla. Nevertheless, *this study does not claim that the findings are absolutely complete and answered all the questions surrounding the Harla people. Thus, further historical-archaeological and anthropological study has to be made to unearth and throw light on several issues which this workleft unanswered.*

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The Role of Safety Net in Ensuring Food Security at the Age of Global Climate Change: the Case of East Harerge Zone

Chemeda Bokora

Abstract: *Food insecurity, a persistent predicament in Ethiopia, covers large area and a considerable number of people. This has given impetus to public attempts. Alongside the government, a number of NGOs and donor agencies have begun taking part in the aspiration to curb the devastating problems of food insecurity by channeling huge investment. A case in point is the Safety Net project in Eastern Hararge Zone. Nevertheless, corroboration, arguably, is lacking to reveal the success of the project in addressing household food requirement. The intent of this inquiry, therefore, is to examine the contribution of Safety net project in three districts of eastern Hararge zone towards household food security. In this sense the research is descriptive and exploratory case study where both qualitative and quantitative methods are used. Both primary and secondary data is used in this undertaking. The statistical computation of the quantitative data is analyzed based on a standard food security model. Analysis of the qualitative data has shown that the project's contribution towards increasing food availability is attractive for it constitutes 67.4% of the mean household food availability. Thus, the income from the project is valued by the beneficiaries in filling the insecurity. But yet 72.1% of the households could not meet the daily minimum recommended allowance of 2100c per capita. By the same token the asset creation role of the project is very minimal in the sense that 65.2 % of the respondents figured out that the squander has forced them to sell their asset instead. Based on the analysis of the quantitative data the researcher further recommends that continues reversal of the situation and the subsequent eradication of food insecurity in the area invariably call for: paying due emphasis to the formulation and implementation of well thought-out and sound project objectives, incorporation of indigenous knowledge at the various stage of the project, emphasizing on asset building strategies, critically reconsidering timeliness in delivering food and tackling delay, modernizing agriculture and application of progressive irrigation, and conducting timely research by rendering significant latitude to the perception of the beneficiaries among others.*

Introduction

Ethiopian economy is among the most vulnerable in Sub-Saharan Africa. The predicaments of poverty, inadequate food and shelter, poor health, unemployment, etc and their causes characterizing states under development are true for Ethiopia. It is perceptible that the country has been haunted by pervasive poverty. Widespread and abject poverty (Eshetu, 2004; Map of the World com. 2011) and the dilemmas thereof are the defining features of life in the country. It has suffered from recurrent drought and the resultant extreme fluctuations in output (Devereux, 2005). This in turn has resulted in relentless hunger.

Ethiopia is one of the Sub Saharan countries most severely haunted by debilitating food shortages and their consequential results of tragic famines. Hunger and food shortages have been endemic in Ethiopia for countless of generations. This goes in contrary to God's prayer "Give us this day our daily bread" (Luke, 11:3). It is humiliating that poverty and famine have been debilitating the livelihoods of the sizable portion of Ethiopia's population (2005, 2). Many Ethiopians live in conditions of chronic hunger with both a low average daily energy supply and a very high prevalence of under-nourishment (Brehanu, 2004: 138). Wide spread hunger is a universal threat, and certainly a fact of life in many parts of the country.

It is depicted, in this connection, by MoARD (2006) that food insecurity in Ethiopia covers a large area and a significant number of people. It has become one of the defining features of both rural and urban poverty and more than 12 million people are chronically or at least periodically food insecure (Maps of the World com, 2011). In simple terms, the country is hit hard by the dangerous and complex food crisis predicted by Mahendra Shah et al. (2000). Food insecurity and sometimes hunger which depicts nutritional stress are the lot of the people.

The food insecurity prevailing in the country is attributed to a number of interlocking factors. Prominent among which is production shortfalls. Food production and supply are constrained by degradation of soil fertility, population pressure, archaic and back ward production techniques and inputs, erratic weather conditions, policy issues. In this connection Goodo sated,

> *……chronic food insecurity is a structural economic problem but not the result of the recurrent drought. The Egyptian civilization and survival depended primarily on a single river, Nile. However, the peoples who live on the source of Nile, and many large rivers such as Ganale and Logita in Sidama (which form Wabeshebelle in Somalia), the Baro and Akobo in Gambella, the Gibe in Oromia and so on failed to sustain their basic livelihood for over a century. The inability to feed ones population is a national embarrassment. It is now clear that the chronic food insecurity in Ethiopia is the result of a chronic problem of governance (American Chronicle, 2008).*

Lack of efficient and effective input and output market systems is also among the major impediments to agricultural development and food production, and thereby contribute to food insecurity.

At the national level the country continues to depend on food aid. This is true of the year 2012/13 as well. As depicted in the table on the next page that is released on 15 March 2012 by the USAID, an estimated 3.54 million people require emergency food assistance.

Table 1. Required Emergency Relief for the year 2012 (in USD).

Implementing partner	Activity	Location	Amount
CRS/JEOP	57, 300 MT of Relief food assistance for Drought-affected areas	Ethiopia	$36,000,000
WFP	78,230 MT of Relief food assistance for Drought-affected areas	Ethiopia	$62,400,000
WFP	19,250 MT of Relief food assistance for Refugees	Ethiopia	$20,000,000
UNHCR	Refugee protection and assistance	Ethiopia	$10,000,000
Total USAID and State Humanitarian Assistance to Ethiopia in 2012			$128,842,194

Source: Famine early warning system network by USAID, March, 2012.

The document also estimates non food administrative and support costs at USD 447,194 (USAID, 2012: 5).

This stubbornly uneradicated evil, to use the expression of Nicephore D. Sologo (2000), has given impetus to public attempts. The government of Ethiopia has decided that there is an urgent need to address the basic food need of the food insecure households via a productive safety net program (MoARD, 2006). The program, to this effect, has been developed by the collaboration between the government of Ethiopia and joint donor groups involved in the vulnerability policy dialogue and the coalition for food security (RHVP, 2007). The establishment of these projects is accompanied by channelling huge investment and marshalling massive outlays of resources.

The project is meant to provide transfers to the food insecure population in chronically food insecure districts of the Zone with the hope that it prevents asset depletion at the household level and creates assets at the community level (Revised Ethiopian Safety Net PIM, 2006). As such, it is intended to provide people in need with immediate employment and income, alleviate poverty, fortify self-help capacity, and enable the construction and improvement of infrastructure for the enhancement of agricultural productivity and stimulation of rural development via works that are labour intensive.

Literature Review

Food Security and Food Insecurity and its Causes

The preceding part of this work is meant to provide a brief introduction to the research. The subsequent part will briefly deal with the concepts of food security, food insecurity and its sources.

Food Security

As the Christian Bible goes, the concept of food security has been with human society and is a policy issue since the time of Pharaoh where seven years of famine which is accompanied by seven years of plenty is predicted by Joseph. The famine during the period was attributed to the harsh drought that spread all over Egypt and the adjacent states (Genesis 41:25-36). The subsequent period of human history are characterized by the failure to produce and ensure access to enough food to the continuously growing world population. Food security has been put into question for the significant number of the world population, especially those living in the least developed countries.

Food security, a major theme in this research, is concerned with a physical and economic access by all people at all times to sufficient food to meet their dietary needs for a productive and healthy life (USAID, 1995). It is defined as access by all people at all times to enough food for an active and healthy life (Markos, 1997). This remarks that food security is a fundamental need for all human society. But it is true that an increase in food production and availability and its accessibility do not guarantee food security unless its efficient utilization is invariably ensured. In the years following 1997 global food production has risen to an all-time high, and if divided on per capita basis, could have given every one around 2,700 calories per day-an adequate diet for most (Barrow, 2005). Nonetheless, in the early 2001, food emergency situations arose in 33 countries and affected more than 60 million people (ibid).

Availability, access and utilization of enough food in turn are attributed back to an array of factors. These include land holdings, agricultural inputs and productivity, income, human capital, policy environments, etc. The reason some households are food insecure, expressed by Devereux and Maxwell, is rooted in the ways entire livelihood systems have changed and adapted to, or failed to adapt to challenges from the ecological and economic environment (2005, 90). The inference, therefore, is that ensuring food security and realizing sustainable livelihood calls for averting the risks that can disrupt food security by affecting all the three components-availability, access, and utilization.

Food Insecurity

Food insecurity, in contrary to food security, refers to the lack of access to enough food and the consequential failure to live an active and healthy life. It can be defined, according to Markos, as "people's inability to secure a regular supply of food from their own farm lands or through off-farm incomes" (1997). Households/individual's failure to meet consumption requirement, as such, significantly reveal the persistence of food insecurity. This goes in contrary to God's prayer that says "Give us this day our daily bread" (Luke, 11:3). The poor are especially vulnerable to food insecurity and famine because, having few resources they are virtually defenceless against series of misfortunes or unprecedented disasters (FAO, 1986). Poverty and food insecurity are highly interwoven issues that reciprocally reinforce each other. Poverty is a driving force for household food insecurity, and food insecurity, in turn, impoverishes a household (Degefa, 2008). And food insecurity is not confined to and defined in association with poor performance in agriculture. As Stephen Devereux and Simon Maxwell put it, “food insecurity is no longer simply seen as a failure of *agriculture* to produce sufficient food at *national* level, but instead as a failure of *livelihoods* to guarantee access to sufficient food at household level” (2005, 135). Food insecurity can be of two types: chronic food insecurity (under nutrition) and acute food insecurity (famine). Both forms of food insecurity are highly prevalent in Africa. As per the report by FAO, out of the total 840 million undernourished people, 26 percent of them live in Africa (FAO, 1996).

Food Security in the Ethiopian Context

Ethiopia is one of the world’s poor countries with indicators suggesting low levels of development. Many Ethiopians live in conditions of chronic hunger with both a low average daily energy supply (kcal/capita) of 1880 and a very high (44%) prevalence of under-nourishment (Brehanu, 2004). As per the 1999/2000 report by Well Fare Monitoring Unit, the proportion of population unable to attain their minimum nutritional requirements is estimated at 52% of the rural population and 36% of the urban population (MEDoC 1999, Brehanu, 2004). Food insecurity as such has become a destiny for substantial number of the populace. In line with this the Ministry of Agriculture and Rural Development stated in revising the productive safety net program in 2006 that: food insecurity has become one of the defining features of rural poverty, particularly in drought-prone areas of Ethiopia. Poverty is widespread in both rural and urban areas. However, the magnitude is much greater in drought-prone rural areas than in urban areas. The problem of food insecurity in recent years has worsened with around 14 million people requiring emergency food aid.

Consequently, there are a number of districts that are chronically food insecure. Gursum, Fedis and Goro gutu are among these districts haunted by pervasive food insecurity in. They are grouped among the chronically food insecure districts identified by the Ministry of Agriculture and Rural Development and Productive Safety Net program is being implemented.

Safety Net and its Implementation

By virtue of the prevailing food insecurity in the nation, the government of Ethiopia has decided that there is an urgent need to address the basic food need of the food insecure households via a productive safety net program. The program has been developed by the collaboration between the government of Ethiopia and joint donor groups involved in the vulnerability policy dialogue and the coalition for food security. Hence, in the parts to come, a brief look at the general conception of safety net, safety in the Ethiopian context, and its implementation will be made.

Safety Net

The various natural and manmade disasters and the resultant increase of victims have called for the establishment of safety net program that is deemed to get appropriate food to people in need. The program, at its initial phase, is meant to ensure temporary alleviation of hunger and prevention of starvation. Nevertheless, some potential may exist, even in this situation, to provide some more lasting benefits in addition to keeping people alive or tiding them over the periods of crisis. In addition to avoiding undercutting development, emergency feeding needs to be linked to disaster mitigation and rehabilitation developmental activities that have significant congruence with and apparently linked to national development plan. As Joseph Mullen has stated with desirable degree of exactitude,

> *.... there is a close link between poverty and vulnerability to recurring emergencies, particularly those caused by drought. If the food security of the most vulnerable people could be improved at the household and community level through development projects, the continued need for emergency assistance could be considerably reduced* (1995, 30).

These recurring emergencies are outlined in line with the national disaster mitigation and rehabilitation strategies and programmes. Safety net, as such, can be looked at as an emergency program that is intended to provide people in need with immediate employment and income, alleviate poverty, fortify self-help capacity, and enable the construction and improvement of infrastructure for the enhancement of agricultural productivity and stimulation of rural development via works that are labour intensive. These labour intensive works and the accompanying food, income and health interventions, according to Joseph, could improve the well being of the poor and help enable them to withstand future food shortages (Ibid). The program also incorporates direct ration of food and/or money to the elderly, the handicapped, orphans, and the weak. That is, though the most important element of safety net program is public work. But members of the community who cannot participate in the public work are destined to benefit from direct support.

Safety Net, as such, can be seen as a non-contributory transfer program that is intended to prevent the poor or those vulnerable to shocks and poverty from falling below a certain level of poverty. It is part of a broader poverty reduction strategy interacting with and working alongside of social insurance; health, education, and financial services; the provision of utilities and roads; and other policies aimed at reducing poverty and managing risk (Wikipedia, Free encyclopaedia). These programmes, as elucidated in the foregoing passages, can be provided by the private sector or the public sector.

The programmes, as stated in the encyclopaedia, should provide coverage to three different groups: the chronic poor (those having limited access to income and the instruments to manage risk, and even small reductions in income can have direct consequences for them); the transient poor (groups that live near the poverty line, and may fall into poverty when an individual household or economy as a whole faces hard times); those with special circumstances for whom general stability and prosperity alone will not be sufficient. The vulnerability of these groups may emanate from disability, discrimination due to ethnicity, displacement due to conflict, “social pathologies” of drug and alcohol abuse, domestic violence, or crime. These groups may need special programmes to help them attain a sufficient standard of well being (Ibid).

Implementation of Safety Net

The different ways through which intervention by safety net is carried out include: cash transfers including family allowances, need-based assistance programs; food based programs including supplementary feeding programs, school feeding programs, food for work, emergency food distribution, and food stamps, vouchers, and coupons; general subsidies such as universal/indirect support for food, subsidized untargeted sales, subsidies for energy and utilities; public works including road construction and maintenance, maintenance of public spaces and buildings, irrigation infrastructure, reforestation and soil conservation; fee waivers and exemptions for schooling and for health care. Fee waivers and exemptions as such are intended to provide poor people with the financial resources to use public services such as education and health facilities.

It is evident that the success/effectiveness of an intervention through safety nets hinges on the process of their implementation and the active and righteous involvement of the stake holders. For a transfer in the program to be adequate there are certain conditions that need to be met. These include: targeting beneficiaries, registering beneficiaries, setting up program conditionalities, making payments, assigning specific tasks and responsibilities to each agent, and adjusting the intervention to local circumstances which calls for the participation of the beneficiaries. It is worth bearing in mind that participation must not be confused with listening to the last and or loudest voice (Kuda Murwira, et al, 2000). Another action of paramount importance for the success of safety is undertaking evaluation and monitoring activities on program performances. Performance evaluation needs to be made by the funding agency, the implementer, and government offices at various stages.

Safety Net in the Ethiopian Context

As mentioned with a desirable degree of precision under the topic devoted to food security in the Ethiopian context, food insecurity in the country is normally understood in terms of recurrent food crises and famines. These situations have, for long, called for emergency food based interventions.

Because of these realities Ethiopian government initiated a productive safety net program in 2004 with the objective of reducing house hold vulnerability, improving household and community resilience to shocks and breaking the cycle of dependency on food aid.

Safety net program in the country is intended to condition the way for "*a gradual shift away from a system dominated by emergency humanitarian aid to productive safety net resources via multi-year frame work"* (FSCB, 2004). Similar line of argument is advanced by Ministry of Agriculture and Rural Development where it is stated "The Government of Ethiopia has decided that there is an urgent need to address the basic food needs of food insecure households via a productive safety net system financed through multi-year predictable resources, rather than through a system dominated by emergency humanitarian aid. Moreover, the Government seeks to shift the financing of the programme from food aid to cash" (MoARD, 2006). The program, accordingly, is intended to scale up the efficiency and productivity of the transfers that flow to the food insecure group and, thereby, reduce vulnerability, improve resilience and promote sustainable community development. It is preordained towards addressing not only immediate food insecurity but also to addressing the underlying causes of food rations. The allotment of cash to the beneficiaries is primarily meant to render households with flexibility over consumption decisions and consequently encourage the development of market in the rural setting.

Because there is a significant donor commitment to the program with donors seeing the PSNP as an innovative and priority action in Ethiopia, the PSNP has been developed by intensive collaboration between the government of Ethiopia and the joint donor group involved in the vulnerability policy dialogue and the coalition for Food Security (RHVP, 2007). The joint donor group, as stated by the brief, is made up of the European Commission, United States Agency for International Development, World Bank, Canada International Development Agency, Development Cooperation Ireland, and the UK Department for International Development (Ibid). Moreover, the brief underscores that the donors have sought to use the Ethiopian government's own documents as the principle guidelines for program implementation and minimize the replication of appraisal documentation (Ibid).

As far as resource allocation for the program is concerned, the program implementation manual describes:

> *The Ministry of Agriculture and Rural Development, in collaboration with the Ministry of Finance and Economic Development, will allocate the Safety Net Budget to regions. Donor financing for the Safety Net will be allocated through the Safety Net Programme budget line included in the Government's budget. The resources will be allocated to the regions based on the number of chronically food insecure households. The Bureau of Agriculture and Rural Development (BOARD) and the Bureau of Finance and Economic Development (BOFED) will allocate the Food Security Budget Support (FSBS) and the Safety Net resources to the districts. The District Rural Development Offices will submit its food security and Safety Net plan and resources to the district Plan and Economic Office, and finally to the district Council. District will clearly allocate their yearly and multi-annual resource budgets within their Safety Net plan (*MoARD, 2006:42).

The final allocation of budget and resources is made at the district level, which means in allocating budgets districts cannot exceed the resources handed to them by the Bureau of Agriculture and Rural Development and Bureau of Finance and Economic Development. The problem, therefore, is whether the budget allocated is proportionate with the actual size of food insecure households.

Introduction to the study Area

The study was conducted in Goro Gutu, Gursum and Fedis districts of Eastern Hararge zone. The selected divisions in the districts include Odaa Oromia and Kaasaa Oromia from Gursum district, Nadhii and Jiruu from Goro Gutu district, and Risqii and Agudooraa from Fedis district. The districts comprise three agro-climatic zones: lowlands, midlands and high land. At the lower altitudes the rural countryside where this research is conducted, parts of Fedis and Gursum districts, crop cultivation is limited. At the higher altitudes the economy is characterized by scanty food and cash crops.

The agriculture system in these districts is rain-fed. Hence, agricultural production and productivity in the districts remain at the mercy of the pattern of rainfall. Thus, food self sufficiency is unimaginable luxury for the multitudes of the community. In addition to production shortfalls, the different skirmishing and interrelated factors prevailing the districts have made food insecurity the lot of the population in these districts. Accordingly, these districts have been regularly requiring major relief food intervention.

The terrible and degrading condition of human life ravaging the community in the country in general and in eastern Hararge in particular has relentlessly attracted the attention of international development agencies. To put it differently, there has been a mounting concern over the persistent plight. These international development agencies are partaking in the fight against food insecurity and poverty. The development agencies have set strategies and programmes that are supposedly geared towards curbing food insecurity and reducing poverty in the districts. If, for instance, you consider the 2008s work of USAID, it contributed approximately 280 million US dollar in emergency food aid through safety net with the assumption to provide a full ration to 1.18 million beneficiaries. Likewise, it has provided 87,910 metric tons of emergency food – valued at approximately 50 million US dollar to the joint emergency operation plan in response to the Ethiopian government's 2009 appeal Weekly Special Report, 2009). Moreover, it contributed 284,149 MT of emergency food approximated at 291, 399, 190 US dollar in emergency food aid through safety net with the assumption to provide a full ration to 4.8 million beneficiaries (USAID, 2011). Similarly, it contributed 154,780 MT of emergency food approximated at 128,847,194 US dollar in emergency food aid through safety net with the assumption to provide a full ration to 3.54 million beneficiaries (USAID, 2012).

It is conspicuous, however, that corroboration is lacking to reveal how far stakeholders in development can and do curtail the pervasive and acute predicaments. Beyond the walls of a particular development project funding agency very little is known about individual project performance (Roger C. Riddell, et. al., 1995). In some cases they fall short of sufficient geographic coverage and as such fail to reach the poor. There is lack of fit between program design and the needs of the poor. Likewise, evidence hardly exists on how much of the money donated by the various funding agencies has served and is serving the purpose it is meant for.

Because there are some who claim that development funds flow into the pockets of the non-targeted few individuals rather than finding their way to poor people (Deepa Narayan, 2000). Still others question whether agencies intervene purely from humanitarian point of view or with expecting some benefits in return (Roger C. Riddell, et.al., 1995). It can, therefore, be inferred that a number of intermingled and sometimes skirmishing problems are apparently recognized as far as the operation of stakeholders in development and, those in safety net for our purpose, is concerned.

The intent of this enquiry, however, is not to entertain apiece of these problems. The research remains modest in its objective if it is to stand any chance of being taken seriously, because the success or failure of a project defies simple generalization. In a similar notice, I would like to be more meticulous and alert my readers not to confuse the objective of this research with the general notion of impact assessment per se which invariably calls for longer durations and the application of highly sophisticated tools. It rather has confined itself to a single aspect of the problem-assessing the contribution of 'safety net' project towards ensuring food security in three East Hararge districts. The purpose of this descriptive and exploratory undertaking is to examine and assess (by using household food balance model explained under model specification) the role the project is playing in Gursum, Fedis and Goro Gutu districts from the vantage point of household food availability.

The Model

The empirical model applied to capture the contribution of safety to household food availability in the districts is a modified Household Food Balance Model (Degefa, 2000). The model is written as:

$Nij=(Pij+Bij+Rij)-(Hij+Sij+Mij)$.

Where:

-Nij is net food available for house hold i in year j.

-Pij is total grain produced by house hold i in year j.

-Bij is total grain purchased by house hold i in year j. (Bij is the sum of Cij and Dij, where Cij is total grain obtained by money gained from safety net, and Dij is total grain purchased by the money obtained from other sources.)

-Rij is total relief food received by house hold i in year j. (This includes direct relief assistance and food for work.)

-Hij is post harvest losses to house hold i in year j.

-*Sij is total crop utilized for seed from home by house hold i in year j.*

-*Mij is total marketed output by house hold i in year j.*

Thus, the contribution of the project to house hold food availability is:

Rij+Cij.

This model demonstrates the interplay of various variables having an impact on household food condition. The model is used to divulge the share of each of the existing variables, and thereby extract the effect of safety net from the overall food balance. Moreover, the model is used to estimate the daily Minimum Recommended Allowance of 2100cal per capita. The analysis is supplemented by the qualitative information obtained through focused group discussion and interview held with peasants (farmers, PA leaders, community elders) and district officers, during field visit; because the researcher has the conviction that steering a middle course between highly rigid structure and too loose frame work is desirable. Because if the framework is too loose, there would be a wider space for subjectivity in judgment that out rightly influence the analysis. By the same token, application of too rigid structure paves the way for under-playing important local characteristics.

In this model data for the different food groups is collected in the course of household survey. Post harvest crop loss is estimated at 10% of the total harvest for those households who replied their produce has suffered from post harvest damages. The data obtained for all food groups comprising variables Pij, Bij, Rij, Hij, Sij, and Mij is converted into an equivalent kilocalorie by using conversion factor. (Consider the conversion table for estimated food groups and their corresponding energy content in appendix 1).

Next, the energy values are added up across all foods acquired by each household. Then the energy in the food acquired by the household over one year period is divided by the number of days in a year and the number of household members. That is each household’s daily food energy availability is divided by household size to adjust for the number of people for which the energy or food is available. Finally, the share of food delivered by safety net is extracted from the mean household food availability in kg after changing all foods into wheat equivalent based on their energy content.

3. Results and Discussion

Analysis of data, as depicted in the following paired sample statistics shows that the project is making a contribution of 67.4% of the mean household food availability.

Table 1:

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Nij	897.5897	240	636.45713	51.96651
	Nijless	329.9690	240	565.83308	46.20008

						T	Df	Sig. (2-tailed)
	Mean	std. Deviation	Std. Error Mean	95% Confidence interval of the Difference				
Pair 1 Nij-Nij less	604.975456	266.11000	21.72779	Lower	Upper	26.124	149	.000
				524.68627	610.55507			

Source: Author's computation of field survey data

N.B. Nijless is net household food availability minus Pij and Bij.

The result shows that the project makes significant contribution to the net household food availability. As it can be inferred from the table on the next page, for one percent increase in relief food, household food availability increases by 76 percent.

In the table asset and household size are newly slotted in by excluding Pij and Hij to overcome the problem of multi-collinearity. They are excluded because there is strong correlation between them. Accordingly, a new economic formula is derived:

$\hat{Y}= Yo+\beta1X1+\beta2X2+\beta3X3+\beta4X4+\beta5X5+\beta6X6$

Which is,

Nij= Rij+Bij+Mij+Sij+Asset+Size

Lnetfood	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Asset	-.0726932	.1270965	-0.57	0.568	-.3239542	.1785678
Size	.0184843	.0472697	0.39	0.696	-.0749647	.1119332
Bij	.0009743	.0003033	3.21	0.002	.0003747	.0015738
Mij	.0009561	.0002082	4.59	0.000	.0005446	.0013677
Rij	.7610494	.1609413	4.51	0.000	.4073195	1.043659
Sij	-.2583893	.0891943	-2.90	0.004	-.4347203	-.0820584
_cons	3.289199	.912888	3.60	0.000	1.484482	5.093916

Source: Author's computation based on field survey

It is worth noticing, however, that 72.1% of the households could not meet the daily minimum recommended allowance of 2100c per capita. This shows households are unable to access a minimum basket of food items (even) after project's intervention and thereby failed to meet the minimum daily recommended allowance. As shown in the following table, only 27.9 percent of them have a daily food access to above 2100 calorie.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	173	72.1	72.1	72.1
	1	67	27.9	27.9	100.0
	Total	240	100.0	100.0	

Source: Author's computation based on field survey.

The implication, therefore, is that, though not dead, substantial majority of the community in the district are yet leading a terrible and degrading life situation. This result authenticates the respondents' inspection that "we did not surrender to death; it has helped us to straddle between life and death".

Moreover, regardless of the food assistance that families have been receiving in the form of cash or grain, as depicted by 67% of the sample households, it could not safeguard them from depleting their asset. The sample households have marketed their livestock and other assets to fill their food gap. Likewise, it is cited by the same number of respondents that the intervention could not enable them to develop resilience to food insecurity. Though the aid has certainly contributed to the life saving mission, it did not help the beneficiaries to use it in more constructive way. By the same token, it is revealed by the focused group discussion that the non-beneficiary households that were better off has now virtually depleted their asset and become food insecure. This has further deteriorated local capacity; depletion of assets has further eroded future coping mechanisms. Thus, it can be voiced with a desirable degree of authenticity that the continual depletion of assets together with the absence of effective supporting programs has invariably contributed to the failure of the project from graduating the anticipated beneficiaries.

As far as targeting of the beneficiaries is concerned, there was an evident ineffective system. It is elucidated by the analysis and the discussion held with selected informants that better-off families were encompassed by the program. That is, there is a leakage of benefits to non-target groups.

In line with food delivery there are instances when food does not reach the neediest on time. This could be one reason for household asset depletion.

The analysis has also shown that safety net is a country wide program that was put under implementation without critical and thorough look at local realities. Donors, foreign implementers', and governmental organs that are far away from the problems at the grass root level have taken too large role in designing strategies and implementing programs and that the beneficiaries were denied of significant leverage in deciding on their foreseeable future by taking part in the project starting from the time of its inception. This has the tendency to continuously incapacitate the community from being intuitive in surmounting their problems. It reasonably implies that determination and flexibility are lacking in identifying and implementing more suitable service delivery strategies.

Climate change and its obvious outcome-drought are also tremendously affecting production and bringing about food insecurity. As 93.5 percent of the respondents clearly stated, these factors counter affect the possibility to obtain a required amount of output from rain fed agriculture or through the application of irrigation that has the tendency to increase and diversify production. This issue is clearly shown by F.A Hassan where he stated "no one can afford to ignore the current and potential impact of climatic variability on our contemporary human affairs, and it would be irresponsible not to seek in the past for insights into the hoe climatic change has influenced food security and the course of change in our human condition" (2002:321). This problem is highly magnificent in the districts under study. The drought in the areas has plighted a number of poor people and adversely affected the livelihood of the community. The cumulative effect of these factors is the gradual decrease in agricultural productivity and the resultant hunger and the miseries thereof.

Conclusions and Recommendations

This research has investigated the role of safety Net in ensuring food security at the age of climatic change considering the cases of Gursum, Fedis and Goro Gutu districts. As depicted by the undertaking, food self sufficiency is unimaginable luxury for the multitudes of the community living in Gursum, Fedis and Goro Gutu districts of Eastern Hararge zone. Climatic change and the other skirmishing and interrelated factors leading to production shortfalls have made food insecurity the lot of the population in these districts. Accordingly, these districts have been getting relief food intervention through the safety net program.

In investigating the contribution Safety net project in the districts in curbing food insecurity a modified household food balance model is used and supplemented by qualitative information. Results of the analysis divulge that the income from the project has undeniably contributed to the lifesaving aspiration. It is making an average contribution of 67.4% to the net household food availability. Nonetheless, it could not enable the households meet the minimum daily recommended allowance of 2,100kcal per capita. Moreover, the proportion of food insecure households by far outweighs those whose mean daily calorie is 2100 and above, i.e., 72.1% to 27.9%.

It is also disclosed that there was ineffective targeting of the beneficiaries. While targeting the beneficiaries, there are discriminations made among people in the same circumstances while at the same time better-off households are incorporated. This has lead to disruption of social structures-prevalence of hatred among the beneficiaries and those who are not included in the program. Equally important, is delay in delivery of food that has exacerbated household asset depletion.

As elucidated during the field survey Donors, foreign implementers', and governmental organs that are far away from the problems at the grass root level have taken too large role in designing strategies and implementing programs and that the beneficiaries were denied of significant leverage in deciding on their foreseeable future by taking part in the project starting from the time of its inception. This has the tendency to continuously incapacitate the community from being intuitive in surmounting their problems.

When we pay a glance back to the practical circumstance in the districts in relation to the four elements in food security (availability, access, utilization, and risks that hamper these elements), the first three elements are terribly missing. The number of meal per day is not improved compared to that of the good time. Risks that counter affect the availability, access, and utilization of food is widely prevalent.

In general terms, regardless of the 'inflow' of emergency relief to the district through the so called safety net program, abject poverty, undernourishment, and merciless food insecurity have taken siege over considerable portion of the population in the district. This circumstance, come what may, gives us an idea that the propensity to wipe out poverty and hunger by 2015, as agreed during the 2000 meeting of head of states and government, is desolately gloomy.

Recommendation:

Significant latitude needs to be rendered to community involvement in designing strategies and implementing programs rather than resorting to the expeditious route so as to create demonstrable positive impact. Because the beneficiaries do have an idea of what would work for them and what they need. As unambiguously declared by Angela, since the poor are supposed to be the primary beneficiaries of food security related policies, it would be prudent to at least listen to them (2004, 9). Thus, the local community must have an increasing say in food security policies and programs that impinge upon them.

Creative partnership needs to be encouraged between and/or within the donors, implementers (domestic and foreign), the concerned government organs at the various levels, and the target community.

Budget allocation should be made in such a way that it reasonably and equally serves those in the same line of food insecurity and thereby overcome disruption of social structures/the hatred that perpetuates between the beneficiaries and the other food insecure group but yet excluded from the program. The government should reconsider its verdict and allow the remaining group already haunted by food insecurity to be beneficiaries from the project. Moreover, there is an apparent need to expand food-basket needs and incorporate food types that are better in their energy content, because the failure of households to meet the minimum recommended allowance might be attributed to these factors.

Timeliness in delivering food has to be critically reconsidered and delay be tackled. Timely delivery of food and non-food assistance has to be ensured if the intension is to sustain positive impact on the nutritional status of the recipients. If this is not made starvation and depletion of household assets will be inevitable outcomes.

Performance monitoring and evaluation needs to be undertaken in such a way that it welcomes feedback from various sources for further strength and effectiveness of the program.

It is audible that food aid cannot be an end in itself. Food solutions will not solve the surpassing problems of poverty. Equally true is the distrustful nature of fiscal sustainability of safety net. Hence, there is an apparent need to adopt basic human rights to food and poverty eradication that will help households to produce enough food or earn enough money to purchase it. In other words, the problem invariably calls for fetching food security policies, programs and strategies with antipoverty programs and their unfailing implementation. Below are core medium and long term policy directives to sustainably address sufferings of the paupers in the district:

By virtue of the spread of drought in the district augmenting productivity based on rain fed cultivation is unimaginable. That is, future of agricultural development in a country that has been subject to rain-fed system but ensnared by persistent drought depends on the exploitation of irrigation technology and various water resources. Hence, increasing agricultural productivity, developing self-reliance, and addressing food insecurity invariably calls for the application of progressive irrigation by drawing water from Awash river canal which is some 20km away from the PAs where the study is conducted. Unequivocal support for irrigation efforts, for mechanizing agriculture, and for promoting and expanding infrastructure is needed to avert what truncated agricultural productivity.

An important policy directive to ensure food self sufficiency at this age of wide spread climate change might include research in to heat-resistant and low-water using crops. It is wise to intensify production through the adoption of improved, simple, low-cost, low-risk water, soil, and crop management. By the same token, problems of post harvest loss must be tackled.

Moreover, given that household asset is tremendously depleted and their livelihood seriously ravaged they are scarcely left with farm-animal and other live stocks. Thus, addressing the surpassing problem demands the availability of either farm animal or farming machinery.

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Appendix 1

Food groups and their equivalent energy content:

Food type	Quantity in Kilogram/liter	Equivalent Kcal
Corn	1kg	4.07
Other cereals	1kg	3.78
Oil seeds	1kg	4.07
Legumes	1kg	4.07
Oil	1kg	8.8

Source: Food Composition Table prepared for Use in Ethiopia by MPH and SIDA based on the 1968s work of Argen G. and Gibson R. The energy content of one litter of oil and its corresponding kg equivalent is acquired from internet.

8. College of Veterinary Medicine

Human-hyena (HHC) conflict in Haramaya district: assessment of the causes, socio-economic impact and its possible conflict mitigation measure

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Abstract: *A study on human - hyena conflict in Haramaya district was conducted from April to July, 2012. The objective of this study was to investigate the cause and magnitude of hyena attack and the socioeconomic impact it brought on the society and to assess the available options for sustainable prevention of the conflict. Data on human hyena interaction were collected based on the direct interview questionnaire, focus group discussion. The collected data were analysed using descriptive statistics. The analyzed data showed that majority of the respondents faced both the problems livestock predation.*

Introduction

Conflict between people and wildlife is a major issue in both wildlife conservation and rural development. The damage that conflict can cause to conservation and rural development initiatives has prompted a considerable amount of research into conflict between carnivores and people (Weber and Rabinowitz 1996, Sillero-Zubiri and Laurenson 2001, Macdonald and Sillero-Zubiri 2002).Conflict of large carnivore with humans can have multiple implications ranging from fear evoked by the presence of the carnivore (Quammen, 2003), to fatal attacks on humans (Loe, 2004). Even in the absence of attacks on humans, livestock depredation by carnivores can hamper the livelihoods of people and affect their economic condition (Ogada et al., 2003). Human-carnivore confilict in terms of livestock depredation is perhaps more common and is seen in several reported cases across the world.

Spotted gregarious predators that occur throughout sub-Saharan Africa outside of tropical forests, alpine areas and true deserts (Frank et al., 1995, Mills and Harvey, 2001). It is a common predator on domestic livestock in Africa. In addition, they have also been known to attack and kill humans, especially during human disease outbreaks (Kingdon 1977, Hofer 2002). In some places in Africa, although hyenas are not much in demand from trophy hunters because they are not viewed as very attractive. They are also hunted sometimes for food or medicine (Kruuk 1972, Hofer 2002). Predation on domestic livestock and poultry by carnivores is a historical and continuing problem faced by agricultural producers throughout; the world (Harrisand Szunders 1993). A study examining the attitudes of people is crucial to identify the impact of conflict as well as to plan future measures of alleviation. However, assessing the attitudes of people is a complex issue (Dickman, 2003) owing to social, cultural, ecological and economic factors.

General Objective

To investigate the cause and magnitude of hyena attack and the socioeconomic impact it brought on the society and to assess the available options for sustainable prevention of the conflict.

Specific Objectives

- Quantify the history, cause, magnitude or extent, type and nature of human hyena conflict in the study area (Completed and published on international journal of ecology and environmental Sciences)
- To develop human hyena conflict mitigation mechanism to prevent hyenas' attack on animals and humans and ling term survival of hyena (Ongoing)
- To assess the human attack (demography of the people injured or died by the hyena and its social consequences) (Completed)
- Determining the type and number of livestock loss due to injury or death by and its economic loss (Completed)
- To estimate the population size and quantify home range size and habitat selection, seasonal distribution patterns of hyena (Ongoing)
- Quantitatively describe the feeding ecology of hyena and identify resources that leads to HHC (Ongoing)

Methodology

Study area

The study was conducted in Haramaya district. The district has a total of 35 Peasant association out of which two are included under the town. The study site is chosen due to the known presence of spotted hyena and the history of attack caused on humans and livestock starting from October 2011 in the area.

Study design

Cross-sectional study types were employed and intensive surveys were conducted in randomly selected households in the peasant associations of the district. Within each PAs, villages that had the highest concentration of attacks were selected according to local government records for focused group discussion.

Data Collection and study procedure

Human Hyena conflict

Information on the history and type of human hyena conflict were collected using questionnaire survey. Villages were identified as areas of active human-hyena conflict. The questionnaire were prepared so that it includes information regarding land use change, cause, impact, history and nature of human-hyena conflict and the impact of conflict on peoples and livestock. Moreover, data were collected by using rapid rural appraisal (RRA) techniques, such as focus group interviews and map-making to evaluate the attitude of communities. Field assessment were undertaken during day and night to collect information in relation to:

Livestock data

- Name of the village where the attack happened on animals
- Species of Animals bitten (Dog, Cattle, sheep, goats, equine etc.)
- No. of animals died (Dog, Cattle, sheep, goats, equine etc.)
- Estimation of the price of each animals injured or killed at the time of the conflict

Data on Humans

Basic information

- ✓ Demography(sex, age, household size etc)
- ✓ Farming system
- ✓ Number and type of animals they own
- ✓ Total human population in the study area
- ✓ House type and safety

Data on Human attack

- ✓ No bitten/ injured
- ✓ No died
- ✓ Age of human bitten died
- ✓ Sex status (Male, Female)
- ✓ Number that visited hospital and treated (Hospital data)
- ✓ Location of attack (inside home, outside home in the village ,on the road, in distant agricultural fields etc)
- ✓ Victims activity during attack(Resting, sleeping, walking, sitting etc)

Social crisis occurred

- ✓ Children prohibited from school (School directors also will be interviewed.)
- ✓ Women did not go to work or market
- ✓ Psychological damage to injured people or those who lost their child.

Perception of the Peoples about the hyenas

- ✓ Traditional beliefs and myths
- ✓ Religious attachments
- ✓ Cultural practice for prevention of conflict

Data Analysis

Statistical Package for Social Science (SPSS) version 17 was used to analyze the data. The questionnaire was coded and run to SPSS. Data were analyzed using descriptive statistics and responses compared using chi-square test and one-way ANOVA. Post hoc Tukey and LSD test were used to identify the real difference after a one-way ANOVA test. Correlation was used to determine the relationship between the different variables.

Highlight of the result

Questionnaire Survey

Demographics

The total numbers of respondents were 100. Out of these 86% were male and 14% were females.

Sex	No. of respondents	Percentage
Male	86	86%
Female	14	14%
Total	100	100%

Human - Wildlife Conflict

Out of the total respondents, majority reported the problem of both human and livestock predation, followed by only livestock predation and they did not face any conflict.

Human Attitude towards Wildlife

Most respondents in the study area named at least some of the wildlife in their area. Respondents who knew more than 3 wildlife had good knowledge, where as respondents who knew less number of local wildlife had poor knowledge about wildlife. Out of the total respondents, majority could name more than 3 wild animals, whereas only few could name less than three local wild animals. Most of the respondents had positive attitude towards the conservation of wildlife.

Attitude of Local People towards the Hyena

Most of the respondents had negative attitude towards hyena.

Discussion

Although the economic impact caused by depredation of hyena on large-scale ranches is not of great concern, it can mean economic ruin for a small rancher, for whom the depredation of a few animals a year represents a considerable loss, difficult to replace. The total estimated economic loss caused by spotted hyena depredation, diseases and theft, worth about US$ 229104, representing US$ 27007.47, US$195888.9 and US$ 6208.32, respectively. Predation on livestock is an important cause of human wildlife conflict (Frank 1998, Ogada et al. 2003). Generally speaking, predators' are responsible for the loss of up to 3% of annual domestic stocks (Jackson and Nowell 1996). Our intensive survey of human-hyena conflicts revealed that livestock losses caused by the hyena represent an economic concern for livestock owners in Haramaya District. Studies elsewhere have shown that tolerance of predators by local communities usually depends on the extent of predation on their livestock (Rasmussen 1999, Patterson et al. 2004, Woodroffe et al. 2005, Kolowski and Holekamp 2006, Holmern et al. 2007). In the present study, ten people were attacked, majority (50%) were induced when people sleep outdoors at night, while the remaining occurred when people go to toilet at night; support others during an attack, or when hyena inters into kraal. Predominantly attacks were at night. Hyenas are nocturnal hunters, possibly because of their improved night vision compared with their prey (Bertram 1979). The findings are in line with studies elsewhere. For example, a sleeping boy was attacked by a spotted hyena in northern Kenya, losing his nose (Flying Doctors Society of Africa 2002). Threat of personal injury due to large carnivores is one of the key concerns of people living with wildlife (Sillero-Zubiri and Laurenson 2001). Such concern does not represent actual levels of attacks, with human injury or death a relatively rare occurrence; however, it demonstrates that even a low actual impact can have a large impact on local perceptions. However, hyena attacks on people do not regularly occur.

Conclusion

In conclusion, adequately addressing human-hyena conflicts to lower costs and enhance benefits resulting from the presence of spotted hyena is expected to promote hyena conservation. Simple improvements in livestock management practices would help mitigate human-carnivore conflicts.

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Problem faced during the present study

The most common problems faced during this project work are;

1. Absence of baseline data
2. Rigid finance system
3. Shortage of transportation
4. Purchasing of field equipment delayed

Future Action plane:

1. Intensive ecological survey and data collection (from September to November 2012)
2. **Developing community based conflict resolution (October, 2012 to January 2013)**
3. Data entry and Analysis (**January to May 2013)**
4. Article write up, final report and publication (May to June 2013)

Enhancing Cognitive Learning in Veterinary Osteology through Student Participation in Skeleton Preparation Project

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Abstract: *This study is focused at veterinary anatomy education. The objective was to assess the importance of cognitive learning via skeletal preparation. The hypothesis that the students would be more interested in the discipline if the teaching methodology used is based on creative and constructivist methods. Camel, Horse, Ox, Sheep and Pig skeletons were prepared. We also prepared multimedia photo and videos to enhance the comprehension ability of our students and subsequent transform in understanding the subject matter and boosting quality education.*

Keywords: *Skeleton, anatomical museum, learning styles, cognitive learning, educational motivation*

Introduction

Veterinary anatomy is one of the most important subjects in the veterinary curriculum and it is the main foundation of veterinary medicine. Veterinary anatomy is one of the oldest basic medical sciences. Most first year student regarded anatomy as a difficult subject due to the burden of nomenclature, descriptive nature of the subject matter, little interactive activity and the view that anatomy is dogmatic subject (Sissons, *et al*., 1975; Notebaert, 2009). In essence, cognitive load theory proposes that since working memory is limited, learners may be bombarded by information and, if the complexity of their instructional materials is not properly managed, this will result in a cognitive overload. This cognitive overload impairs schema acquisition, later resulting in a lower performance (Paas *et al*., 2004).

The first chapter taught in many anatomy courses is osteology. Thus the skeleton becomes more important teaching aid. Hands on teaching aids are extremely valuable for all aspect of cognitive learning. Often skeleton can complement teaching methods allowing visualization and actual structures of the animal body. Young people can learn most readily about things that are tangible and directly accessible to their senses visual, auditory, tactile, and kinesthetic (Paas *et al.* 2004). With experience, they grow in their ability to understand abstract concepts, manipulate symbols, reason logically, and generalize. These skills develop slowly; however, the dependence of most people on concrete examples of new ideas persists throughout life (Paas, 2003). Thus the objective of this study was to assess the impact of teaching anatomy with the help of student hands on projects to evaluate the student motivation, attitude and cognition behavior in learning veterinary anatomy.

Materials and Methods

Skeleton preparation: the skeleton preparations were undertaken at Haramaya University. The following animal species were used: oxen, camels, horse, pig sheep, goat and oxen,

Deboning: The animals were slaughtered and skinned. And deboned on the same day, all meat was removed by knife. Holes were drilled in the ends of bone of the wet skeleton proximal and distal parts of a joint by means of a hand tool power driller using 1-3mm drill bite gauges. Then the bones of the fore and hind limbs were jointed using craft wire 1.5- 4 gauges. The neck was disarticulated from the cranium and thorax. Then 20-30 mm gauge wire was passed through the intervertebral canal. The heads of the ribs were drilled and attached to their respective thoracic vertebra. The sterna ribs were also fixed to the sternum. The asternal ribs were attached by twisting a wire against each other. This procedure reduced the time to assemble the skeleton and facilitate the removal of marrow from bones during boiling. The size and length of the wire depended on the size of the bone.

Degreasing and Cleaning

The partially articulated skeleton, fore and hind limbs, lumbar and sacral vertebra, the thorax, the cervical vertebra and the head were boiled fully covered in water in a metal container (1.5m x1m x 1.25m) for large animals while for small animals we used small cooking pot. The boiling facilitated the remaining tissue to become loose and the removal of fat was speeded up by simmering up to 3 times remove grease. The time required for boiling depended on the condition of the carcass at the start and the size .The boiling time and procedure is shown on Table 1. Because over boiling discolors and damages the skeleton. Scapular cartilage were not boiled but were subjected to all other processing procedures. Also fragile and small bones were boiled separately in small container to keep them from disappearing during the simmering process. Once the soft tissues were scraped off, the bones were soaked in water with detergent OMO® and bleach for a day .Next; the bones were dried in the sun for two days and were immersed in sealed container filled with gasoil sufficient enough to accommodate the bones. The bones were left for a week. And then removed and dried for two days. The bones were again soaked in thinning lacquer containing acetone for a week. The bones are then dried.

Table 1. Recommended processing time (in days) and procedures for preparation of dry-skeleton

Steps	Processes	Ovine and Canine	Bovine and equine	Camel
1	Slaughtering and deboning	1	1	1
2	Stitching with wire	1	1	1
3	Boiling	0.25	0.8	1
4	Scraping remains	1	2	3

5	Soaking in Soap and bleach	3	7	10
6	Soaking in gasoline	7	7	10
7	Soaking in 5% formalin	7	7	10
8	Air Drying	7	7	10
9	Mounting	1	1	1
	Total days	28.25	33.8	47

Bone assembly and mounting

Finally the bones were painted with 30% hydrogen peroxide and were immediately dried in the sun. Then the wires which were used for reattaching bones were replaced with a new galvanized wire and the skeleton is mounted on a platform as shown on Figure 1. The names of the parts of the armature and their dimensions are depicted in Table 2. In addition to full skeleton mounts artistic gluing of poultry skeleton, bovine lower limb and an anatomical display cabinet were set for individual bones and collection of skull from different species. And an exhibition titled "Body and Mind" man plowing with a pair of oxen was also displayed as part of the project.

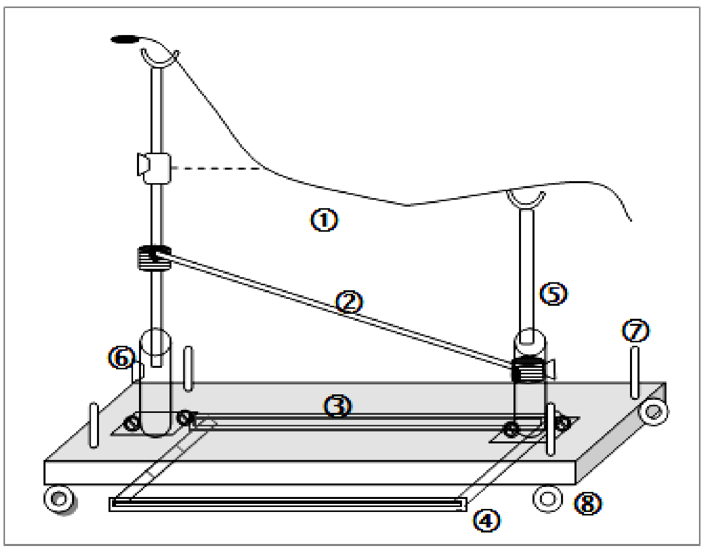


Figure 1. Diagram of skeletal armature

Table 2. Skeleton aperture parts and dimensions (in cm)

Part No.	Part name	Ovine and Canine	Bovine and equine	Camel
1	Axial support	75	190	210
2	Horizontal cross bar	non	150	170
3	Wooden platform	2.5x50x100	2.5x60x200	2.5x60x210
4	Bottom metal frame	40x190	50x180	50x200
5	Top sliding bar forked	70	100	120
6	Bottom tube for sliding bar support	60	100	100

7	Appendage support	15	30	40
8	Wheel diameter twin wheel caster Plate Black Hood	5	5	5

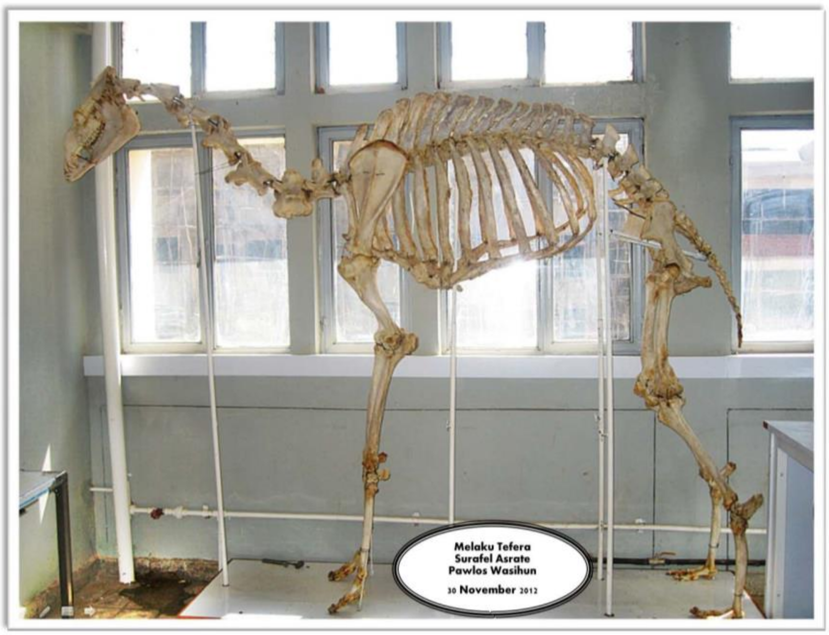
Multimedia preparation:

Once the skeletal specimens were prepared photographs were taken individual structures and partially and whole articulated skeleton. Using Canon digital camera IXUS 750 and a video film was produced using Sonny handcam HDR-CX7 6.1 MEGA pixel. The photographs were labeled and edited in Photo editor (Photos cape ver. 3.5). A sound system was added to the video track so that students can listen and memorize the vocabulary with correct pronunciation. Students were asked 10 minute seminar presentation mainly on the osteological structure from the multimedia.

Results

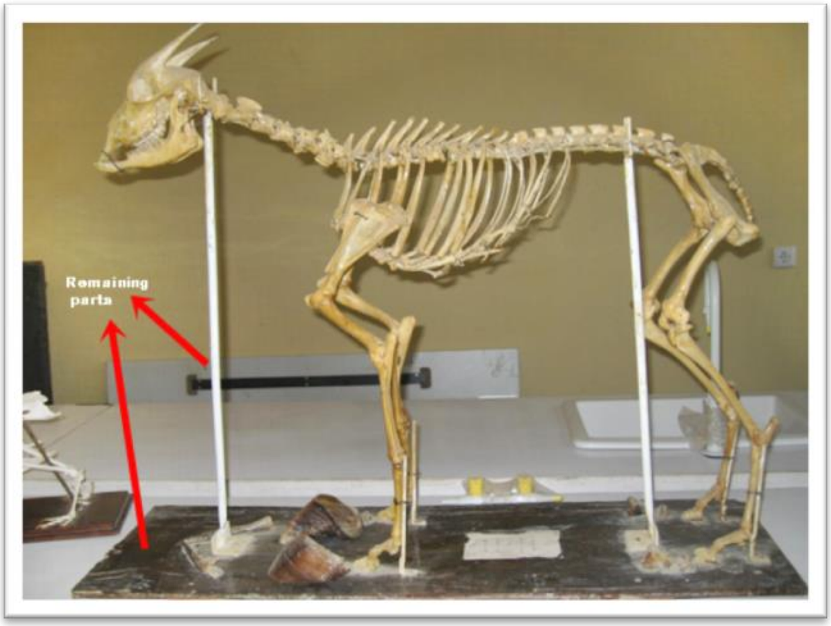
Camel skeleton

The camel skeleton was assembled. It was displayed during the exhibition organized on the occation of 2013 graduation. We had feedback from public that it was excellent. It is the best skeleton ever produced in Ethiopia



Goat Skeleton

The goat skeleton was processed and assembled, a platform is remaining of skeleton is remaining



Swine Skeleton

The swine was also semi processed all bones were cleaned assembly

Horse skeleton

Horse skeleton bones were processed and individual bones were used for teaching and no skeleton assembly was envisaged as some bones were lost during processing.

Problems Encountered

- Time
- Labor, people were reluctant to work on skeleton preparation
- Some materials like paste driller pins were not available in market

- Platforms were difficult to construct

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Prevalence of *Salmonella* from raw chicken eggs in Haramaya, Eastern Ethiopia

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Abstract: *A cross-sectional survey of Salmonella in chicken table eggs in Haramaya University (HU) poultry farm and local chicken eggs from Haramaya local markets was conducted from November 2012 to July 2013 with the objective of determining the presence and extent of Salmonella table egg contamination produced under different farming conditions in Haramaya, and breeding stock egg contamination at HU poultry farm Eastern Ethiopia. A total of 480 eggs composed of 150 eggs from Haramaya local market, 150 eggs from Haramaya University caged white leghorn chicken and 180 eggs from breeding white leghorn chicken were used to investigate prevalence of Salmonella in this study using conventional bacteriological methods. Questionnaire survey was also conducted to determine habit of egg consumption and egg storage duration and condition in the area. The overall prevalence of Salmonella contamination of eggs was found to be 1.67% (95% CI, 0.7-3.2). Egg shells from local market were found to be the most contaminated with prevalence of 5.3% (95% CI, 2.3-10.2). All egg contents including eggs from local market and all egg shells from HU poultry farm yielded no Salmonella isolates. The questionnaire survey revealed that raw egg consumption and utilization of eggs cracked during storage and transportation was 28% and 94.7%, respectively. Although the overall Salmonella prevalence of chicken eggs is low, the prevalence of the organism in local chicken eggs is of public health concern. Efforts should be made to create public awareness of the risks associated with consumption of raw chicken eggs.*

Key words: chicken egg, egg contamination, egg shells, Haramaya, *Salmonella*

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INTRODUCTION

Salmonellosis is the leading most common foodborne zoonoses (Mead *et al*., 1999; Acha and Szyfres 2001) caused by organisms of the genus *Salmonella* (Radostits *et al*. 2007). Non-typhoidal *Salmonella* represents an important human and animal pathogen worldwide (Hoelzer *et al*. 2011). Infection in animals is of importance because of the direct economic effect. Of even greater importance is that animals constitute a vast reservoir of these organisms for human infection (Libby *et al*. 2004).

The sources of *Salmonella* infection for domesticfowl are numerous. Poultry and many other animalsare often unapparent carriers, latentlyinfected or, less frequently, clinically ill, and theymay excrete *Salmonella* in their feces and form alarge reservoir and source of contamination forother animals, humans and the environment.Poultry often become infected via horizontaltransmission by litter, feces, feed, water, fluff,dust, shavings, straw, insects, equipment andother fomites contaminated with *Salmonella* andby contact with other chicks or poults, rodents,pets, wild birds, other domestic and wild animalsand personnel contaminated with *Salmonella*.Vertical transmission occurs when follicles in theovary are infected or the developing eggs becomeinfected in the oviduct. Management practicesmay have a significant influence on the degree oftransmission of *Salmonella*. Many of the factorsthat influence horizontal and vertical transmissionare interrelated (Freitas *et al*., 2010).

Many of the humanoutbreaks of nontyphoidal salmonellosis, particularly of *S.enteritidis* infections havebeen traced to contaminated eggs and to the layinghens at the farm that supplied the eggs(Telzak *et al.*, 1990; CDC, 1992; van de Giessen*et al.*, 1992; Altekruse *et al*., 1993; Henzler *et al*.,1994). Shell eggs, scrambled eggs, soft-boiledeggs, lightly cooked eggs, lightly cookedomelettes, food products containing raw or partlycooked eggs, including mayonnaise, sauce tartare,milk shakes, mousses, egg sandwiches,dishes containing raw egg-white, ice-cream containinguncooked eggs and poultry meat have allbeen implicated in outbreaks of *S. enteritidis*infection (Coyle *et al*., 1988;Humphrey *et al*., 1988; Paul and Batchelor, 1988;Perales and Audicana, 1988; Hennessy*et al*., 1996).*Salmonella* Newport outbreak affecting Gonder University,College of medicine students in 1992 was also found to be caused by consumption of undercooked un-pealed table eggs (Aseffa *et al*., 1994).

Different housing systems may have may affect the flock *Salmonella* egg contamination differently. A move from conventional cages to either an enriched cage or a noncage system may affect the safety or quality, or both, of the eggs laid by hens raised in this new environment. The safety of the eggs may be altered either microbiologically through contaminationof internal contents with *Salmonella enterica* serotype Enteritidis (*Salmonella* Enteritidis) or other pathogens (Holt *et al*., 2011).

Despite the presence of several investigations on the prevalence of *Salmonella* in Ethiopia, mainly in pigs (Molla *et al*., 2006; Aragaw *et al*., 2009), ruminants (Nyeleti *et al*., 2000; Alemayehu *et al*., 2003; Woldemariam *et al*., 2005; Molla *et al*., 2006; Sibhat *et al*., 2011), camel (Molla *et al*,. 2004) poultry meat (Tibaijuka *et al*., 2002; Molla and Mesfin, 2003), minced beef (Ejeta *et al*., 2004), and humans (Assefa *et al*., 1994), very little information is available on the situation of *Salmonella* from table eggs. The objective of this study was therefore to determine the presence and extent of *Salmonella* table egg contamination produced under different farming conditions in Haramaya, Eastern Ethiopia.

Material and methods

Study Type and Sampling

A cross-sectional survey of *Salmonella* in chicken table eggs in Haramaya University (HU) poultry farm and local chicken eggs from local markets directly from the farmerswas conducted from November 2012 to July 2013. Questionnaire survey wasconcurrentlyadministered to investigate the storage, preparation and utilization pattern of chicken table eggs in Haramaya local market to both egg sellers and buyers. The sample size required for this study was determined based on the expected prevalence of salmonellosis and the desired absolute precision according to Thrusfield, 2005. A previous study on *Salmonella* in chicken eggs at Kombolcha, Northern Ethiopia indicated the prevalence of *Salmonella* to be 11.5%. Therefore, with this expected prevalence,at 95% desired confidence interval and 5% absolute precision,the sample size required to determine the prevalence of *Salmonella* in both groups. Accordingly, a total of 150 eggs from HU poultry farm; 150 eggs from Haramaya open market directly from the farmerswill be collected. Ten eggs from market (one egg from one egg seller) and 10 eggs from HU caged white leghorn birds weredirectly collected from the cage once per week using systematic random sampling technique. Eggs were individually packed with sterile plastic bag and shipped to the laboratory. To establish the presence of *Salmonella* shedding in Haramaya breeding stock,egg samples were also collected with the objective of determining the prevalence and seasonal shedding pattern in the breeding stock. Ten egg samples were collected once per week from December 2012 to February 2013 and only 60 eggs representing the wet season were collected from mid-June to July 2013 months of the year with a total of 180 eggs.

Sample Processing

Salmonella isolation was conducted utilizing the conventional methods for the detection of *Salmonella* following the standard guidelines from ISO 6579: 2002. The ISO protocol utilized for the purpose of this study required the use of non-selective pre-enrichment and selective enrichment for optimal detection of the organism from food sample.

Non-selective enrichment

The sterile plastic bags containing selected eggs were opened with scissors and the samples processed immediately. Swab technique was used to sample the shell surface of the intact eggs. Sterile cotton swabs dipped into sterile buffered peptone water (BPW) was used to swab the entire surface area of the eggshell. The swabs were directly inoculated into 10 ml BPW in screwcapped bottles. The same eggs from which shell sample were collected were also used for interior (egg content) sampling. The eggs surfaceswere sterilized by immersing in 70% alcohol for 2 min, air dried in a sterile chamber for 10 min and then opened bycracking with a sterile scalpel blade. Each egg's content wereinoculated into 225 ml of buffered peptone water (BPW)in stomacher bags and homogenized for two minutes with a stomacher. Both types of samples were incubated at 37°C for 18 hrs (ISO, 2002).

Selective Enrichment

From the pre-enrichment broth after incubation and mixing with vortex mixer,0.1 ml of the broth wastransferred into screw cupped tubes containing 10 ml of Rappaport-Vassiliadis medium (RV broth). Another 1 ml of the pre-enrichment broth were also transferred into a screw cupped tubes containing 10 ml of Muller-Kauffmann tetrathionate broth (MKTT broth). The inoculated RV broth containing tubes were incubated at 41.5 °C for 24 hours while the inoculated MKTT broth containing tubes were incubated at 37 °C for 24 hours (ISO, 2002).

Plating out and Identification

Xylose lysine deoxycholate (XLD) agar was used for plating out and identification purpose. A loop-full of inoculums from the RV and MKTT broths were transferred and streaked separately onto the surface XLD agar. The plates were incubated at 37°C for 24hours. After proper incubation, the plates wereexamined for the presence of suspected *Salmonella*colonies, which on XLD agar are pink with a darker centerwhereas lactose-positive salmonellae are yellow with orwithout blackening.*Salmonella* presumptive colonies were transferred to non-selective, tryptose soy agarplates for further tests. Identificationwas done by using biochemical testaccording to ISO 6579 (ISO, 2002). Accordingly *Salmonella* presumptive colonies which tested positive for citrate, negative for urease, those which decarboxlated lysine on lysine decarboxylation broth and those with red slant, yellow but and positive for hydrogen sulfide production on triple iron sugar agar were identifiedas*Salmonella*.

Data management and analysis

Data was entered in to Microsoft Office Excel 2007. Descriptive statistics such as proportions (percentages) were used to describe samples detected positive to *Salmonella* from the total sample analyzed by source of sample and type.

Result and discussion

Result

Result of questionnaire survey

The farmers and egg consumers were requested to respond to questionnaire developed to find out egg storage and utilization practices indicated that out of 75 respondents 28% responded that they have consumed raw eggs but not on a frequent basis while the rest responded that they had never consumed raw eggs. Regarding habit of egg washing before cracking the egg open, only 9.3% of the respondents have practiced washing when they thought that the eggs were too dirty. The survey further indicated that 94.7% respondents have consumed eggs cracked during transportation and storage.

Concerning method of egg storage, 57.3% of the respondents stored their eggs in open containers such as paper cartons and bamboo baskets while 42.7% stored eggs together with crops. Regarding the duration of storage, 64%, 29.3% and 6.7% stored eggs for a period of one, two and more than two weeks respectively.

Prevalence of Salmonella in chicken eggs

Out of 540 chicken eggs examined for bacteriological status of *Salmonella*, only eight (n = 8) samples yielded Salmonella. All the isolates were from egg shells of those samples collected from Haramaya local market. No *Salmonella* isolate was recovered from samples collected from Haramaya University poultry farm (Table 1).

Table 1. Prevalence of salmonella in chicken raw eggs by source and type of samples

Sample source	**Egg shell**			**Egg content**		
	No. examined	**No. positive**	**% 95% CI**	**No. examined**	**No. positive**	**%**
Local market	150	8	5.3 (2.3, 10.2)	150	0	0.0
Caged layers*	150	0	0	150	0	0.0
Breeding stock*	180	0	0	180	0	0.0

Total	**480**	**8**	**1.6 (0.7, 3.2)**	**480**	**0**	**0.0**

*HU poultry farm

Discussion

The overall *Salmonella* prevalence in eggs in the study area is low (1.6%). The finding of this study is lower than 11.5% (n =46/400) obtained by Aseffa et al. 2011 in Kombolcha, Northern Ethiopia. The prevalence of eggs shells from local market 5.3% in this study was similar to those found in Kombolcha local market 5.5%. Therefore the major difference between the two studies was attributed to the difference between the prevalence of *Salmonella* in Kombolcha poultry farm (7%) and Haramaya University poultry farm where no isolate was found. The reason for this difference could be better bio-security measures and hygienic farm management practices at Haramaya University farm.*Salmonella* contamination of the egg shells from local market could be due to egg surface contamination with feces, dust and hands of egg collectors.

The results of questionnaire survey showed that there is widespread use of raw and cracked eggs. Given the long duration and lack of appropriate egg storage conditions revealed by the survey, consumption of raw eggs is of concern because of the presence of *Salmonella* on eggs surfaces which could gain access to the content through cracks developed during egg handling.

The absence of *Salmonella* contamination of eggs from both caged birds and breeding stock at Haramaya University poultry farm could indicate good bio-security measures taken to prevent diseases and absence of trans-ovarian transmission of the organism from parents to successive generations. It should be remembered however, that seasonal dynamics of the organism was only partially done and ovarian samples from breeding stock were not performed due to logistical problems which might have limited this claim.

Conclusion and recommendations

The study showed that *Salmonella* contamination of eggs in Haramaya area is low. There is consumption of raw eggs and cracked eggs in the area indicating lack of awareness of zoonoses. Both breeding and caged layers in Haramaya university poultry farm showed no *Salmonella* contamination. The presence of Salmonella contamination in local chicken eggs is of public health concern. Therefore the public should be made aware of risks associated with consumption of raw chicken eggs and raw eggs cracked during storage and transportation particularly in the very young, old and the immunocompromised.

Acknowledgements

The investigators would like to acknowledge the Office of Vice President of Research, Haramaya University and the Director for Research Group for funding and facilitating logistics for this study. We also would like to thank all College of Veterinary Medicine Laboratory staff as well as those who participated in collecting and providing their valuable time during data

collection.

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