Proceedings of the 2nd Annual Regional Conference on Completed Natural Resources Management Research Activities

(18-19 September 2007)


Edited by: Yihenew G.Selassie (PhD)

Amhara Regional Agricultural Research Institute
(ARARI)

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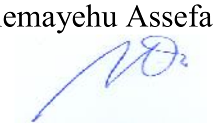
Forward

The annual regional conference on completed research activities, a new orientation in the research system, has three main purposes. Compiling results of completed research activities by researchers without being critically evaluated for proper data analyses and interpretation without insuring validity of the findings has significant negative impact on the quality of the information to be delivered to the users. Hence, this annual forum is primarily important to monitor and evaluate research outputs and insure its validity. Secondly, the research output critically evaluated and sieved in this way will help to update technology manuals regularly based on proven technologies published in the proceeding. Hence, beyond publishing the proceeding it is important to extract appropriate recommendations or research outputs from the proceeding and update the technology manuals so that the information will be utilized by the extension. Researchers are therefore expected to take prompt action in this regard and prepare manuals regularly in Amharic for further dissemination of the findings to development agents working down at *kebele* level. In this way the interface between research and extension can also be expressed in a better way if the output from the forum is properly utilized. Another benefit of this annual forum is experience sharing among researchers regardless of seniority and its benefit can not be substituted by any form of training. Therefore, it is a good opportunity for live interaction among researchers and it is the responsibility of all to keep its continuity.

Alemayehu Assefa (PhD)



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Soil Fertility Management

Symbiotic Blue Green Algae (Azolla): A Potential Biofertilizer for Low Land Rice Production at Fogera Plain

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Abstract

Two Azolla strains (*Azolla filiculoides* and *Azolla microphylla*) were introduced from India in 2004. They were maintained and multiplied in plastic containers at Adet in a green house and inoculated to concrete tanks for adaptability test. Both strains were well adapted to Adet condition and produced 42 - 56.4 tons with an average of 48 tons and 30 - 45 tons with an average of 40 tons fresh biomass per hectare during summer respectively. Biomass production was reduced during autumn and winter due to temperature fluctuation. Field experiment was conducted at Fogera plain, where low land rice is widely produced, during 2005 and 2006 in a randomized complete block design in three replications to assess the adaptability of the strains and generate information on their nitrogen contribution efficiency. 54.4 t ha^{-1} of Azolla fresh biomass was harvested at Fogera. Maximum plant height, number of tillers, straw yield and grain yield of rice was recorded by 64 kg N + 20 kg P ha^{-1}followed by *Azolla filiculoides* + 20 kg P ha^{-1}, 32 kg N + 10 kg P ha^{-1}. Inoculation of *Azolla filiculoides* and *Azolla microphylla* incorporated once to soil has increased rice yield by 911 kg ha^{-1} (19%) and 721 kg ha^{-1} (15%) over the control respectively. However, there was temperature fluctuation and colonization of azolla roots by algae. Multiplication and maintenance of azolla needs special attention. It also needs continuous watering to a depth of 5 -10 cm and P fertilizer, thus, irrigation facility and alternate P sources are vital. Azolla produce high biomass and easy to manage and establish and should be used as biofertilizer for rice and its effect on high value and perennial crops shall be studied.

Key words: Azolla, biofertilizer, fresh biomass, nitrogen, rice, symbiotic

Introduction

Nitrogen is the key element required for growth and productivity of plants. It is abundant in atmosphere (80%) but can not be utilized by plants as such and has to be converted to nitrate or ammonium form either by chemical or biological process (Singh, 1998; Banu, 2003). Chemical synthesis of nitrogen by industrial means is energy intensive and costly. However, the same process can also be carried out enzymatically by cyanobacteria and certain species of bacteria. Most of the cyanobacteria exist under free living conditions but some are found in symbiotic association with lower plants like water fern Azolla (Singh, 1998).

Azolla partners blue green algae inside its lobes and is capable of harvesting atmospheric nitrogen. Due to this invisible partnership, the fern multiplies very fast. The symbiotic association of the algae aid in the creation of a huge amount of biomass on the surface of the water. In Azolla-anabaena symbiosis, the fern is a macro symbiont which gives protective environment and nutrients to blue green algae (the micro symbiont) which in turn gives nitrogen and other growth hormones to the fern for its growth and multiplication. Both partners harvest solar energy via photosynthesis and the total nitrogen requirement can be supplied by the assimilation of N fixed by anabaena. Each leaf of Azolla has the potential of harboring 75,000 anabaena cells containing 3 to 3.5% nitrogen (www. ineedcoffee.com/06/azolla/). The beauty of this fern is that it is quite hardy and during favorable environmental conditions multiplies in geometric proportions. The algal symbiont is closely associated with all stages of the fern's development and resides in the cavities formed in the dorsal lobe of the fern. Rapid multiplication of the fern takes place in summer months. Azolla lives on water surface of rice fields harmoniously under the canopy of rice plants without affecting its growth (Gevrek, 1999), on small ponds, canals, and rivers (Dhar *et al*., 2003; Ferentinos, 2002). Generally, it multiplies vegetatively and often sexually. Its size is 1- 5 cm. Azolla has high protein content of approximately 23-37 % (dry biomass). Hence, it can also be used as, feed supplement with other low protein rations, feed for fish, pigs, ducks, chicken and cattle that like to eat it fresh as well as dried and used in salads and sandwiches, just as alfalfa and bean sprouts are used (Ferentinos et al., 2002; Gevrek, 1999).

Azolla is a world wide in distribution. Seven species are recognized in temperate and tropics viz. *Azolla filiculoides*, *A. rubra, A. caroliniana, A. mexicana, A. microphylla, A. pinnata* and *A. nilotica* (Dhar *et al.*, 2003). All these species has anabaena as symbiont in leaves (Singh, 1998).

The high nitrogen fixing ability, rapid growth, high biomass accumulation and N content determines the potential of Azolla as fertilizer for increasing rice yield under low cost rice production technology. Biological nitrogen fixation through *Azolla anabaena* complex is considered a potential biological system for increasing rice yield at comparatively low cost (Singh, 1998). Becking, (1979) showed that doubling time of population of Azolla varies between 2 to 10 days for most species. Maximum biomass production according to Kikuchi *et al*, (1984) was ranged from 0.4 to 5.2 t dry matter ha^{-1} and averaged 2.1 t dry matter ha^{-1} N content ranged from 40-146 kg ha^{-1} with an average of 70 kg N ha^{-1}.

Azolla derives more than 80 % of its N from Nitrogen fixation in the field (Giller, 2001). Annual N production rates by Azolla can be as high as 500 kg N ha^{-1} (for *A. pinnata*) to 1200 kg N ha^{-1} (for *A. filiculoides*) with average of 1000 kg N ha^{-1} yr^{-1} with daily production rates of 0.4 – 3.6 kg ha^{-1} day^{-1} with average of 2 kg N ha^{-1} day^{-1} (Kikuchi et al., 1984). Azolla grown as an intercrop with rice can accumulate 40-170 kg N ha^{-1} (average 70 kg N ha^{-1}) (Kikuchi *et al*., 1984). Singh, (1978) in Gevrek, (1999) reported that mineral nutrient composition inside the plant body on *A. pinnata* was Nitrogen, 4-5 %; Phosphorus, 0.5-0.9%; Potassium, 2-4.5 %; Calcium, 0.4-4 %; Magnesium, 0.5-0.65 %; Iron, 0.06-0.26 %; Manganese, 0.11-0.16 % and crude protein 24-30 5 on dry matter basis. Gevrek and Yagmur (1997), also recorded the chemical composition of *A. mexicana* as N, 3.92 %; P, 0.52 %; K, 1.25 %; Ca, 4.3 %; Mg, 1.10 %; Na, 1.08 5; Zn, 0.1 %; Mn, 0.3 % and etc on dry matter basis. This indicated that Azolla has higher rate of nitrogen than compost (0.5 – 0.9 % N) and animal manure.

Losses of Azolla N were found to be small (0-11%) in comparison to the loss from an equivalent amount of urea fertilizer (30 %) which was probably due to direct volatilization of ammonia to the atmosphere (Watanabe *et al*., 1989). Giller (2001), observed that the pH of the flood water was reduced by 2 pH units due to the presence of mat of Azolla on its surface and resulted in reduction in N losses by ammonia volatilization and increased the recovery of fertilizer N applied as urea up to 60 %. When Azolla was incorporated into the soil, overall fertilizer losses were reduced by 35-55 % (Kumarasighe and Eskew, 1993). Biological N_2 fixation through *Azolla anabaena* complex is considered a potential biological system for increasing rice yield at comparatively low cost (Singh, 1998; Khan, 1988 and Main, 1993). Recently, Azolla has been used as biofertilizer in many countries in the world viz. China, Vietnam, India, North America, Thailand, Philippines, Korea, Srilanka, Bangladesh, Nepal, West Africa and etc (Dhar *et al*., 2003; Khan, 1988). Some of these countries use Azolla as one of the substitutes to commercial fertilizer. A report made by Gevrek, (1999) revealed that Azolla is used in more than a million hectares of rice land in China and in more than 400,000 hectares in Vietnam.

Low land rice is recently introduced to Ethiopia and has got special attention at Fogera plain and well adopted by farmers. According to Fogera Office of Rural and Agricultural Development, its area coverage has increased from 80 to 6400 hectares within less than a decade (1996-2004) with yield of less than 3.5 t ha^{-1}. However, Its productivity declines from time to time due to continuous cereal cultivation and nutrient depletion and failurity by most farmers to use chemical fertilizer due to rise in cost (Gezahegn and Tekalign, 1995). When in excess, azolla is converted into compost to be used as fertilizer for dry land crops and vegetables (Singh, 1998). Rice yield was increased by 1,470 kg (112%) over the control when one layer of 60 kg N $ha^{-1}$of *A. filiculoides* was incorporated into the paddy soil and further increased by 2700 kg ha^{-1} (216%) by incorporating one layer and then growing Azolla as dual crop with rice (Talley *et al*,. 1977). Since Azolla is a low cost nitrogen source, ecologically friendly, easy for management and used as nitrogen fertilizer source in different countries in the world, introduction and use of this cheap and ecologically friendly N source to our system is vital to increase rice yield and hence, this work was initiated with the objective of introducing Azolla strains and generating information on their N contribution to the newly introduced low land rice at Fogera plain

Materials and Methods

The experiment was done in two phases:

Phase I

Two Azolla strains namely, *Azolla filiculoides* and *Azolla microphylla* were introduced from India in 2004 and stayed at Addis Ababa in National Soils Research Center green house in a nutrient media and were brought to Adet Agricultural Research Center to maintain and test their adaptability. Labeled plastic containers were filled with 5 kg of forest soil and tape water was added at a depth of 10 cm and left over night to let the suspended materials settle. To maintain the mother culture, fresh and healthy Azolla fronds were inoculated to the containers and water was maintained to $\geq$ 5 cm depth every day. A pinch of TSP was added initially and when the deficiency symptom was seen to each container. There was no insect problem in the plastic containers. Both strains were multiplied very well and covered the surface of the containers in the green house within three weeks.

After enough biomass of both strains was attained, two concrete tanks of a dimension 4mx1.5mx0.45m were constructed and filled with forest soil at a rate of 5 kg m^{-2} (i.e. 30 kg of forest soil per tank) and filled with tape water at a depth of 10 cm and left over night to let the suspended materials settle. Next day fresh *Azolla filiculoides* was added to one tank and *Azolla microphylla* to the other tank at a rate of 1kg per tank. The water level was kept to a depth of $\geq$ 5cm every day. 87 gm TSP (40 gm P_2O_5) was applied to each tank initially and when deficiency symptom was observed.

The adaptability of the strains to the new environment was studied based on the biomass produced, pheneotypical appearance at different weather conditions, occurrence of disease and insect pests. Two additional concrete tanks of a size 5x10 m^2 were constructed for multiplication of Azolla for field experiment (to produce enough biomass) following the same procedure, forest soil (250 kg was added to each tank) the strains were inoculated and water was maintained to 5-10 cm depth every day. Two third of the Azolla mat was collected every two weeks from each container and tank leaving one third for further multiplication and the collected mat was weighed sun dried and stored.

Phase II

The field experiment was conducted at Fogera plain where paddy rice is produced widely practiced during 2005 and 2006 in a randomly completed block design with three replications. The experimental site of size 13m x 34m was selected each year and prepared as per the farmers practice and divided to replications and experimental plots of 2m x 3m. The distance between plots and blocks was 2m each. The plots were leveled and rows at a spacing of 20cm were prepared and fertilizer was applied to rows of respective plots evenly at a rate of 64 kg N ha^{-1}+20 kg P ha^{-1}, 32 kg N ha^{-1}+ 10 kg P ha^{-1}, 20 kg P $ha^{-1}$and 10 kg P ha^{-1} then mixed with the soil and rice variety x-jigna was sown at a rate of 80 kg ha^{-1} in rows with 20 cm spacing between rows. N was applied in split i.e. half of N and all P were applied initially and the split was applied at flowering during Azolla incorporation. N and P sources were urea and TSP respectively. After sowing, ridges were made for each plot to collect water which could float the Azolla strains and then the strains were inoculated to their respective plots at a rate of 1kg fresh biomass after the field was flooded with water. The strains were incorporated to the soil in a plot by draining the water after producing enough biomass (forming thick mat).

Treatments:
1. Control
2. 64 kg N ha^{-1}+20 kg P ha^{-1}
3. 32 kg N ha^{-1}+ 10 kg P ha^{-1}
4. *Azolla filiculoides* + 20 kg P ha^{-1}
5. *Azolla microphylla* + 20 kg P ha^{-1}
6. *Azolla filiculoides* + 10 kg P ha^{-1}
7. *Azolla microphylla* +10 kg P ha^{-1}
8. *Azolla filiculoides*
9. *Azolla microphylla*

Agronomic data

Five representative plants were randomly selected from each plot and number of tillers were counted and the average was recorded. Similarly, average plant height was measured for five randomly selected plants per plot using a meter scale. Fresh biomass of Azolla in kg per m^{-2} was measured by a spring balance taking a mat from 1m x 1m area using a quadrant and the average was recorded. The measured fresh biomass of Azolla was sun dried and the equivalent dry weight was recorded.

Among 10 rows of rice per plot, 8 central rows were harvested from each plot and grains and straws were separated to measure straw and grain yield per plot. The grain yield was recorded after adjusting the moisture to 12.5% and expressed as kg per hectare. The straws separated from grains from each plots were sun dried and weighed to determine the straw yield in kg $plot^{-1}$.

Result and Discussion

Both strains were well adapted to Adet in a green house and out door concrete tanks. The strains started multiplying within two days and covered the whole surface of the containers forming a thick mat within three weeks after inoculation (Fig 1). The starter inocula were very small in amount and hence the multiplied strains were inoculated to other containers to achieve enough biomass for further activities (Fig 2a).

Figure 1. Mother culture of *A. filiculoides (a)* and *A. microphylla (b)* in a green house at Adet

After enough biomass was achieved from the plastic containers, both strains were inoculated to the out door concrete tanks at a rate of 1 kg fresh biomass per tank (Fig 2b). The strains started multiplying and covered the surface of the tanks after three weeks. After first harvest, the strains covered the surface of the tanks forming thick mat every two weeks (Fig 2c). The fern is light green in color until the micro symbiont (*anabaena azollae*) makes association with and turned deep green after association. The blue green algae formed series of oval rings on the dorsal lobe of each leave of the fern under microscope as reported by Anand and Geeta (www.ineedcoffee.com/06/azolla/). They observed that each leave of azolla has the potential of harboring 75,000 anabaena cells and has high nitrogen fixing capacity. Both strains were performed well, deep green in color and formed thick mat from June to September (Fig 2).

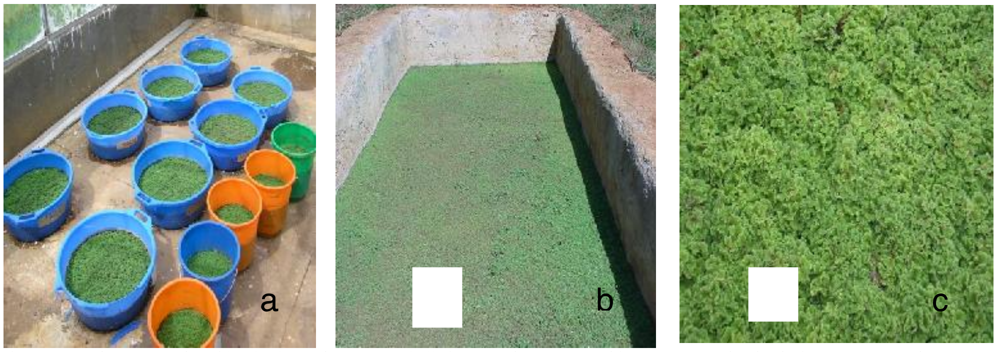

Figure 2. Performance of *A. filiculoides* and *A. microphylla* in green house (a) and in concrete tanks (b) during June – October (c) thick mat of azolla

A. filiculoides tolerated relatively low temperature and performed better from October to January and poorly performed from Feb to April. Whereas *A. microphylla* tolerated relatively high temperature and performed better from February to April and poorly performed from October to January. This result is in agreement with FAO (1982) report. The biomass produced by both strains during these seasons is indicated in Table 1. Both strains turned brown (Fig 3a) when exposed to high temperature or low temperature and/or during maturity (Fig.3b) and green to slightly brown otherwise. Pinkish color was developed during the occurrence of P deficiency and can be corrected by applying P from P source such as TSP. However, both strains may poorly perform if the temperature too cold or too hot. Therefore, partial shade is needed for their better performance.

Figure 3. Azolla turned brown during temperature fluctuation (a) and during maturity (b)

Growth of algae was a common problem for both strains particularly during October to April and seriously affected the *A. microphylla* strain and than *A. filiculoides*. It greatly hindered growth and multiplication of the strains at Adet during these months. The reason was due to addition of excess P to the tanks to recover the strains from damage due to temperature fluctuation for similar symptom was observed and this caused the growth of algae in excess and failure to remove from the tanks by hand. Therefore, lesson was learned in such a way that excess P should not be applied and even be applied in split to avoid algal growth and maintain the strains.

Table 1 Average fresh biomass produced by azolla strains during different seasons

S.N	Season	Fresh biomass in t ha^{-1}		Remark
		A. filiculoides(A.f)	*A. microphylla (A.m)*	
1	May - Sept	48	40	Maximum biomass of 56.4 t and 45 t ha^{-1} was harvested from *A.f* and *A.m* respectively
2	Oct - January	30	11	Though *A.f* performed well it turned cloudy pinkish during severe temperature drop and do not perform as good as from May to Sept
3	Feb - April	14	32	Though *A.m* performed well it turned brown during severe temperature raise and do not perform as good as from May to Sept

From the field experiment conducted at Fogera, it was observed that both strains were well adapted, multiplied and covered the plots within two weeks. The fern formed a thick mat (Fig. 4) and produced 54.4 t fresh biomass ha^{-1} within 40 days after inoculation. Literature revealed that the fresh biomass produced by Azolla ranges from 10-20 t ha^{-1}(Singh, 1998). There was no insect and disease problem for both strains at all locations. The fresh biomass produced indicates that Azolla can adapt and perform well in Ethiopia and hence may serve as source of nitrogen and other macro and micro nutrients for rice and high value crops.

a

Figure 4. Thick mat of Azolla produced in a plot (a) and in a space between blocks (b) at Fogera plain

Significant difference in mean plant height was observed among treatments (Table 2). The maximum mean plant height was recorded due to full recommended NP (64 kg N ha^{-1}+ 20 kg P ha^{-1}) followed by *A. filiculoides* + 20 kg P ha^{-1}, *A. filiculoides* + 10 kg P ha^{-1}, *A. filiculoides* alone and *A. microphylla* + 20 kg P ha-[1]. Whereas the least was recorded by the control followed by *A. microphylla* + 10 kg P ha^{-1}. The result revealed that *Azolla filiculoides* alone increased plant height as equivalent as *A. filiculoides* with full recommended P. In addition, both strains significantly increased plant height than the control (Table 2).

Table 2. Effect of Azolla on plant height at Fogera during 2005 and 2006

Treatment	***Mean plant height (cm)***		
	2005	2006	Combined
Control	95.30	95.00	95.15 d
64 kg N + 20 kg P ha^{-1}	107.27	102.20	104.70 a
32 kg N + 10 kg P ha^{-1}	99.50	98.83	99.17 c
Azolla filiculoides + 20 kg P ha^{-1}	103.70	100.70	102.20 b
Azolla microphylla + 20 kg P ha^{-1}	101.53	97.30	99.42 c
Azolla filiculoides + 10 kg P ha^{-1}	101.90	96.30	99.10 c
Azolla microphylla + 10 kg P ha^{-1}	99.53	93.03	96.28 d
Azolla filiculoides	101.63	100.70	101.20 b
Azolla microphylla^{-1}	100.47	96.93	98.70 c
LSD (0.05)	1.76	1.693	1.661
C.V (%)	1.01	1	1

Significant difference in number of tillers was observed among some treatments (Table 3). Maximum number of tillers was recorded by full recommended NP followed by half recommended NP (32 kg N ha^{-1} + 10 kg P ha^{-1}), *A. filiculoides* alone, *A. microphylla* alone and *A. filiculoides* + 20 kg P ha^{-1}. Both strains significantly (P<0.05) increased number of tillers over the control.

Table 3. Effect of Azolla on number of tillers of rice at Fogera during 2005 and 2006

Treatment	***Mean number of tillers per plant***		
	2005	2006	Combined
Control	9.67	8.33	9.00 c
64 kg N + 20 kg P ha^{-1}	15.00	13.00	14.00 a
32 kg N + 10 kg P ha^{-1}	12.00	11.33	11.67 b
Azolla filiculoides + 20 kg P ha^{-1}	11.00	10.00	10.33 bc
Azolla microphylla + 20 kg P ha^{-1}	10.67	9.33	10.17 bc
Azolla filiculoides + 10 kg P ha^{-1}	11.00	8.67	9.67 c
Azolla microphylla + 10 kg P ha^{-1}	10.67	9.00	10.00 bc
Azolla filiculoides	11.67	9.67	10.50 bc
Azolla microphylla^{-1}	11.33	9.00	10.33 bc
LSD (0.05)	2.550	1.252	1.928
C.V (%)	12.86	7.37	10.91

Maximum straw yield was recorded due to recommended NP followed by half recommended NP combined over years whereas straw yield due to the other treatments have no significant difference(P<0.05) than the control (Table 4). However, *A. microphylla* + 20 kg P ha^{-1} and *A. filiculoides* + 20 kg P ha^{-1}as well as *A. microphylla* + 10 kg P ha^{-1}, *A. filiculoides* + 10 kg P ha^{-1}and *A. filiculoides* alone affected straw yield as equally as half recommended NP but not significantly different from the control and *A. microphylla* alone.

Table 4. Effect of Azolla on straw yield of rice at Fogera during 2005 and 2006

Treatment	***Mean straw yield (kg per ha)***		
	2005	2006	Combined
Control	7417 c	7359 g	7388 c
64 kg N + 20 kg P ha^{-1}	10132 a	9035 a	9584 a
32 kg N + 10 kg P ha^{-1}	8931 ab	8357 b	8644 ab
Azolla filiculoides + 20 kg P ha^{-1}	8396 bc	8063 c	8230 bc
Azolla microphylla + 20 kg P ha^{-1}	8757 abc	7799 de	8278 bc
Azolla filiculoides + 10 kg P ha^{-1}	8354 bc	7674 e	8014 bc
Azolla microphylla + 10 kg P ha^{-1}	8688 bc	7514 f	8101 bc
Azolla filiculoides	7444 c	7924 cd	7684 bc
Azolla microphylla^{-1}	7708 bc	7480 fg	7594 c
LSD (0.05)	1430	148.1	1017
C.V (%)	10.2	1.13	7.48

Table 5 shows that there was significant difference in grain yield among the treatments. The combined analysis showed that recommended NP fertilizer gave the maximum grain yield of 6.2 t ha^{-1} followed by half recommended NP fertilizer and *A. filiculoides* + 20 kg P ha^{-1} with grain yield of 5.9 and 5.8 t ha^{-1} respectively. All treatments have significant difference in grain yield over the control. *A. filiculoides* + 20 kg P ha^{-1} equivalently increased grain yield with half recommended NP followed by *A. filiculoides* alone. *A. filiculoides* alone has recorded significantly different ($P<0.05$) grain yield over *A. microphylla* alone. However, *A. microphylla* with and without P has recorded significant grain yield increment over the control. *A. filiculoides* and *A. microphylla* without P incorporated once to the soil has increased rice yield by 911 kg ha^{-1} (19%) and 721 kg ha^{-1} (15%) over the control respectively.

Table 5. Effect of Azolla on grain yield of rice at Fogera during 2005 and 2006

Treatment	**Mean grain yield (kg ha^{-1})**		
	2005	2006	Combined
Control	4812 e	4932 f	4872 f
64 kg N + 20 kg P ha^{-1}	6167 a	6219 a	6193 a
32 kg N + 10 kg P ha^{-1}	6041 b	5826 b	5934 b
Azolla filiculoides + 20 kg P ha^{-1}	5937 bc	5758 b	5848 bc
Azolla microphylla + 20 kg P ha^{-1}	5791 d	5603 cd	5697 de
Azolla filiculoides + 10 kg P ha^{-1}	5812 d	5555 de	5683 de
Azolla microphylla + 10 kg P ha^{-1}	5749 d	5473 e	5611 e
Azolla filiculoides	5840 cd	5726 bc	5783 cd
Azolla microphylla^{-1}	5729 d	5458 e	5593 e
LSD (0.05)	117.1	125	121.1
C.V (%)	1.22	1.28	1.28

In general, results due to inoculation of *A. filiculoides and A. microphylla* with and with out P has significant difference for most parameters over the control. *A. filiculoides* with 20 kg P ha^{-1} have equivalently affected most parameters with half recommended NP. *A. filiculoides* alone and *A. filiculoides* with 20 kg P ha^{-1} have equivalently affected grain yield of rice combined over years.

Azolla is rich in major nutrients such as N, P, K and S and micro nutrients such as Fe, Zn and others. It is a recycling source of P, S and other nutrients to rice and hence the increase in grain yield and other yield parameters may be due to this fact (Main, 1991; Singh and Singh, 1987 and Singh et al;. 1981). Talley *et al*;. 1977 reported that rice yield was increased by 112% (1470) kg over the control by incorporating *A. filiculoides* once (at the rate of 60 kg ha^{-1}) and by 216% (2700 kg ha^{-1}) by incorporating once and then growing Azolla as a dual crop with rice. In addition, scientists in China also reported rice yield increases due to azolla ranging from 0.4-158% with an average of 18.6% (Lumpkin and Plunknet, 1980). Therefore, the result achieved at Fogera plain (15-19%) is in line with these findings.

Conclusion

Azolla should be used as a biofertilizer for rice production in Ethiopia since:

- ✓ it has high nitrogen fixing capacity,
- ✓ produce high biomass,
- ✓ easy to manage and establish,
- ✓ increase the availability of macro and micronutrients (it scavenge K and recycles P and S),
- ✓ improves soil physical and chemical properties and fertilizer use efficiency,
- ✓ increase crop yield 15-19% (by one incorporation) in Ethiopia,
- ✓ release plant growth hormones and vitamins and does not attract rice pests

However, it:

- ✓ requires nursery for multiplication
- ✓ occupy land for production
- ✓ requires continuous watering and high labor for incorporation and watering
- ✓ needs irrigation facility
- ✓ needs rice crop to be sown in rows

- ✓ may be difficult to establish during dry season due to temperature fluctuation
- ✓ may be attacked by algae
- ✓ requires high P fertilizer for multiplication
- ✓ may be a weed in irrigation channels

Recommendation

- Multiplication tanks should be constructed at Fogera and other potential areas to multiply and scaling up azolla
- Its effect on high valued crops (vegetables and fruit crops) should be studied
- Control mechanism for algae should be studied
- Its effects on water bodies (when entered rivers and lakes) should be evaluated
- Cheap P sources should be investigated
- Rice should be planted in rows by transplantation

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Soil K Status and K Requirement of Potato Growing on Different Soils of Western Amhara

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Abstract
An experiment was conducted in 2005/06 and 2006/07 cropping seasons on Nitosols, Acrisols and Luvisols of Western Amhara to investigate the inherent soil K status and K requirement of potato growing on these soils. The field experiments were conducted in Yilmana Densa (West Gojjam Zone), Farta (South Gondar Zone) and Banja (Awi Zone) woredas. Soil samples were collected from experimental sites before planting of potato and analyzed for exchangeable K status. The treatments included in the field experiment were 6 levels of potassium fertilizer (0, 30, 60, 90,150 and 210 kg K_2O ha^{-1}) that were arranged in randomized complete block design with three replications. All of the K fertilizer for each treatment was band-applied at planting along and in one side of the rows at a distance of 5 cm below and 5 cm aside the seeds. Muriate of potash (KCl) was used as a source of K. Moreover, 81kg N and 69kg P_2O_5 (recommended rates for western Amhara) were added to all plots. This was done by applying 150kg DAP and 58.5kg urea at planting and side dressing 58.5kg urea at flowering stage. Results of the experiment indicated that there was no significant increase in potato tuber number, plant height, number of main stems per plant, potato dry matter yield due to increase in K fertilizer rate on Nitosols, Acrisols and Luvisols. However, increase in K fertilizer rate significantly increased mean tuber weight and tuber yield of potato on Acrisols of Banja Woreda and improved shelving life of potato collected from all soil types.

Keywords: Acrisol, Luvisol, Nitosol, yield, yield components

Introduction
Of all the essential elements, potassium is the third most likely crop yield limiting nutrient after nitrogen and phosphorus. It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil. Potassium is also essential for photosynthesis, protein

synthesis, nitrogen fixation in legumes and for starch formation and increasing tuber yield (Brady and Weil, 2002). It is also especially important in helping plants adapt to environmental stresses like drought and frost. Nevertheless, this nutrient has received little attention in Ethiopian agriculture. This is mainly because K has been regarded as adequately available nutrient in Ethiopian Soils. Murphy (1963) in his work, which is recognized as the first systematic approach in characterizing the nutrient status of Ethiopian soils, reported that Ethiopian soils have adequate potassium. However, his work lacked adequate data on crop yield response to fertilizers (Taye, 1998). Moreover, more recent information of Mesfin (1998) indicated that Ethiopian Alfisols, as all moderately to intensively weathered soils, have limited amounts of basic rocks that usually contain more easily weatherable potassium, which affects the potassium content of these soils. This situation could be even worse on more weathered and leached Ultisols of Injibara area where potato is widely cultivated.

It is also apparent that intensive cropping in the absence of K replenishment would not only lead to "hidden hunger" but also can precipitate diminished productivity. Therefore, preliminary study on potassium status of Nitosols, Acrisols and Luvisols would help to devise strategies for proper soil fertility management. Moreover, studying the K requirement of potato, a crop which is believed to be highly responsive to K application, may play a significant role in improving land productivity and assist the food security endeavors of the region. Therefore, the objective of this study was to assess the potassium status of Nitosols, Acrisols and Luvisols and investigate the K requirement of potato growing on these three soils of western Amhara.

Materials and Methods

Determination of Soil K Status

Representative soil samples were collected from Nitosols, Acrisols and Luvisols of western Amhara where potato is intensively cultivated. Exchangeable potassium was determined by extracting potassium with 1*N* NH_4OA and analyzing the K status as outlined in Sahlemedihin and Taye (2000).

Tretments experimental design and field lay out

The field experiment was conducted in Yilmana Densa, Farta and Banja woredas representing three soils of western Amhara. The treatments included in the experiment were 6 levels of potassium fertilizer; i.e., 0, 30, 60, 90, 150 and 210 kg K_2O ha^{-1}.

The treatments were arranged in randomized complete block design with three replications. The gross plot size of the experimental site was 3.0m x 3.0m ($9.0m^2$) and the net plot size was 1.5m x 2.4m ($3.6m^2$). Spacing between rows was 75cm and between plants was 30cm. The distance between plots was 0.5m and between blocks was 1.0m

Fertilizer application and cultural practice

All of the K fertilizer for each treatment was band-applied at planting along and in one side of the rows at a distance of 5 cm below and 5 cm aside the seeds. Muriate of potash (KCl) was used as a source of K. Moreover, 81kg N and 69kg P_2O_5, recommended rates for western Amhara (personal communication), was added to all plots. This was done by applying 150kg DAP and 58.5kg urea at planting and side dressing 58.5kg urea at flowering stage. Weeding and ridging operations were conducted to all plots as necessary.

Statistical Analysis

Analyis of variance and simple regression analysis were carried out for yield and yield components studied following statistical procedure appropriate for the experimental design. Whenever, treatment effects were found significant, the means were separated using Duncan's Multiple Range Test using SAS statistical package (SAS Institute, 1999).

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Results and Discussion

Soil Potassium Status

In 2005/06 and 2006/07 cropping seasons, the experiments were conducted on five and six location, respectively located in Yilmana Densa, Banja and Farta woredas. The results of soil analysis indicated that Nitosols of Yilmana Densa had better K status followed by Luvisols of Farta . Acrisols of Banja had the lowest values (Table 1).

Table 1. Exchangeable K status of different soils covered by the experiment in 2005/06

Location	Woreda	Soil Type	Exchangeable K ($cmol_c$ kg^{-1})
Mossobo	Yilmana Densa	Nitosol	0.814
Adet Hanna	Yilmana Densa	Nitosol	0.712
Wonjella	Banja	Acrisol	0.102
Debre tabor	Farta	Luvisol	0.305
Tsegur	Farta	Luvisol	0.407

Soil analysis results of soils samples collected from six experimental sites in Yilmana Densa, Banja and Farta woredas in 2006/07 cropping season also indicated in Table 2. Based on the results, Nitosols of Yilmana Densa Woreda contained relatively higher amount of exchangeable K followed by Luvisols of Farta Woreda and Acrisols of Banja Woreda.

Table 2. Exchangeable K status of different soils covered by the experiment in 2006/07

Location	Woreda	Soil Type	Exchangeable K ($cmol_c$ kg^{-1})
Mossobo	Yilmana Densa	Nitosol	1.41
Debre Mewi	Yilmana Densa	Nitosol	1.32
Biden Jebella	Banja	Acrisol	0.18
Injibara	Banja	Acrisol	0.22
Debretabor	Farta	Luvisol	0.51
Tsegur	Farta	Luvisol	0.41

The two years results indicated that, based on Beerneart (1990), K status is high and very high in Nitosols of Yilmana Densa, medium in Luvisols of Farta and low in Acrisols of Banja.

Potato Tuber Number

Potassium fertilizer rate did not have a significant effect on potato tuber number at four of the five locations in 2005/2006. A significant difference in potato tuber number per plant due to K fertilizer application was achieved only on Acrisols of Wonjella in Banja Woreda (Table 3). However, the significant increase was achieved up to application of 30kg ha^{-1} K_2O.

Increasing the rate beyond this rate did not bring a significant effect on the parameter considered.

Table 3. The Effect of K Fertilizer Rates on Potato Tuber number in 2005/06 cropping season (number/3.6m^2)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	166.7a	135.0a	33.7b	126.0a	94.7a
30 kg ha^{-1}	141.0a	130.0a	57.0a	133.3a	122.0a
60 kg ha^{-1}	195.0a	101.7a	55.3a	94.7a	94.7a
90 kg ha^{-1}	171.7a	124.3a	34.0b	112.3a	103.0a
150 kg ha^{-1}	187.3a	112.7a	39.3b	109.7a	146.0a
210 kg ha^{-1}	149.0a	115.0a	32.7b	107.7a	136.7a
CV (%)	17.6	20.3	15.9	28.3	31.4
P(0.05)	ns	ns	*	ns	ns

* = significant; ns= not significant

However, results of the experiment conducted in 2006/07 cropping season indicated that application of K fertilizer also did not give a significant effect on number of tubers produced per plant across all locations (Table 4). It is worthy enough to note that locations incorporated in the experiment in this year in each Woreda had relatively higher exchangeable K levels as compared to sites included in each Woreda in the previous year which generally diminished the effect of K fertilizer on this paramenter.

Table 4. The Effect of K Fertilizer Rate on tuber number in 2006/07 cropping season (number per 3.6 m^2)

Treatments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	76.3 a	76.3 a	89.0 a	94.0 a	104.0 a	71.7a
30 kg ha^{-1}	79.3 a	76.3 a	85.0 a	117.0 a	93.7 a	71.0 a
60 kg ha^{-1}	57.0 a	62.0 a	76.7 a	108.7 a	116.3 a	89.0 a
90 kg ha^{-1}	78.3 a	59.0 a	90.7 a	113.7 a	112.3 a	93.3 a
150 kg ha^{-1}	64.0 a	75.3 a	99.7 a	105.3 a	86.3 a	101.0 a
210 kg ha^{-1}	57.3 a	55.7 a	88.3 a	115.0 a	93.0 a	79.7 a
CV (%)	21.2	30.2	14.0	11.9	31.0	23.4
P(0.05)	ns	ns	ns	ns	ns	ns

ns= not significant

This suggests that this yield component did not play a significant role in determining the tuber yield of potato.

Plant Height

Except at one location (Mossobo Nitosols), K fertilizer rate did not have a significant effect on plant height of potato (Table 5). It is also necessary to note that the data on plant height obtained from this specific location did not have defined trend to make firm conclusion.

Table 5. The Effect of K Fertilizer Rates on plant height of potato plant in 2005/06 cropping season (cm)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	38.0b	37.2a	28.3a	33.7a	28.7a
30 kg ha^{-1}	40.3ab	32.4a	27.7a	36.6a	30.6a
60 kg ha^{-1}	39.7ab	36.5a	28.3a	34.6a	32.6a
90 kg ha^{-1}	42.1a	36.7a	30.0a	34.7a	33.0a
150 kg ha^{-1}	41.6a	35.6a	28.4a	35.1a	32.8a
210 kg ha^{-1}	40.5ab	32.5	30.1a	36.3a	31.3a
CV(%)	4.4	8.1	5.3	6.7	15.2a
P(0.05)	*	ns	ns	ns	ns

* = significant; ns= not significant

The result obtained in 2006/07 cropping season also indicated that potassium fertilizer did not give a significant effect on plant height of potato plants on four of the five testing sites included in the experiment (Table 6).

Table 6. The Effect of K Fertilizer Rate on plant height of potato in 2006/07 cropping season (cm)

Treat-ments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	49.2 a	46.6 a	46.6 a	20.3 b	49.6 a	49.1 a
30 kg ha^{-1}	51.2 a	47.2 a	44.3 a	23.0 ab	52.2 a	48.6 a
60 kg ha^{-1}	49.3 a	44.5 a	44.9 a	24.1 ab	54.3 a	52.8 a
90 kg ha^{-1}	51.8 a	43.8 a	45.7 a	25.9 ab	56.1 a	53.2 a
150 kg ha^{-1}	45.6 a	43.3 a	44.9 a	25.5 ab	52.6 a	52.3 a
210 kg ha^{-1}	50.0 a	44.7 a	46.9 a	26.9 a	55.8 a	49.7 a
CV (%)	8.9	5.4	11.8	12.1	6.4	7.6
P(0.05)	ns	ns	ns	*	ns	ns

* = significant; ns= not significant

It is, therefore, possible to suggest that potassium nutrient may not have a significant contribution in increasing the height of potato plants.

Number of Main Stems per Plant

Application of different rates of K fertilizer did not affect the number of main stems per plant of potato at all of the locations included in 2005/06 cropping season (Table 7).

Table 7. The Effect of K Fertilizer Rates on number of main stems per plant of potato in 2005/06 cropping season (number/plant)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	5.0a	4.7a	3.0a	4.0a	6.3a
30 kg ha^{-1}	3.7a	4.7a	3.7a	3.7a	5.7a
60 kg ha^{-1}	5.0a	5.0a	3.0a	4.3a	5.7a
90 kg ha^{-1}	4.3a	5.3a	3.3a	3.7a	5.3a
150 kg ha^{-1}	4.7a	5.3a	3.0a	4.3a	6.0a
210 kg ha^{-1}	4.3a	5.0a	3.0a	3.7a	6.3a
CV (%)	28.7	19.7	14.1	12.8	12.7
P(0.05)	ns	ns	ns	ns	ns

ns= not significant

Similar trend was observed in 2006/07 cropping season as that of the previous year. Significant effect was observed only at Acrisol of Injibara on-station. On the rest of the locations, K fertilizer application did not significantly affect the number of stems per plant (Table 8). The two years results suggest that this yield component did not significantly contribute to the difference obtained in potato tuber yield.

Table 8. The Effect of K Fertilizer Rate on number of stems per plant in 2006/07 cropping season (number/plant)

Treat-ments	Location					
	Mossobo Nitosols	Debre Mewi Nitosols	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisols
0 kg ha^{-1}	5.7 a	5.7 a	3.3 a	2.7 b	4.3 a	4.3 a
30 kg ha^{-1}	6.7 a	6.0 a	3.3 a	3.3 ab	6.0 a	4.0 a
60 kg ha^{-1}	5.7 a	5.7 a	3.0 a	3.3 ab	5.0 a	4.3 a
90 kg ha^{-1}	6.0 a	6.0 a	3.3 a	3.7 ab	5.3a	4.7 a
150 kg ha^{-1}	4.7 a	5.7 a	3.3a	3.7 ab	5.3 a	5.3 a
210 kg ha^{-1}	6.0 a	6.3 a	2.7 a	4.0 a	5.7a	3.7 a
CV (%)	18.3	10.6	17.3	14.7	17.5	22.3
P(0.05)	ns	ns	ns	*	ns	ns

* = significant; ns= not significant

Mean Tuber Weight

Application of K fertilizer gave a significant effect on mean tuber weight of potato at 3 locations (Adet Hanna Nitosol, Wonjella Acrisol and Tsegur Luvisol) out of the five locations incorporated in the experiment in 2005/06 cropping season (Table 9).

Table 9. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2005/06 cropping season (gm/tuber)

Treat-ments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	59.1 a	70.5 ab	19.3 b	35.4 a	63.2 ab
30 kg ha^{-1}	61.5 a	61.1 b	24.1 ab	35.6 a	53.6 ab
60 kg ha^{-1}	50.4 a	82.5 a	24.8 ab	44.0 a	75.3 a
90 kg ha^{-1}	56.3 a	65.6 ab	30.1 ab	45.4 a	68.2 ab
150 kg ha^{-1}	47.4 a	70.3 ab	24.3 ab	46.1 a	52.3 b
210 kg ha^{-1}	60.5 a	68.8 b	33.1 a	46.9 a	55.0 b
CV (%)	12.9	13.5	22.0	18.9	17.1
P(0.05)	ns	*	*	ns	*

* = significant; ns= not significant

However, in 2006/07 cropping season only two locations in Banja woreda which have Acrisol soil type gave significant difference in mean potato tuber weight (Table 10). From the results of the experiments of the two years it is possible to conclude that this yield component affected tuber yield of potato on Acrisol of Banja Woreda. Therefore, in both years, significant effect on mean tuber yield was obtained on Acrisols of Banja Woreda.

Table 10. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2006/07 cropping season (gm/tuber)

Treat-ments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	88.7 a	63.3 a	29.5 b	29.6 c	61.1 a	53.9 a
30 kg ha^{-1}	87.3 a	61.7 a	45.9 a	32.4 cb	76.3 a	47.7 a
60 kg ha^{-1}	95.5 a	70.7 a	43.6 ab	36.1 ab	59.0 a	58.2 a
90 kg ha^{-1}	97.5 a	69.4 a	45.1 a	41.0 a	59.3 a	55.5 a
150 kg ha^{-1}	83.4 a	65.5 a	48.2 a	40.3 a	71.2 a	50.1 a
210 kg ha^{-1}	93.7 a	65.9 a	46.5 a	42.0 a	68.3 a	54.8 a
CV (%)	8.4	10.3	19.4	9.1	23.9	22.6
P(0.05)	ns	ns	*	*	ns	ns

* = significant; ns= not significant

Percent Tuber Dry Matter Yield

Application of different rates of K fertilizer did not affect the % tuber dry matter yield at four of the five locations. At Adet Hanna Nitosol, where significant difference was achieved, the data seem inconsistent and lack clear trend to make a conclusion (Table 11). Therefore, it is possible to suggest that K nutrient does not contribute a lot in determining potato dry matter yield.

Table 11. The Effect of K Fertilizer Rates on % tuber dry matter yield of potato in 2005/06 cropping season

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	17.1a	22.5ab	22.4a	24.6a	24.1a
30 kg ha^{-1}	16.6a	22.9ab	18.7a	23.4a	23.2a
60 kg ha^{-1}	18.2a	21.9b	21.5a	23.6a	23.8a
90 kg ha^{-1}	18.2a	24.7a	19.4a	24.3a	23.0a
150 kg ha^{-1}	18.2a	22.8a	21.6a	25.2a	23.1a
210 kg ha^{-1}	17.6a	22.0ab	20.2a	23.4a	23.5a
CV (%)	10.2	5.0	10.7	4.7	2.6
P(0.05)	ns	ns	ns	ns	ns

ns= not significant

Potato Tuber Slices Shelving Life

Application of K fertilizer improved shelving quality of sliced potato tubers by hindering oxidation of starch and darkening of the tuber surface at four of the five locations (Table 12). Nitosols of Mossobo and Adet Hana, which had relatively higher soil K level, exhibited no response for K application in terms of shelving quality of sliced potato tubers shelved for 48 hours after being sliced.

Table 12. The effect of K fertilizer rates on darkening of potato tuber tissue surface due to oxidation of starch in 2006/07 cropping season (%)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	54.7a	64.4a	74.2c	81.3ab	89.4c
30 kg ha^{-1}	48.3a	58.3a	59.4cb	86.1b	75.8b
60 kg ha^{-1}	56.7a	63.9a	41.1ab	73.5ab	64.5ab
90 kg ha^{-1}	43.5a	60.6a	40.9ab	76.7ab	60.0a
150 kg ha^{-1}	45.0a	62.0a	32.2a	67.6a	68.3ab
210 kg ha^{-1}	37.5a	52.5a	38.0ab	70.0ab	66.9ab
CV(%)	25.6	23.3	26.4	10.9	9.5
P(0.05)	ns	ns	*	*	*

* = significant; ns= not significant

Potato Tuber Yield

Results of the experiment indicated that K fertilizer rate does not have a significant effect on potato tuber yield on Nitosols of Yilmana Densa and Luvisols of Farta Woredas. A significant difference was attained only on Acrisols of Wonjella in Banja Woreda (Table 13). However, a significant yield increase was obtained up to application of 30 kg ha^{-1}. Beyond this rate significant yield increase was not observed.

It is important to note that the yield from Wonjella location was very low as compared to other locations which indicated overall deficiency of major nutrients and deteriorated soil physical condition. In such cases, increasing K rate alone cannot bring yield increase unless the demand for other yield limiting nutrients is met.

Table 13. The effect of K fertilizer rate on tuber yield of potato in 2005/06 cropping season (Kg ha^{-1})

Treat-ments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	21259a	19407a	1805.6b	11019.0 a	16287a
30 kg ha^{-1}	19259a	17185a	3101.9a	12685.0 a	17852a
60 kg ha^{-1}	21704a	18222a	3796.3a	11481.0a	18167a
90 kg ha^{-1}	21037a	18000a	2850.6ab	13882.0a	18713a
150 kg ha^{-1}	19630a	17481a	2731.5ab	13981.0a	20944a
210 kg ha^{-1}	20000a	17630a	2618.5ab	13982.0a	20213a
CV (%)	9.2	17.9	29.9	13.9	22.4
P(0.05)	ns	ns	*	ns	ns

* = significant; ns= not significant

Results of the experiment conducted in 2006/07 cropping season also indicated that potato planted on Acrisols of Banja Woreda responded for K application. Similar to the previous year, potato planted on Nitosols of Yilmana Densa and Luvisols of Farta (one location) did not respond to K application (Table 14).

Table 14. The Effect of K Fertilizer Rate on Tuber Yield of Potato in 2006/07 cropping season (Kg ha^{-1})

Treat-ments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Nitosol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha^{-1}	18519.0 a	13334.0 a	7296.0 c	7750.0 b	17639.0 a	8704.0 b
30 kg ha^{-1}	19074.0 a	13148.0 a	8213.0 bc	10481.0 ab	18009.0 a	11065.0 ab
60 kg ha^{-1}	15185.0 a	11944.0 a	9305.6 b	10926.0 ab	18287.0 a	14352.0 a
90 kg ha^{-1}	21296.0 a	11667.0 a	11287.0 a	12889.0 a	18287.0 a	14213.0 a
150 kg ha^{-1}	18667.0 a	13426.0 a	12250.0 a	11824.0 a	16065.0 a	14120.0 a
210 kg ha^{-1}	14815.0 a	10000.0 a	12064.8 a	13222.0 a	17593.0 a	12130.0 ab
CV (%)	20.2	28.7	9.1	14.3	21.3	18.8
P(0.05)	ns	ns	*	*	ns	*

* = significant; ns= not significant

Relationships between Soil K and Potato Tuber Yield

From the experiment, it was also clearly seen that there was curvilinear and positive relationships between soil exchangeable K levels and potato tuber yield (Figure 1). Those sites that had lower exchangeable K levels gave lower tuber yield and vise versa. However, the intensity of the response diminishes as the soil K level increases and significant difference in potato tuber yield among treatments was not achieved on locations with relatively higher K status and vise versa.

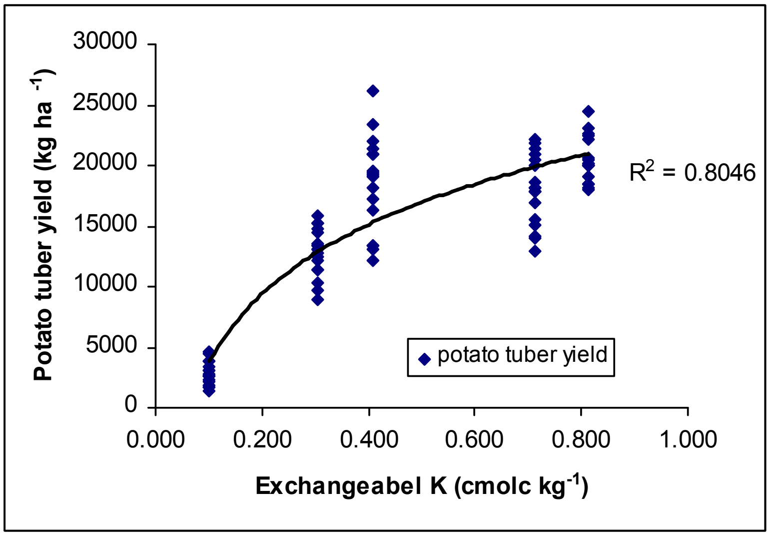

Figure 1. The relationships between soil exchangeable K status and potato tuber yield in 2005/06 cropping season

It is also possible to suggest that those sites that had relatively lower K status can also have lower levels of other macro and micro nutrients and unfavorable soil properties that can produce lower yield. This was justified by previous works of Yihenew (2002) indicating that Acrisols of Injibara area has lower levels total N and base saturation. Conversely, these soils have higher levels of C:N ratio and acidity levels as compared to the other areas covered in this experiment (Table 15).

Table 15.Selected chemical properties of some soils of western Amhara

Site	Soil type	Total N (%)	OC (%)	C/N	Available P (ppm)	Base saturation (%)	Soil pH (1:1)	Exchangeable H^+	Al^{3+}
								(cmol$_c$ kg^{-1})	
Adet	Nitosol	0.17	1.7	10	2.64	41.07	5.38	0.14	0.10
Injibara	Acrisol	0.03	3.5	117	9.50	35.69	4.81	0.08	2.32
Debre-Tabor	Luvisol	0.08	3.2	40	3.70	45.19	5.17	0.04	0.24

Source (Yihenew, 2002)

Conclusions and recommendations

From the results of the experiment, it is possible to draw the following conclusions:

1) Increasing K fertilizer rate did not significantly increase potato tuber number, plant height, number of main stems per plant and potato dry matter yield on Nitosols, Acrisols and Luvisols;
2) Increase in K fertilizer rate significantly increased mean tuber weight, and tuber yield of potato on Acrisols;
3) Increase in K fertilizer rate significantly improved shelving life of potato.
4) Potato tuber yield had linear and positive relationship with soil exchangeable K status. However, potato tuber yield response level to K fertilizer application had negative relationship with soil K status.

From the results of the experiment, it is possible to recommend that application of 30kg ha^{-1} on Acriosls of Banja Woreda could be taken as blanket fertilizer recommendation. For those soils with exchangeable K values of greater than 0.3 cmol$_c$ kg^{-1}, it is less likely that response for K fertilizer may be obtained. Therefore, it is advisable to make soil analysis prior to determine whether to apply K fertilizer or not. But still, further investigation is required to reach to firm recommendation.

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Response of Barley and Faba Bean to Application of Litter-Wood Ash Mixture in the Central Highlands of Ethiopia

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Abstract

Each household at the rural areas of central highlands of Ethiopia produces ash and house refuse mixtures almost every day and gather it near the homestead. The stockpile of litter-wood ash material is one of the locally available soil replenishing resources used by the farmers. The study assessed the importance, extent and use of litter-wood ash as a source of fertilizer to cereal and pulse crops. Initially, the study was conducted as an on-station experiment with solely/pure ash rates then the treatments rates and type of ash were modified according to the farmers' practice of litter-wood ash. The experiment was conducted at Mush and Atakilt on farmers' field permanently for 4 years. The treatments used for the on-farm experiment were control, 3 litter ash treatments (11, 22, and 44 t ha $^{-1}$) and a recommended chemical fertilizers for barley and faba bean and replicated 3 times. The study showed that many farmers do believe ash materials have the potential to amend soil conditions and replenish soil for the crop. the rates of litter-wood ash used by the farmers varies depending on the availability of litter-wood ash mixture in the farmstead, the inherent soil fertility status of the farmland and the crop type to be fertilized. Results showed that significantly higher faba bean and barley yields were obtained from the use of 1 t ha^{-1} and 22 t ha^{-1} of litter-wood ash applied at every 2 years period. Litter-wood ash could be used as the best soil amendment material that adds plant nutrients to the soil. If managed properly, litter-wood ash could be sustainable alternative to agricultural lime, with many economic and environmental benefits. Since ash has low density and small particle size, it is necessary to avoid spreading it on very dry and windy days as well as on waterlogged conditions. Hence, farmers should be advised to store their litter-wood ash mixtures away from runoff and avoid its application immediately after prolonged rainfall.

Key words: Litter-wood ash, Sole ash, Barley, Faba Bean

Introduction

Agricultural production in the highlands of Ethiopia is limited by many factors, including nutrient deficiencies and soil acidity. To overcome these problems, crop producers utilize different farming practices and apply fertilizers. Organic fertilizer represents the cheapest and most sustainable option for crop producers. Among organic fertilizers, farm yard manure (FYM) offers an affordable and readily available plant nutrient to the plant, build up the fertility status of the soil and eventually improves the soil structure.

Litter-wood ash mixture is inorganic and organic residue remaining after the combustion of wood or unbleached wood fibers mixed with house refuses. This ash has been considered as a waste product instead of a resource as few industries have taken advantage of the beneficial properties of the ash. Today, several million tons of wood ashes are produced annually in the world. In most developed countries wood ash is produced by pulp and paper mills from the incineration of hog fuel that consists of waste wood, knots, and barks. Agronomic benefits resulting from land application of pulp and paper mill by-products such as biosolids from effluent treatment systems or wood ash from energy systems have been widely studied in Europe (Karsisto, 1979), the United States (Vance, 1996; Mitchell and Black, 1997), and more recently in Canada (Lickacz, 2002). For centuries, farmers have recycled wood ash during the clearing of forests to increase arable lands. As a result, yields in these cleared areas often increased because of ash-induced changes in soil pH and chemical composition (Hopkins, 1910; Giovannini *et al.*, 1993). Many of these developed countries are utilizing wood ash as a soil amendment material and this has been documented. Applications of ash at rates of less than 50 t ha^{-1} in greenhouse and field studies increased dry matter yield in oat (*Avena sativa* L.) (Krejsl and Scanlon, 1996), wheat (*Triticum aestivum* L.) (Etiegni *et al.,* 1991; Huang *et al.,* 1993), bean (*Phaseolus vulgaris* L.) (Krejsl and Scanlon, 1996), barley (*Hordeum vulgare* L.), alfalfa (*Medicago sativa* L.) (Meyers and Kopecky, 1998) and some forage crops (Naylor and Schmidt, 1989; Muse and Mitchell, 1995; Meyers and Kopecky, 1998).

The rural people in least developed countries like Ethiopia are using bulk of wood and cattle dung as source of energy and sources of cash income. Each household at the rural areas of central highlands of Ethiopia produces ash and house refuse mixtures almost every day and gather it near the homestead. This stockpile of litter-wood ash material is one of the locally available soil replenishing resources used by the farmers. However, in some areas, farmers do not want to collect the ash near their houses. Most farmers, particularly female farmers, have been using litter-wood ash as a fertilizer and spread it under vegetables and some other garden plants. Beyond the old soil burning or 'gai' practices, farmers in North Shewa (Baso, Angolelana Asagirt, Sheno and Hagere Mariam) have long tradition of applying litter-wood ash mixture to their farmlands. Farmers are applying litter-wood ash mixtures to their farmlands in particular in heavy Vertisols. Usually the litter ashes are being applied in a week or two weeks time before cropping. Sometimes these ashes are mixed with small amount of FYM and form manured ash. However, neither field nor greenhouse studies were conducted with regard to the use of ash as soil amendment material under varieties of crops. In order to support or nullify such a practice, there need to be research based information. Hence, the purpose of this study was to assess and understand the extent and use of ash as a fertilizer source in selected areas of North Shewa, and to investigate the effect of ash on yield and yield components of barley and faba bean.

Material and Methods

A survey and two field experiments were carried out in two phases: The first study was conducted on station with solely ash (ash free of unburned or bleached materials), while the second study was conducted on farm with litter/wood-ash mixture (the actual farmers practice) sampled from farmers' ash stockpiles. In Phase I of this study, the extent and use of litter ash as a soil amendment material was assessed and first hand information from group of farmers at different locations was compiled. The application rates of ash and the general information gathered from the farmers were quantified in the field during main cropping season. Further, designed field experiment on the effect of ash on barley yield and yield components was conducted for one year. The on-station field experiment was carried out to evaluate four rates of solely ash (4.7, 9.4, 14, and 21 t ha^{-1} on dry weight base), 41/46 kg ha^{-1} N/P_2O_5 as Urea and DAP, and control (without ash and fertilizer) for two cropping seasons. The experiment was laid out in randomized complete block factorial design with 4 replications. The experimental field was made to have broad bed and furrows (BBF) to drain excess water. . The survey data was displayed with descriptive statistics, while the data from the field experiment was subjected to statistical analyses.

In Phase II**, a**fter conducting the on-station experiment, it was realized that the actual ash type used as soil amendment/fertilizer sources by farmers was not solely ash material, but it was rather litter-wood ash mixtures. Hence, the on-farm experiment was conducted in a more practical and rational way with litter-wood ash mixtures used by the farmers. The litter-wood ash used for the study was collected from representative farmers' homestead in Mush and Keyit areas. A sample was taken from the collected material for chemical and physical analyses in the laboratory. The treatments for field experiments were formulated based on the laboratory data and the information generated from the 1st phase of this study. The experimental design used in the study was split plot with four replications. Two application times (Once and twice in every two years applications) as main-plot treatments and five ash application rates (Control, 11 tons ha^{-1} litter-wood ash, 22 tons ha^{-1} litter-wood ash, 44 ton ha^{-1} litter-wood ash, and 21 tons ha^{-1} sole ash that were selected from the on station experiment and blanket recommendation of 41/46 and 18/46 kg ha^{-1} N/P_2O_5 as Urea and DAP for barley and faba bean, respectively were used as sub-plot treatments. The total experimental area used for the experiment was 1026 m^2. The test crops used for the field experiments were food barley and faba bean. The experiment was conducted in the same place for 4 years being each crop as a precursor crop for the other as practiced by the farmers, faba bean followed by barley. In both cases, planting was done in 2 weeks time after application of the litter-wood ash mixture to the field. The survey data was displayed in descriptive statistics, while the data from the field experiment was subjected to statistical analysis.

Results and Discussions

Farmers in Keyit, Mush, Angolela Asagirt and Hagere mariam woredas use high amounts of litter-wood ash alternatively under faba bean (*Vicia faba*), field pea and barley (*Hordeum vulgare* L.) crops.

Farmers knowledge on the use of ash

Fortified litter-wood ash mixture is one of the traditionally and commonly used organic fertilizers. Hence, a survey was conducted on the use and importance of ash as a soil amendment material by the farmers. Many farmers do believe that ash materials accumulated for a period of time would have the potential to amend soil condition as well as replenish soil for the improvement of crop growth. In the survey conducted at two locations, on average 21 – 25 farmers per group responded to the questions related on the use of ash as an input in agriculture. According to the farmers, the application of wet litter-wood ash reaches approximately 8 - 12.8, 17.9 - 33.2, 33.3 - 60.6 t ha^{-1} respectively, is practiced by the poor, medium and rich (based on their livestock wealth) farmers. The study showed that the approximate rate of litter-wood ash application ranges from 3.1 – 5.2 and 7.8 – 19.6 t ha^{-1} (on 6% moisture level bases) at Keyit and Mush areas, respectively (Table 1).

Table 1. Approximate farmers' usage of litter-wood ash and estimated labor required for its distribution around Debre Birhan, North Shewa, 1999.

Site	Farmers' land size (m^2)	Group of Respondent	Approximate use of ash per ha. (on dry wt. basis), (tones) Min	Max	Average Min	Average Max	Labor required for ash distribution. Man-days/land size	Number of donkeys used for ash transportation per farm size
Mush	782	GI	9.6	16.8	8.4	15.6	15	20
		GII	7.2	14.4			15	20
Mush	400	GI	1.4	23.5	13.3	19.6	4	10
		GII	1.3	15.6			4	10
Mush	440	GI	8.5	12.8	7.8	14.2	5	12
		GII	10.7	17.1			6	15
		GIII	4.3	12.8			2	20
Keyit	400	GI	3.8	5.2	3.7	5.2	-	-
	3250	GI	3.1	4.1	3.1	4.0	-	55

GI, GII and GIII -- Group of farmers

In fact, these rates vary from farmer to farmer depending on the availability of litter-wood ash mixture in the farmstead and the inherent soil fertility status of the farmland. Unfortunately, barley fields that are treated with litter-wood ash are usually exposed to high weed infestation. Therefore, farmers are expected to weed their crop fields on time. Moreover, such a practice requires quite high donkey and human labor, for ash transportation and distribution on farmlands.

Effect of pure ash on yield of barley and faba bean

Prior to the onfarm litter-wood ash experiment an on-station experiment was conducted using pure wood ash (solely ash) as a soil amendment material.

Thus the study showed that the barley yields obtained were significantly different among the different pure ash rate treatments. The on-station field experiment showed that there were no significant barley grain yield difference ($P<0.05$) between two solely ash rates (14 and 21 tons ha^{-1}) and these ash treatments gave very comparable grain yield with that of the recommended chemical fertilizer rate (41/46 N/P_2O_5). The grain yields obtained from the above two treatments ($\geq$1.0 tons ha^{-1}) were more than double of the grain yield obtained from control treatment (0.5 t ha^{-1}) (Table 2). The yield increments from these treatments were 124, 158 and 165.5% over the control (Table 3). Barley plants grown with the applications of both the chemical fertilizer and solely litter-wood ash rates matured earlier than the control treatment. The mineral fertilizer and the three highest ash rates gave earlier days to heading (4 to 11 days prior) and better tillering capacity (Table 3). The solely ash treatments used on the on-station experiment showed significant impact on grain yield of barley.

Table 2. Grain yield, days to maturity, number of tillers and stand count of barley for solely applied ashes rates.

Treatments	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	Straw yield (t ha^{-1})	Days to heading	Number of tillers	Plant stand count
Control (without ash/fertilizer)	0.5 c	1.7 b	1.2 b	83.00 a	4.38 d	56.00
4.7 t ha^{-1} solely ash	0.7 c	1.7 b	1.0 b	80.75 ab	5.75 cd	60.75
9.4 t ha^{-1} solely ash	0.8 bc	1.8 b	1.0 b	79.00 bc	6.75 bc	62.75
14 t ha^{-1} solely ash	1.0 ab	2.4 b	1.2 b	76.00 cd	6.75 bc	60.75
21 t ha^{-1} solely ash	1.3 a	2.6 b	1.3 b	74.00 de	7.63 b	66.75
41/46 kg ha^{-1} N/P_2O_5	1.3 a	3.8 b	2.4 a	71.50 e	9.88 a	65.00
CV (%)	26.34	28.14	40.98	2.71	15.16	19.72
$LSD_{0.05}$	0.39	0.98	0.83	3.16	1.57	NS

Table 3. Grain yield of barley obtained with the use of ash as a fertilizer

Treatments	Grain yield, t ha^{-1}	% Relative yield increment over the control
Control	0.51	--
4.7 t ha^{-1} solely ash	0.70	39.57
9.4 t ha^{-1} solely ash	0.84	65.84
14 t ha^{-1} solely ash	1.13	124.17
21 t ha^{-1} solely ash	1.31	158.40
41/46 kg ha^{-1} N/P_2O_5 (Urea/DAP)	1.34	165.58

We came to realize that there was clear variation between sole ash (used for the on station experiment) and litter-wood ash (used by the local farmers), the later being a justification to modify our treatments in the on-farm experiment discussed below. Results obtained from the on-farm experiment showed that both barley and faba bean considerable response to application of litter-wood ash rates for two alternative years. Despite the applied treatments, both barley and faba bean yields obtained from Atakilt area had poor performance in comparison with yields obtained from Mush. The overall combined barley grain, biomass and straw yields obtained from the two areas were illustrated in figure 1, 2 and 3 for barley and in figure 4, 5 and 6 for faba bean. The experiment on both barley and faba bean showed that all litter-wood ash and the chemical fertilizer treatments showed yield advantage over the control.

For ease of the reporting data obtained from each site were not presented here. With respect to the barley yield results obtained from the different ash rates at Atakilt area did not show significant yield differences ($P>0.05$). The 44 t ha^{-1} litter/wood-ash mixture was the only treatment that gave grain yield comparable with that of the recommended chemical fertilizer. Except 44 t ha^{-1} litter-wood ash, most ash treatments did not show grain yield advantage from the previous year litter-wood ash application. Similarly, the highest litter-wood ash (44 t ha^{-1}) showed the highest grain yield of barley over all the treatments at Mush area. In the second year the residual effect of 44 t ha^{-1} litter ash gave significantly different ($P<0.05$) grain yield advantage over the control and the rest of ash treatments. This indicates that in favorable environmental conditions like Mush, barley benefited from the left over plant nutrients applied in previous year.

Figure 1, 2 and 3 showed the results biomass, grain and straw yields obtained from the combined data analysis for the two sites. Barley biomass yield from litter-wood ash rate 22 t ha $^{-1}$ and over and straw yield from litter-wood ash rate 11 t ha $^{-1}$ and over applied every 2 years showed significantly different than application of the same rates every year (Figure 1 and 3). Contrary to the every 2 years application of litter-wood ash every year application of the chemical fertilizer gave better grain as well as straw yields. However, except for the straw yield there were no significant biomass and grain yield differences with the application of chemical fertilizer between the application periods. Due to the waterlogging problem occurred at Atakilt site the combined analysis did no clearly showed the impact of litter-wood ash on grain yield of barley. However, all litter-wood ash treatments showed a tendency to increase grain yield when applied every 2 years (Figure 2). Grain yield due to the every 2 year application of litter-wood ash at the rate of 22 t ha $^{-1}$ and over showed significant grain yield at Mush site. In the second year the residual effect of 44 t ha^{-1} litter ash gave significantly different ($P<0.05$) grain yield advantage over the control and the rest of ash treatments. Barley benefited from the left over litter-wood ashes applied in previous year. This suggests that farmers in Mush area do have the chance to use litter ash in alternate years (minimum 2 years). During the study period for all measured parameters of barley, the chemical fertilizer and the two highest litter-wood ash treatments responded better than the sole ash treatments. Every 2 years application of the solely/pure ash treatment showed significant biomass and straw yield differences (Figure 1 and 3). All litter-wood ash, solely ash and chemical fertilizer sources showed significant yield advantage over the control during both fertilizer application periods.

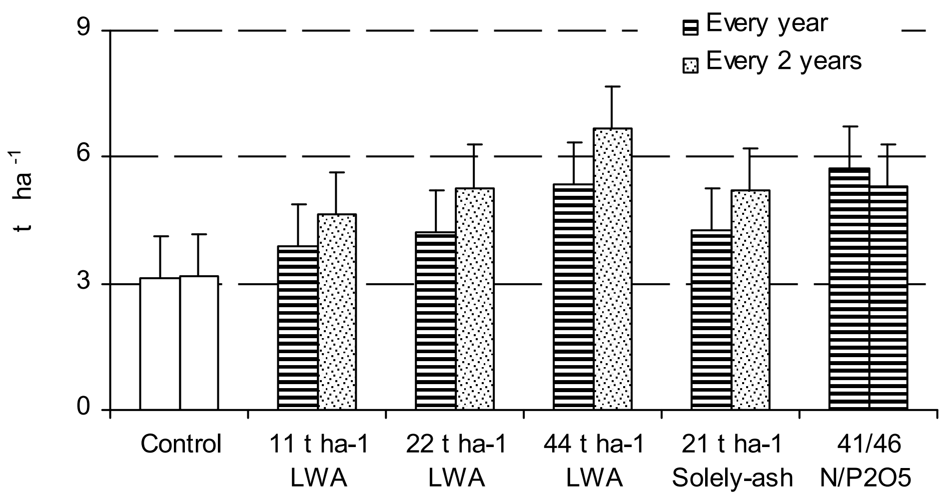

Figure 1. Barley biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

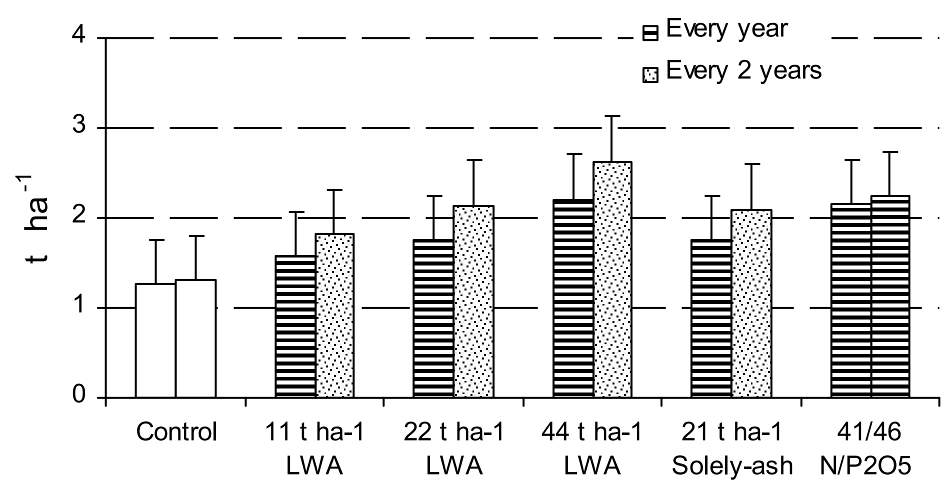

Figure 2. Barley grain yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

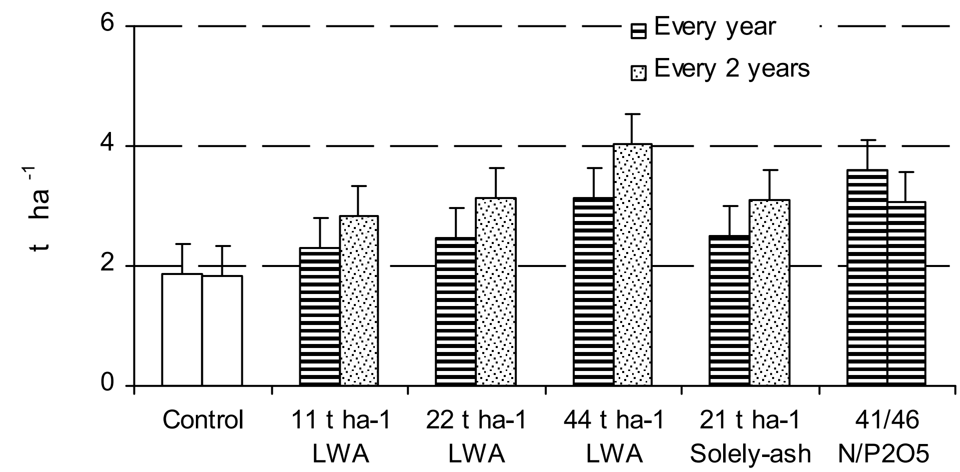

Figure 3. Barley straw yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

The overall faba bean yield obtained during the study period showed significant seed yield difference for both Atakilt and Mush locations (P<0.05). However, the coefficient of variation for the Atakilt area (43.05%) was very much higher than the Mush area (11.7%). Similar to the barley yield, due to waterlogging problem the Atakilt site was not conducive for the production of faba bean. Nevertheless, the combined data analysis for the 2 sites showed that biomass yield of faba bean was significant with every 2 years application of litter-wood ash at 11 t ha $^{-1}$ and over (Figure 4). However, litter-wood ash at the rate of 44 t ha $^{-1}$ and over did not show significant yield advantage for the two application periods. The minimum rates of litter ash to get the seed yield advantage were 11 and 22 t ha $^{-1}$, for at Atakilt and Mush area, respectively. Twenty two to 44 t ha $^{-1}$ litter-wood ash gave the best yield across the sites for all measured parameters of faba bean. The solely ash and litter-wood ash treatments did not show significant seed yield difference at P>0.05 level. The combined data analysis for faba bean did not show significant seed yield difference. At both locations faba bean might not utilized the applied chemical fertilizer properly. In all occasions the chemical fertilizer gave significantly low faba bean yields than the litter-wood ash treatments.

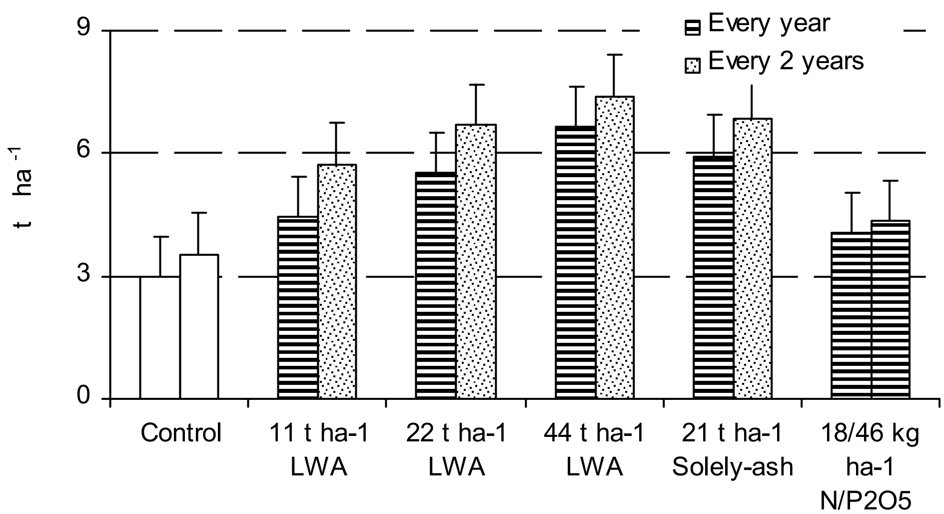

Figure 4. Faba bean biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

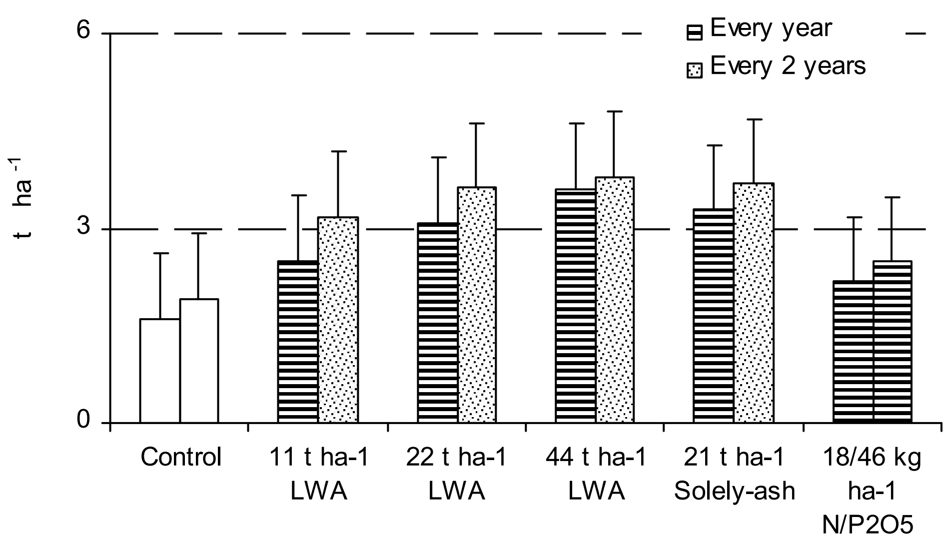

Figure 5. Faba bean biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

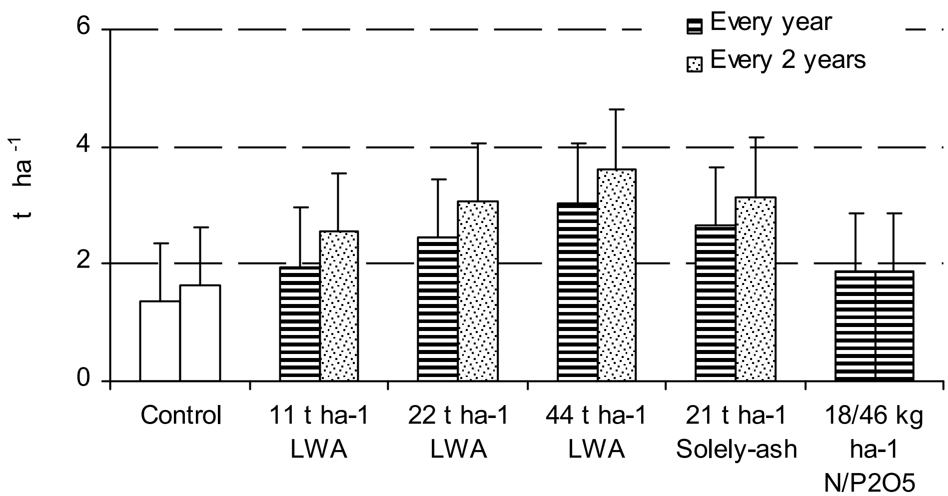

Figure 6. Faba bean seed yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

The effect of ash application on soil properties

A number of litter-wood ash samples preserved for years were collected from different farmers' houses for physical and chemical analysis (Tables 6 and 7). The laboratory results for the representative litter-wood ash samples showed they had a strong alkaline pH condition (8.92) with EC values 1.71 dS m^{-1}. It was rich with phosphorus and potassium contents and had optimal C:N ratio. The litter and unbleached materials contained 1.86% organic carbon (Table 6**).** Application of litter-wood ash had the capacity to neutralize the low pH values measured for the two locations (pH 6.3 and 6.4 respectively, for Atakilt and Mush) in the top 30 cm of soil depth. Considering the correlation between pH and availability of plant nutrients as a whole, Brady (1984) indicated a pH range of 6 to 7 seems to promote the most readily available plant nutrients. The application of litter-wood ash to the soil showed a tendency to increase plant nutrients to the soil. However, table 7 indicates the total N and organic carbon content before sowing and after harvesting approximately equal for all treatments. As the ash sample had large amount of P, the available P in the soil increases as the rate of application increases. All the treatments showed low amounts of available K left in the soil after the barley crop treated with litter-wood ash. This suggests that much of the available K from the litter-wood ash might be utilized by the plant and/or the litter-wood ash made easy the uptake of the inherent soil K to the plant.

Table 6. Laboratory analysis of litter ash preserved for 3 years under farmers' condition

Characteristics	Contents
pH H_2O (1:2.5)	8.92
EC (dS m^{-1})	1.71
TN (%)	0.182
O.C (%)	1.855
C/N	10
Av.P (ppm)	245.40
Potassium (meq $100g^{-1}$ soil)	59.2

Table 7. Results of soil sample analysis before planting and after harvesting

Treatments	TN (%)	Av. P, (ppm)	Avail. K (meq/ 100 g)	OC (%)	pH, $_{H2O}$ 1:2.5	EC (mmhos/ cm)	Texture, %		
							Sand	Silt	Clay
Composite soil sample before the treatments	0.24	5.26	3.20	1.95	5.78	0.06	11.7	31.0	57.3
Control	0.22	4.17	1.83	1.83	5.87	0.04	10.7	30.0	59.3
4.7 ton/ha pure-ash	0.22	7.07	1.61	1.91	5.94	0.05	8.7	32.0	59.3
9.4 ton/ha pure-ash	0.22	9.70	1.37	1.37	5.96	0.05	12.7	31.0	56.3
14 ton/ha pure-ash	0.23	12.53	1.59	1.96	6.07	0.06	11.7	31.0	57.3
21 ton/ha pure-ash	0.22	47.67	2.08	1.92	6.58	0.12	10.7	34.0	55.3
41/46 N/P2O5 kg/ha	0.22	4.38	1.33	1.90	5.81	0.03	15.7	27.0	57.3

Conclusions and Recommendations

The use of litter-wood ash as a nutrient source for food crop production depends largely on the prevailing farming system and farmers' fuel tradition. Since most farmers in the study areas do have very similar fuel wood sources based on our results from this study we like to make the under mentioned, suggest and recommendations in terms of litter-wood ash application. In North Shewa area and other similar areas, litter-wood ash could be used as the best soil amendment material that adds plant nutrients to the soil. The use of litter-wood ash as a nutrient source for food crop production depends largely on the prevailing farming system and farmers tradition. Applications of litter-wood ash based on agronomic principles such as lime requirement or fertility recommendations have the potential to increase yields in dry matter, and grain. Single applications of litter-wood ash resulted in long-term increases in plant productivity. Farmers in acid soil, waterlogging areas could be advised and encouraged to use litter-ash under their crops. If managed properly, litter-wood ash could be sustainable alternative to agricultural lime, with many economic and environmental benefits. In order to get yield advantage, farmers from litter-wood ash application, farmers should apply minimum of 11 t ha^{-1} and 11 - 22 t ha^{-1} of litter-ash for faba bean and barley, respectively. Hence, farmers should be advised to store their litter-wood ash mixtures away from runoff and avoid its application immediately after prolonged rainfall. If additional fertilizer applications are needed, there should be formulated. Since ash has low density and small particle size, it is necessary to avoid spreading it on very dry days. Also it is necessary to avoid the use of pesticide chemicals at least for 3 to 5 days prior to ash application since ash has absorbent nature to the chemicals.

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Soil and Water Conservation

On-farm Demonstration of Physical and Biological Soil Conservation Measures for Gully Stabilization and Biomass Production in the Wag-Lasta area of Amhara Region

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Abstract

A demonstration study was conducted on gully stabilization using physical and biological soil conservation measures. In the study, multi-purpose trees (MPTs), shrubs and grasses were used as biological materials, whereas the physical structure is only the stone fencing check dam. To conduct these experiment three gullies of similar length, width, depth and slope were selected on cultivated and grazing lands. As a result, root collar diameter and height of Acacia Saligna and Susbania Susban was increasing through time in gullies of both the cultivated and grazing lands. But it can be definitely concluded that Susbania Susban was well performed than the Acacia saligna in the gullies. On dry-land areas, like Wag-Lasta, planting trees and shrubs in gullies have a mutual advantage, conserving the soil and water and the other is getting forages from the gullies.

Keywords: Wag-Lasta, Gully, physical structures, biological structures, Acacia, Sesbania

Introduction

Although erosion is a natural process, man induced factors, such as improper land use and management (ploughing of shallow soils on steep-sloped lands), non-conservative grazing practices (open grazing and over grazing), removal of natural vegetation, and clearing and development of new farm lands, have accelerated the formation of gullies (Elliot *et al*., 1993). Among the causes of gully formation, unprotected water ways and steep-slope cultivation are the most important (Shertz *et al*., 1989)

Gully formation begins with the formation of small rills. During intense rains, the walls of these rills crack, and the loose soil material is washed down-slope. As this process continues small rills gradually increase in size to become larger rills, or small gullies. Unless counter measures are taken, these small gullies will become progressively longer and wider making intervention with stabilization measures more and more difficult.

One of the major reasons for the reduction of farm size in Ethiopia is erosion. Gully formation, an example of extensive erosion, rapidly decreases the area available for cultivation. In Wag-Lasta area, gully formation contributes to major losses in productive farm and grazing lands.

Wag-Lasta area is characterized by antique settlement tradition, severe land degradation, and a multitude of socioeconomic problems. The current ploughing technology dates back to medieval times. This archaic ploughing technique coupled with land fragmentation is causing irreversible land degradation vis. gullies. This land degradation is a very serious problem in Wag-Lasta, removing a substantial amount of land from production.

Fortunately, nowadays, gully treatment endeavours have received greater attention. Unlike in the past, conservationists have given greater emphasis on vegetative means of gully treatment. Structural measures, in spite of their effectiveness in silt trapping, are not sustainable because they have to be supported by vegetative means. Only constructing structures, trapping the sediment and see what it happens afterwards is considered as conservation. But the surcharge of the sediment causes failure on the structure. The sediment trapped stayed without use giving no production for the immediate problem of the farmers causing un-sustainability. With this introduction the following objectives were set:

- To recommend interventions for the stabilization of gullies in local watersheds.
- To obtain concrete information about the methods, including their stability, survivability, and amount of sediment trapped,
- To evaluate the efficiency of temporary structures, multipurpose trees (MPT), grasses and shrubs in gully stabilization.
- To collect farmers opinion about sustainable gully stabilization and biomass production

The vegetation was requiring time for establishment and their effectiveness will change as time passes. Therefore, the study were looking at the progress of vegetative establishment along and across with gully stabilization.

Materials and Methods

On the execution of the study, farmers were participating in protecting the gully structures, multi-purpose trees (MPTs), shrubs and grasses from damages due to grazing animals . Two types of gully treatment methods were used: mechanical or physical, and biological gully stablizations in combined and separate manner. The mechanical gully structure to be tested was constructed from stone fencing check-dam. Multi-purpose trees (MPT), shrubs, and elephant grass were the biological materials tested in combination with the physical structure and separately.

To conduct these experiment three gullies of similar length, width, depth and slope were selected. Adjacent check dams were spaced with a vertical interval of one meter that was equal to the height of the spillway. Check dams were trapezoidal in shape. They had 0.5m top width and 1m bottom width. Shrubs were planted with 0.5m spacing between rows and 0.2m spacing between shrubs, and the rows were planted perpendicular to the flow of run-off. Grasses were broadcasted as per recommended rate per hectar.

In case of check-dams, sediment depositions behind the dams were measured by the use of graduated sticks (Foster, 1988)

Through a thorough discussion on how to manage the gully (Check dam construction with the farmers, establishment of the biological measures, maintenance, follow up/ protection of the study treatments, sharing benefits derived from gullies and others were done accordingly among the participating farmers.

The treatments were:

T1= Mechanical structure with grasses, Shrubs and MPTs (Length-wide alignment)
T2= Mechanical structure with grasses, Shrubs and MPTs (Cross-section alignment)
T3= Mechanical structure alone for a control

Data collected:

- For shrub: Survival rate, number of sprouts, biomass yield and height
- For MPTs= Survival rate, root collar diameter, height and DBH, For mechanical structures: Silt depth, gully width and depth, side slope, soil type,

Result and Discussion

From Tables 1, 2 and 3, it can be observed that the RCD and height of Acacia Saligna and Susbania Susban was increasing through time on both the cultivated and grazing lands. But it can be definitely concluded that Susbania Susban was well performed than the Acacia Saligna in the area.

Furthermore, the height and RCD of Sesbania sesban was better in the grazing land than on the cultivated land, this may be due to the difference in soil type and the size of the catchments. Where as the height of Acacia saligna on the cultivated land was much better than the height on the grazing land.

Table 1. Root collar diameter and plant height (Data taken at 28/6/98)

Species	Cultivated Land		Grazing Land	
	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)
Acacia Saligna	13.4	106.35	12.5	94.1
Susbania Susban	17.85	200.85	21.8	254.4

Table 2. Root collar diameter and plant height (Data taken at 7/10/98)

Species	Cultivated Land		Grazing Land	
	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)
Acacia Saligna	18.45	125.9	14.93	103.73
Susbania Susban	27.1	187.9	29.8	272.3

Table 3. Root collar diameter and plant height (Data taken at 9/1/99)

Species	Cultivated Land		Grazing Land	
	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)
Acacia Saligna	26.9	187.18	19.67	141.23
Susbania Susban	30.6	257.35	40.0	345

Table 4 indicates that the sticks were installed along the gullies. Multi measurements were taken along the check dams and silt depths indicated on the table were the average depths of five reading along the check dams. Silt depths were taken in each month through out the years from the start of the experiment and figures in the above table were the final reading which were taken in September 1998 E.C.

Table 4: Depth readings from the graduated sticks for the grazing land and cultivated land (15/1/1998)

Graduated stick	Silt Depth (cm)	
	Grazing land	Cultivated land
Stick 1	35	20
Stick 2	35	40
Stick 3	35	28
Stick 4	38	42
Stick 5	65	20
Stick 6	30	28

Conclusions and Recommendations

From the above result and discussion constructing only physical structures on gullies will have no value for the farmers. In dry-land areas, like Sekota planting trees and shrubs in gullies have a mutual advantage, one is conserving soil and water and the other is getting forages from the gullies. Especially Acacia Saligna and Susbania Susban were well adapted in the gullies and having a large biomass for livestock feeding. Farmers opinion during demonstration were very encouraging, and now in the water-shed farmers were rehabilitate gullies so that gullies now are not problem areas rather they are productive once.

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Appendix Tables

Table 1: Base line data of the gully on the grazing land

Stru. No	Width at the back of each structure (m)	Depth at the back of each structure (m)	Side slope (%)	Land use system
1	5.80	1.70	90	
2	6.00	1.70	90	
3	7.00	2.20	85	
4	7.00	2.50	90	Grazing land
5	5.50	2.50	60	
6	7.00	3.50	45	
7	OUT LET	OUT LET		
Ave	7.133	2.35		

Table 2: Base line data of the gully on the cultivated land

Stru. No	Width at the back of each structure (m)	Depth at the back of each structure (m)	Side slope (%)	Land use system
1	5.50	1.45	45	
2	4.00	1.50	45	
3	4.00	1.70	50	
4	4.00	1.65	50	
5	6.00	1.50	30	Cultivated land
6	4.80	1.55	30	
7	6.20	1.80	30	
8	5.30	1.63	30	
9	OUTLET	OUTLET		
Ave	5.75	1.6		

Agricultural Water Management

Testing Low-cost Gravity Drip Irrigation Technology Suitable to the Current Water Harvesting Structures

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Abstract

Currently, high attention is given for efficient utilization of the labor power and land for improved productivity. Constructing water harvesting structures and collecting runoff water on individual farmers' field for additional agricultural productivity purpose is one part of the strategy. Though a number of water harvesting structures are constructed at the different corners of the country, the adoption rate and return of these structures is not as expected. Lack of low cost, simple and efficient irrigation technologies for appropriate utilization of harvested water is the major reason for the above problems. Therefore this study was conducted with the objective of demonstrating, testing and evaluating low cost smallholder drip irrigation practices relative to can /manual water application for better utilization of harvested water. From the study smallholder drip systems gave better yield with lower irrigation water. In addition, drip irrigation was found more efficient, less laborious and with better economical return. From the practical training and field demonstration, the attitude of farmers about better utilization of harvested water with small holder drip irrigation system is changed and farmers have confessed as they will adopt water harvesting structures.

Key words: Irrigation water, tomato, onion, water use efficiency, yield

Introduction

Out of 113 Woredas of Amhara Region, 52 are food insecure at both community and household level (Ewnetu Gedif, presentation, 2005). Population pressure will further increase food insecure areas of the region if the agricultural activity continues dependant on this risky rain-fed staple-food production condition (Sijali, 2001).

Therefore, irrigation can and should play an important role in raising and stabilizing food production. Hence, a well-managed irrigation system is crucial. The vital task of increasing and stabilizing food production in drought prone regions must therefore include a concentrated effort to improve on-farm water management.

Realizing this situation, the region is undertaking different activities to intensify irrigation at small householder farmers' level. Lots of water harvesting structures have been constructed and ground water ponds developed widely in the dry land areas through different approaches.

Regardless of the heavy investment incurred to construct water-harvesting structures, most of them could not provide the desired results because of the high water demanding traditional surface irrigation methods. Because the only familiar technology for farmers is flood or manual irrigation, most of them are not convinced of the sufficiency of stored water for supplemental or full irrigation. Therefore, the adoption rate of water harvesting structures is low and even those constructed before are mostly idle. As a result, there is need of introducing and evaluating efficient, easily affordable and water saving irrigation systems that could help to utilize the limited water collected by water harvesting structures.

The time is ripe for new approach, an approach extending water-harvesting structures as package with appropriate drip irrigation method. Household drip irrigation systems are given attention in different parts of the world for such small stored waters.

The system is cost effective in that it uses gravitational force and most materials are locally available. The daily operation of the system should not require knowledge and abilities beyond those of the smallholder farmer. So that this experiment was conducted to demonstrate, test and evaluate low cost family drip irrigation system's suitability for the utilization of water harvested by conventional water harvesting structures relative to can /manual water application.

Materials and Methods

Three representative farm households having harvested water using hemispherical water harvesting structures were selected at Aliyu Amba, Ankober. Onion and tomato were grown side by side on selected farms and were irrigated using smallholder drip irrigation and traditional can irrigation methods. The two irrigation systems, drip irrigation system and traditional can (manual) irrigation were the two treatments compared.

Water storage, either barrel or plastic bucket in this case, was placed at about one meter height from the ground surface. Water used for irrigation was fetched manually from water harvesting structures and filled in water storage devices. Water from one storage barrel or bucket irrigates one onion and one tomato beds using one drip line. What is purchased from the drip system was the drip line and few accessories which are low cost (about 50 Birr, 5 USD each drip line with accessories). In one experimental area, two onion beds and two tomato beds were irrigated using each system, drip and can.

The amount of irrigation for drip case was determined by checking the moisture status of the soil using fill method, which is calibrated through continuous sampling. The experiment was conducted for two years (irrigation seasons) and data on total amount of water applied, time and labor required, yield and farmers view were taken for both systems.

Result and Discussion

Amount of Irrigation Water Applied and Required Labor

In this study, using low cost family drip irrigation was found to reduce the total amount of irrigation water applied by 24.23 m^3/ha and 22.51 m^3/ha for tomato and onion respectively compared to manual can irrigation method (table 1). This much water difference per hectare base may not seem much, but compared to the total amount of water utilized for irrigation, saving this much water will help a lot to irrigate additional area. Irregular small application of can irrigation water by farmers and the rainfall condition of the area in mid irrigation seasons may have contributed for the decrement of the difference.

Regardless of farmers' suspicion of the adequacy of the harvested water for vegetable production, we were able to demonstrate it on their farm as they can produce vegetables with harvested water. Irrigation for drip system was applied each time until the soil reaches its field capacity. The irrigator used feel method, which was calibrated to field capacity by continuous sampling of moist soil and measuring the moisture content by gravimetric method, to determine the amount of irrigation requirement before each application. However, average irrigated soil depth usually didn't exceed 5 cm for can application method and roughly speaking it could be said that, farmers were showering the crop with water rather than irrigating it. Therefore, regardless of the same irrigation frequency for both methods, the amount of irrigation depth was quite different between the two systems.

Labor for drip case was calculated by recording the whole time spend from adjusting drip lines to end of irrigating fields with out considering different additional activities individuals can do once they adjust the drip system. For this reason, the labor used for drip was exaggerated add goes against the advantages and principles of drip irrigation. This under estimates the benefits of drip irrigation. Therefore, by considering the addition al activities farmers were doing side by side to irrigating their fields after adjusting the drip system, the total time was divided by two. This was done to have better cost benefit analysis information. But it is still over estimated and the labor for drip is higher for two onion plots (Abera and Dejene onion plots).

Time saving advantage of drip was assured by farmers who were participants of the demonstration based training we provided for the Woreda and Kebele Agricultural experts and farmers of the experimental area.

Table 1. Amount of applied water and labor required for drip and can method of application

Farm owner	Crop type	Volume of Water Applied(m^3/ha)			Labour (man-day/ha)		
		Drip	Can	Difference (Drip - Can)	Drip	Can	Difference (Drip - Can)
Abera Wessenie	Tomato	53.33	70.41	17.07	82.38	98.85	16.48
	Onion	142.55	177.86	35.31	255.21	245.54	-9.67
Dejene Tadesse	Tomato	77.58	113.27	35.69	108.95	181.76	72.81
	Onion	256.25	267.86	11.61	368.31	358.63	-9.68
Weldie Atlaw	Tomato	83.64	103.57	19.93	100.45	247.66	147.22
	Onion	244.37	265.00	20.63	293.90	602.68	308.78
Overall Mean	Tomato	71.52	95.75	24.23	97.26	176.09	78.83
	Onion	214.39	236.90	22.51	305.81	402.28	96.48

Yield and Water Use Efficiency

Considerable yield advantage was also obtained from the drip compared to can irrigation applications except low yield of onion from Abera's plot because of grazing problem of animals. The over all additional mean yield advantages of using drip irrigation were 62.92 qt/ha and 14.29qt/ha tomato and onion respectively (table 2**).** Though the local price of tomato and onion was low during the harvesting period, farmers have found better income or benefit using family drip system. The rainfall, which is much higher than the previous years during the cropping season, may have an impact on yield difference between the two methods. The yield obtained from can application would have decreased by far if it would have not been for this unusual much rainfall condition.

Table 2. Yield of tomato, onion, and water use efficiency for both irrigation systems.

Farm owner	Crop type	Yield, qt/ha			Water Use efficiency(kg/lt)	
		Drip	Can	Diff	Drip	can
Abera Wessenie	Tomato	234.95	171.94	63.01	0.44	0.24
	Onion	80.36	100.00	-19.64	0.06	0.06
Dejene Tadesse	Tomato	160.46	103.06	57.40	0.21	0.09
	Onion	357.14	296.43	60.71	0.14	0.11
Weldie Atlaw	Tomato	409.18	340.82	68.36	0.49	0.33
	Onion	158.93	157.14	1.79	0.07	0.06
Overall Mean	Tomato	268.20	205.27	62.92	0.38	0.21
	Onion	198.81	184.52	14.29	0.09	0.08

The two irrigation methods can be also compared in terms of water use efficiency. In the study, drip has shown better water use efficiency than the can method. From table 2, the over all mean water use efficiency of tomato is 0.38 and 0.21 and that of onion is 0.09 and 0.08 for drip and can applications respectively. Water use efficiencies for onion in Abera's plot were the same for both systems because of the previously mentioned problem on yield. Still tomato has saved much water than onion irrespective of the application methods.

Cost Benefit Analysis

The cost of labor was estimated based on labor cost during the study time, 8 Birr/man/day. One full set of drip line, which can give service for at least four irrigation seasons and two vegetable producing beds (one onion and one tomato), was purchased 50 Birr. The cost of drip lines per hectare basis was calculated by considering the above realities. The partial cost and benefit analysis indicated that the benefit obtained from drip system is much better than the farmers' method of water application (table 3). In spite of the low price of onion (1.50 Birr/kg) and tomato (1.00 Birr/kg) taken from the local market during harvesting season, drip rate of return which is 451.18% for tomato and 138.27% for onion is higher. From the partial budget analysis, one can easily identify and choose that tomato can give much higher return than onion. This is due to the high labor demand for shifting of smallholder drip lines to irrigate densely populated (15 cm between plants) onion than tomato (60 cm spacing between plants)

Table 3. Partial budget analysis and water use efficiency for drip irrigation technology compared with farmer method at Aliyu Amba

	Tomato		Onion	
Variables	Drip	Can	Drip	Can
Labor cost (Birr/ha)	778.05	1408.72	2446.44	3218.27
drip material cost	1860.20		1860.20	
Total cost (Birr/ha)	2638.25	1408.72	4306.64	3218.27
Benefit, yield(Birr/ha)	26819.67	20527.33	29821.50	27678.50
Benefit, water(Birr/ha)	484.62		450.29	
Total Benefit (Birr/ha)	27304.29	20527.33	30271.79	27678.50
Net Benefit (Birr/ha)	24666.04	19118.61	25965.15	24460.23
Marginal Rate of Return (%)	451.18		138.27	
Water use efficiency (kg/lt)	0.38	0.21	0.09	0.08

Training and Field Day

Field day was prepared for about thirty male and 10 female a total of farmers and development agents of the peasant association in order to make aware of the farmers about drip irrigation methods. Demonstration based training about drip irrigation was also given for 15 farmers, 2 development agents of the peasant association and 1 expert of the Woreda's Bureau of Agriculture and Rural Development. This training was undertaken for motivating the farmers to practice drip irrigation in the future.

During the training, most farmers were highly astonished of family drip technology. They have convinced that, it could be possible to produce different vegetables using rain-harvested water. Besides the technology's water saving importance farmers indicated that its simplicity and the possibility to do other activities side by side to irrigating crops will enable everybody at home to handle the practice at any time. Trainees expressed that it was because of their lack of awareness they refused to construct their own water harvesting structures in-group. Almost all express their regression fore not having and as they need to construct and practice drip irrigation.

Those farmers owning farms with water harvesting structures where the experiment has conducted started to use their land and harvested water intensively after we started to work with them.

Conclusions and Recommendations

In the demonstration based evaluation and comparison study, drip irrigation gave better yield advantage with relatively less water than farmers manual can application. Water Use efficiency of vegetables was also higher in the drip case. As result, the economical return of drip irrigation, which is expressed in terms of marginal rate of return, was relatively better.

During the field demonstration and training, local growers were happy for the simplicity, low cost, water saving, better yielding properties of small holder drip technology. Farmers witnessed as it saves much water, does not require any outside power for water pressure, increases the quantity and quality of yield, reduces labor requirement and reduces weed.

Therefore, Scaling-up smallholder drip irrigation technology in the area by establishing Farmers Research Extension Group (FREG) or in other means will improve productivity and utilization of harvested water. This will in turn facilitate the adoption rate of water harvesting structures.

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Determination of Optimum Irrigation Scheduling for Onion at Kewot Woreda

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Abstract

Kewot woreda, which is located in Nort Shewa about 200 km away from Addis Ababa on the road to Dessie or Mekelle, has long experience in traditional irrigated agriculture. Farmers mainly grow onion in most of irrigation schemes. The irrigation schedule of farmers is not supported by any improved technology and is based on the availability of water and the farmer's turn regardless of the crop type, land size and water requirement. This causes the decline of productivity and quality of onion. For this reason, this study was conducted to determine the optimum irrigation scheduling of onion for that specific location.

The experimental design was split plot design with three replications using four irrigation intervals i.e. 4, 7, 10, 13 days as sub plot and three watering depths 30, 50, 70 mm as main plot treatments. Data of different yield and quality indicator parameters were collected for two years and analyzed using SAS statistical software. From the analysis irrigation interval was found important to affect yield and quality than irrigation depth. Though the interaction of main plots and sub plots failed to show significant difference: irrigating 30mm water depth per seven days interval gave high total and marketable yield, low unmarketable yield and better water use efficiency. Irrigating per ten days interval also gave high marketable and low unmarketable yield.

Key words: irrigation interval, marketable yield, water use efficiency

Introduction

As an Agrarian state, Ethiopia's economy is entirely dependant on natural resources, land and water, and the same is true for Amhara Region. For the attainment of food self-sufficiency in the region and the country as a whole, it is necessary to utilize these resources wisely and efficiently by harmonizing it with the labor power.

Though Amhara Region is endowed with ample amount of water resources that can be utilized for irrigation, what is utilized so far is insignificant share of the potential. Currently there is a good start to intensify irrigated agriculture. However, most of irrigation practices in the region are run traditionally without considering the spatial and temporal supply of water that in turn affects growth, quantity and quality of crop production.

According to the diagnostic farming system survey of Kewot and Efratana Gedim woredas, there is immense water resources (streams and springs) with potentials for irrigation at both high lands and low lands. However, most of the irrigated farms are found in the low lands mainly Shewarobit, Jewha, Negesso, and Yellen. Extensive use of irrigation at Jewha – Negesso dates back to 1975, but not all potentially irrigable land is still cultivated because the amount of water currently diverted is not enough to irrigate the farmlands (Survey report of Efratana Gedem Woreda, 2001**).**

Onion, the main supplementary component of our daily diet and the high valued cash crop of the area, is the dominant vegetable crop growing by irrigation in these areas. According to A.M. Michael (1981) schedule irrigations of vegetables to maintain continues high soil moisture level in the soil is essential to get desirable yield.

The irrigation system of the study area is mainly traditional and has not been supported by improved technologies that could maximize productivity and water use efficiency. The ultimate economic and environmental consequence of poorly managed irrigation is the destruction of an area's productive base because application of too little water is an obvious waste as it fails to produce the desired benefit. Excessive flooding of the land is still more harmful as it tends to saturate the soil for too long, inhibit aeration, leach nutrients, induce greater evaporation and salinity, and ultimately raise the water table to a level that suppress normal root and microbial activity and that can only be drained and leached at great expense (Daniel, H., 1997)

The experimental area is about 200 km away from Addis Ababa on the road to Mekelle at latitude of 12° 1' 11" North of the equator and longitude of 39° 37' 48" East of the Prime Meridian. In the experimental irrigation scheme, when and how much to irrigate is determined by Water Users Committee of the Schemes based on the amount of available water with out considering land size, soil type, crop type, weather conditions. This causes farmers to apply excess water until water logging is created because they fill that, unless it is extremely irrigated, it will face water stress until their turn reaches. This led to the decrement of yield quality and quantity in addition to its soil degradation impact such as salinity development and soil erosion.

In a three-year experiment conducted at Worer, onion was found to respond better at frequent rather than prolonged intervals of irrigation and maximum fresh bulb yield was recorded for an irrigation regime of one week frequency and 50 mm application (Michael, A. 2001). The over all three year results of Melkassa also reveal that 50 mm of water at 3-6 days intervals gave the highest yield with the optimum water use efficiency (Lemma, D. and E.Hearth.1992).

But there are not any researches done before in this area regarding irrigation scheduling for better yield and quality of onion while utilizing resources efficiently. Therefore this study was conducted for two years to determine the optimum irrigation amount and frequency of onion in order to utilize water resources in an environmentally friendly and economically feasible way while improving the yield

Materials and Methods

Treatments were set uniformly using Blanely Criddle Crop Water Requirement estimation method (to determine 30 mm per four days interval), previous recommendation from Worer Research center (50 mm water depth per week) and additional 70 mm water depth with various intervals. Blanely Criddle is used for initial estimation because of data limitation for other methods.

Onion seedlings were raised in the nursery and transplanted to the experimental fields at the stage of having three to four true leaves. Recommended onion spacing,40 cm bed including furrow, 20 cm between rows on bed 10 cm between plants used during transplanting. The experimental design was split plot design with three replications using four irrigation intervals i.e. 4, 7, 10, 13 days as sub plot and three watering depths 30, 50, 70 mm as main plot treatments. Though it was intended to include farmers traditional irrigation amount and frequency as treatment, finding common practice was very difficult. The random application of irrigation practice based on the availability of water, labor and time makes it difficult to include it as a treatment.

Prior to the application of treatments, common (equal amount) irrigation was applied daily for all experimental plots for one week to favor the establishment of seedlings. The amount of irrigation water for each plot was measured using partial flume in the first year and barrel fitted with plastic hose, which delivers water to the plot in the second year. Recommended Crop protection and agronomic activities were practiced during the experiment.

Data collected include total, marketable, and unmarketable (Decay, split, bolt and under weight) bulb weight, dry matter content, total soluble solids, storability, bulb color and vegetative data (leaf number, plant height, sheath length). Though data on pungency and trips count were planned, undertaking trips count was found to consume too much onion stands and there are no in land laboratories for pungency analysis.

Results and Discussion

Analysis of Variance was conducted by combining two years of irrigation seasons data using SAS statistical software. Analysis of variance shows as there is no significant difference between main plot treatments, depth of irrigation water, for most analyzed parameters except water use efficiency (WUE). Water use efficiency of irrigating 30 mm irrigation depth gave the highest efficiency. Sub plot treatment, irrigation interval, is found more important to affect total, marketable and unmarketable yield than depth of irrigation for this specific location. Though there is no significant difference of parameters for most main plot treatments, irrigating 30 mm depth gave better total and marketable yield, water use efficiency and low unmarketable yield.

Total yield, marketable yield, unmarketable yield (decay, split and bolt), average bulb weight, average leaf number, average sheath length and plant height were found significantly different for irrigation interval while only average sheath length and plant height shows significant difference for irrigation water depth.

A study was conducted for three years at Melkassa using adama red variety to identify the optimum irrigation regime that gives high yield under upper awash sandy loam soil condition. In the study, from three levels of irrigation regimes (3, 5, and 7 cm) and four frequencies (3, 6, 9 and 12 days) relatively higher yield was obtained in the first two frequencies with the highest being at 5cms of water (IAR, 1988a). However, in our case the interaction between main plots (irrigation depth) and sub plots (irrigation interval) is not found significantly different except for unmarketable yield. The rainfall condition of the area during the irrigation season (140.9 mm during first year and 179.1 mm second year) which is by far higher than average value of previous ten years, which was 57.9 mm from 1983 – 2000, and the heavy clay nature of the soil which holds water for long may have contributed for non significant interaction between irrigation depth and frequency. Moreover, the practice of unregulated continuous irrigation system may have raised the ground water level that may limit the downward movement of applied irrigation water. The color of onion bulb for all treatments was the same, Amaranth.

Effect of Irrigation interval on yield, quality and Water use efficiency

From table 1, total yield for four and seven days irrigation interval is relatively higher and significantly different from other intervals while there is no significant difference between the two intervals. However, irrigation per four days interval is not significantly different from 10 days interval, which is lower and significantly different from seven days interval. From all irrigation frequencies, 13 day irrigation interval gave the least and significantly different total yield. As interval increases from seven days to thirteen days, the average total yield decreased by 59.52 qt/ha. Therefore irrigating per seven days interval is better and safe to get relatively higher total yield.

Marketable yield for frequencies of four, seven and ten days interval is found relatively better and not significantly different each other. But marketable yield for four days interval is not significantly different from thirteen days interval which is the least and significantly different from seven and ten days interval. Therefore, seven and ten days interval are relatively better and safe to get better marketable yield. Marketable yield here refers to yield without any physiological and disease problem.

Table 1. Average Total and Marketable yield of onion for the whole experimental season

Main Plot	Year 1/1998		Year 2/1999		Combined	
	Total Yield (qt/ha)	Marketable yield (qt/ha)	Total Yield (qt/ha)	Marketable yield (qt/ha)	Total yield (qt/ha)	Marketable Yield (qt/ha)
1(30mm)	252.88a	154.955a	183.87a	163.88a	218.38a	159.419a
2(50mm)	246.15a	136.783b	164.48a	147.65a	205.32a	142.217a
3(70mm)	245.41a	131.162b	176.54a	158.48a	210.97a	144.821a
C.V (%)	5.0	6.3	9.9	9.2	7.8	9.4
LSD(0.05)	NS	16.312	NS	NS	NS	NS
Sub Plot						
1(4days)	243.45b	121.507b	191.51a	168.41a	217.48ab	144.96ab
2(7days)	288.46a	154.475a	188.35a	162.26a	238.40a	158.37a
3(10days)	242.45b	155.733a	180.47a	165.08a	211.46b	160.41a
4(13days)	218.23b	132.152b	139.53b	130.94b	178.88c	131.54b
C.V (%)	5.1	5.2	8.6	7.9	6.8	8.1
LSD(0.05)	26.212	18.835	36.465	30.247	23.599	19.92

As can be seen in table 2, dry Matter content does not show significant difference per irrigation intervals. This indicates as the interval and amount of irrigation in that specific location are not important to affect the dry matter content of onion. Average bulb weight for four and seven days irrigation frequency is found better than other frequencies. But irrigating per four days interval is not found significantly different from 10 days interval which is not significantly different from 13 days interval which is the least of all. Therefore irrigating per seven days interval is relatively better and safe to have high average bulb weight. Total soluble solids laboratory analysis for first year samples was done by taking composite samples from combined samples of the same treatment from all replications; therefore it was not possible to undertake statistical analysis. For this reason, here the second year data is used for interpretation. Irrigating per seven days interval was found to give good and significantly different total soluble solids.

From water use efficiency (WUE) perspective, irrigating per ten and seven days interval gave the highest water use efficiency and irrigating per four days interval the lowest. From the analysis trend, WUE decreases as irrigation frequency decreases.

Table 2. Average dry matter content, bulb weight and total soluble solids of onion

Plots	Year 1/1998		Year 2/1999			Combined		
	Dry matter Content (%)	Average bulb weight (gm)	Dry matter content (%)	Averag e bulb weight (gm)	Total soluble solids (%)	Dry matter content (%)	Average bulb Weight (gm)	WUE (kg/lt)
Main plot								
1(30mm)	22.01a	101.94a	13.51a	59.25a	12.74a	17.76a	80.59a	0.41a
2(50mm)	22.07a	100.38a	13.26a	53.99a	12.77a	17.67a	77.19a	0.23b
3(70mm)	21.66a	104.73a	13.56a	55.36a	12.52b	17.61a	80.05a	0.16c
C.V (%)	3.9	4.3	2.4	9.1	0.57	3.5	7.4	8.25
LSD(0.05)	NS	NS	NS	NS	0.1316	NS	NS	0.0275
Sub Plot								
1(4days)	22.62a	98.47b	13.94a	61.97a	12.36c	18.28a	80.22ab	0.12c
2(7days)	21.42a	114.36a	13.39a	61.84a	13.07a	17.40a	88.09a	0.23b
3(10days)	22.29a	99.91b	13.29a	55.82a b	12.59b	17.79a	77.87bc	0.36a
4(13days)	21.34a	96.67b	13.15a	45.18b	12.69b	17.24a	70.92c	0.38a
C.V (%)	3.4	4.4	2.1	7.8	0.5	3.1	6.4	8.25
LSD(0.05)	NS	10.95	NS	10.73	0.152	NS	8.33	0.03

Unmarketable yield of ten and thirteen days irrigation interval gave least and significantly different yield from four and seven days interval. From unmarketable yield components, decay has shown the same trend as total unmarketable yield. Split is also high and significantly different for seven days interval. However, split is considered as unmarketable for export; in

Ethiopian case it is traditionally marketable. The amount of onion with bolter problem is found least for thirteen days irrigation interval, but other intervals did not show significant difference for this bolt problem. The other unmarketable component i.e. under sized/under weight (below 20 gm bulb weight) does not show significant difference for all frequencies (Table 3 and 4).

Table 3. Mean value of unmarketable yield and its components

Plots	Year 1/1998		Year 2/1999		Combined	
	Unmarketable Yield (qt/ha)	Decay (qt/ha)	Unmarketable Yield (qt/ha)	Decay (qt/ha)	Unmarketable yield (qt/ha)	Decay (qt/ha)
Main plot						
1(30mm)	97.929a	50.588a	19.991a	6.991a	58.960a	28.789a
2(50mm)	109.371a	56.624a	16.833a	5.094a	63.102a	30.859a
3(70mm)	114.244a	68.376a	18.055a	4.985a	66.149a	36.681a
C.V (%)	9.0	16.4	24.4	49.1	11.8	23.4
LSD(0.05)	NS	NS	NS	NS	NS	NS
Sub Plot						
1(4days)	121.940a	78.632a	23.100ab	6.743ab	72.52a	42.688a
2(7days)	133.987a	74.501a	26.086a	9.763a	80.04a	42.132a
3(10days)	86.718b	39.815b	15.391bc	3.981ab	51.05b	21.898b
4(13days)	86.082b	41.168b	8.595c	2.273b	47.34b	21.721b
C.V (%)	7.8	14.2	21.1	42.5	10.3	20.2
LSD(0.05)	20.381	20.217	9.4061	5.8934	10.615	10.722

NS = non significant

Table 4. Mean value of unmarketable yield components

Plots	Year 1/1998			Year 2/1999			Combined		
	Split (qt/ha)	Bolt (qt/ha)	Under Weight (qt/ha)	Split (qt/ha)	Bolt (qt/ha)	Under Weight (qt/ha)	Split (qt/ha)	Bolt (qt/ha)	Under Weight (qt/ha)
Main plot									
1(30mm)	33.547a	12.981a	0.8140a	4.194a	5.688a	3.1181a	18.871a	9.334a	1.966a
2(50mm)	37.714a	14.530a	0.5034a	3.264a	3.578a	4.8972a	20.489a	9.054a	2.700a
3(70mm)	32.585a	12.607a	0.6760a	4.519a	4.887a	3.6632a	18.552a	8.747a	2.170a
C.V (%)	14.6	18.1	34.8	66.5	37	28.3	20.9	24.7	36.1
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub Plot									
1(4days)	26.353b	15.954a	0.9999a	5.637ab	7.595a	3.125a	15.995b	11.775a	2.0624a
2(7days)	42.877a	15.954a	0.6536a	7.429a	5.708a	3.187a	25.153a	10.831a	1.9203a
3(10days)	33.903ab	12.607ab	0.3927a	1.903ab	5.171a	4.336a	17.903b	8.889a	2.3642a
4(13days)	35.328ab	8.974b	0.6117a	1.002b	0.396b	4.924a	18.165b	4.685b	2.7676a
C.V (%)	12.7	15.7	30.2	57.6	32	24.5	18.1	21.4	31.3
LSD(0.05)	10.693	5.11	NS	5.5991	3.6807	NS	5.773	3.1948	NS

From the above findings, we can understand that irrigating per four and seven days interval gives high unmarketable yield. This may be directly linked to high amount of applied irrigation water related to other treatments. Therefore, as the amount of applied irrigation water increases the amount of unmarketable yield components decay and bolt increases.

Regardless of high amount of unmarketable yield recorded for four and seven days irrigation interval, the amount of total and marketable yield for seven days intervals is higher. Taking in to consideration as split, here we considered as unmarketable, marketable in local markets, irrigating per seven days interval gives high marketable and low unmarketable yield.

Therefore irrigating per seven days interval is relatively advantageous for total, marketable and unmarketable yields and for better average bulb weight. But in a situation when labor and water are serious problems in the irrigation area, irrigating per ten days interval can give higher marketable yield though not significantly different from four and seven days interval.

Effect of Irrigation interval on Vegetative development

From Table 5 it is possible to see that vegetative data (average leaf number, average sheath length and plant height) gave high value for four and seven days interval, but seven days interval is not significantly different from ten days interval for sheath length and plan height. As previously discussed, irrigating per four and seven days interval gave high and significantly different average bulb weight. Therefore, we can say that as the frequency of water application increases the vegetative condition of onion will be the better and this will increase the average bulb weight of onion. Hence, irrigating more frequently may be important when there is a need to produce better average bulb weight.

Table 5. Mean value of Vegetative data (leaf number, sheath Length and plant height)

Plots	Year 1/1998			Year 2/1999			Combined		
	Average Leaf no	Average Sheath Length (cm)	Plant Height (cm)	Average Leaf no	Average Sheath Length (cm)	Plant Height (cm)	Average Leaf No	Average Sheath Length (cm)	Plant Height (cm)
Main plot									
1(30mm)	12.118a	5.929a	59.288a	11.2289a	8.9965ab	46.073a	11.6736a	5.929a	52.681ab
2(50mm)	12.267a	5.463b	59.354a	11.2292a	9.3958a	46.823a	11.7479a	5.463a	53.089a
3(70mm)	12.650a	5.404b	59.275a	10.3056a	8.3085b	42.326b	11.4778a	5.404b	50.800b
C.V (%)	3.5	4.3	2.6	7.3	4.7	3.3	5.3	7.9	3.0
LSD (0.05)	NS	0.4255	NS	NS	0.7541	2.8469	NS	0.5447	1.9194
Sub Plot									
1(4days)	13.219a	6.139a	61.368a	11.9431a	10.2467a	48.629a	12.5810a	8.193a	54.998a
2(7days)	12.294b	5.683a	60.322a	11.6574ab	9.5417a	46.032ab	11.976a	7.613ab	53.177ab
3(10days)	12.106b	5.772a	59.672a	9.9782b	8.2619b	43.759bc	11.042b	7.017b	51.716b
4(13days)	11.761b	4.800b	55.861b	10.1061b	7.5509b	41.875c	10.934b	6.176c	48.868c
C.V (%)	3.0	3.7	2.3	6.3	4.1	2.9	4.6	5.3	2.6
LSD (0.05)	0.903	0.4913	3.2354	1.6422	0.8708	3.2874	0.8858	0.629	2.2164

Conclusions and Recommendations

Though there was clear visual observation at field condition, irrigation frequency and depth interaction failed to show significant difference for yield and other quality parameters except water use efficiency. Heavy clay soil which can hold water for long, higher rainfall condition during the research period and ground water level change because of continuous irrigation may have contributed for lack of interaction. Though it is irrigation frequency found more important in the study area, irrigating 30 mm depth gave better total and marketable yield, water use efficiency and low unmarketable yield.

From water use efficiency (WUE) perspective, irrigating per ten and seven days interval gave the highest water use efficiency and irrigating per four days interval the lowest. From the analysis trend, WUE decreases as irrigation frequency decreases.

From the study, irrigating per seven days interval at clay soils of Kewot irrigation areas, gave high total and marketable yield, water use efficiency, average bulb weight, total soluble solids and vegetative data. Irrigating per ten days interval also gave high marketable and low unmarketable yields and high water use efficiency. However, when we consider marketable in Ethiopian context by including split as marketable, irrigating per seven days interval outsmarts marketable yield in addition to its higher values of average bulb weight, total soluble solids and vegetative condition.

Therefore, 30 mm irrigation depth per seven days interval is relatively advantageous in clay soils of Kewot and other similar areas where the soil and agro climatic conditions are identical. But in a situation when labor and water are serious problems in the irrigation area, irrigating per ten days interval can give higher marketable yield with minimal water consumption though not significantly different from four and seven days interval.

Though the best possible interactions between irrigation depth and frequency were identified for the treatments of the study, investigating the exact reason for the insignificancy of irrigation depth and frequency interactions or searching significantly different and combinations will help a lot to determine appropriate and better irrigation scheduling for onion in the area.

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Investigation of Drainage Problems around Chacha Area, North Shewa

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Abstract

Production is augmented by increasing cultivated area and/or increasing the productivity of a unit land. However, rising productivity of the existing cultivated land is the most feasible option since arable land can not be indefinitely increased. Often it is observed that some cultivated lands are not being cropped at pick production seasons due to various reasons. The Chacha area is among such places where waterlogging has impaired production in the main rainfall season for which the mechanism was not known. The case for Chacha irrigation schemes was investigated by studying the soil properties, monitoring the ground water fluctuations with the seasons and ground configuration. The soil in the irrigation scheme was primarily clay textured and black in color with water holding capacity moderately high to high, low infiltration and low hydraulic conductivities (3-12 mm per day). Piezometer observation proved there existed high ground water table levels starting late June to early November 2006 and during late April and early May 2007. Based on the study results, it is recommended that the natural drainage capacity of the river be enhanced, since waterlogging was brought about by lack of sufficient drainage, in order to cultivate the area during the rainy season.

Key words: electrical conductivity, soil pH, water logging

Introduction

Production is said to be augmented by increasing cultivated area and/or increasing the productivity of a unit land. Even so, cultivated land can not be indefinitely increased. As a result rising land productivity is the most feasible option. Productive soil and crop management contributes towards productivity of land. However, often it is observed that some lands are not being cultivated at pick production seasons. For example, large portions of land in North Shewan plateau are currently not cultivated during rainy season due to waterlogging. The Chacha area is among such places where waterlogging has impaired production in the main rainfall season. This study focuses on the newly built irrigation scheme which has a serious waterlogging problem. The scheme is mainly covered by Vertisols where soil drainage is a problem. Vertisols owe their specific properties to the dominance of swelling clay minerals. Dry Vertisols may have a high infiltration rate but, when wetted, they become almost impermeable. Crops need a well drained root zone for optimum growth and productivity. The main objective of agricultural land drainage is therefore to remove excess water in order to enhance crop growth and improve crop yields there by improve the profitability of farming the land. However, drainage requires prior investigation of the source and type of waterlogging problem.

Agricultural drainage systems are systems which make it easier for water to flow from the land, so that agriculture can benefit from subsequent reduced water levels. Agricultural land drainage has two criteria. 1) Agricultural drainage criteria defined as criteria specifying the highest permissible level of the water table on or in the soil so that agricultural benefits are not reduced by the problem of waterlogging. 2) Technical drainage criteria are criteria to minimize costs if installation and operation of the drainage system (R.J. Oosterrbaan 1994).

The importance of land drainage is substantiated whether waterlogging happens each year or is it only a problem in very wet years. Obviously if it is a regular problem, and lasts for many weeks, then it is more important to do something about it. In this regard the problem of waterlogging in Chacha area is a regular phenomenon. The other important concept in land drainage is whether there is a sufficient outlet.

This is probably one of the most important factors to be considered. In some areas where the land is relatively flat, there are insufficient main drains to take away excess water quickly. A further complication is that often these are not deep enough, which limits the ability of the farmer to drain land on his own property. If this is the problem then the only solution is for landholders to have group drainage schemes that enable sufficiently deep and large main drain systems to be dug over a large area, and which are properly maintained so that no harm is done to the environment. Therefore, this experiment was intiated with the objective of of dentifying the sources and extent of excess water that cause water logging in Chacha irrigation scheme so that drainage options could be considered.

Materials and methods

The Study area is located near Chacha town between $9^0$31’21” and $9^0$32’33” N and $39^0$27’9” and $39^0$28’57” E has an annual rainfall of 984 mm. Its maximum humidity reaches to 90 %. The topography is dominantly flat with a slope of 2%. There is a recently built irrigation scheme by Co-SEARAR facing waterlogging problem during the main rainy season. The design flood is about 90 lit/sec of 10 year return period (Co-SEARAR, 2002).Crop production commences after the recession of flood. This phenomenon has been the case for years. Currently, cultivation is performed once in a year in the irrigated areas as in the rain fed system.

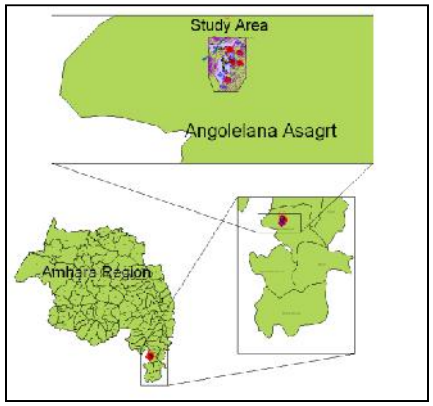

Figure 1. Chacha, the study area

Six profiles (see locations in figure 2) were opened within and around the scheme to see soil properties. Moreover, topographic investigations were performed to study the cause of waterlogging problem in Chacha area. Water tables react to the various recharge and discharge components that characterize a ground water system and is therefore constantly changing. Therefore, the highest and lowest water table heights, as well as the mean for the year are important in any drainage investigation. For this reason, water level measurements were taken at intervals of one week using PVC piezometer wells. The piezometers were installed by digging a hole using a 10 cm diameter auger until an impervious layer is reached or sufficiently deep to study the water table fluctuation. Then, a perforated 5 cm diameter PVC tubes were inserted filing the gap with coarse sand. The tubes were made to rise above the ground level to prevent surface water entrance. Finally, the mouth of each tube was cased in a metal pipe with screw opening to safeguard it from any mechanical damage by people or animals. The piezometers were situated in the plane containing the irrigation scheme in two rows one in a higher elevation and the second in a lower elevation along the river coarse.

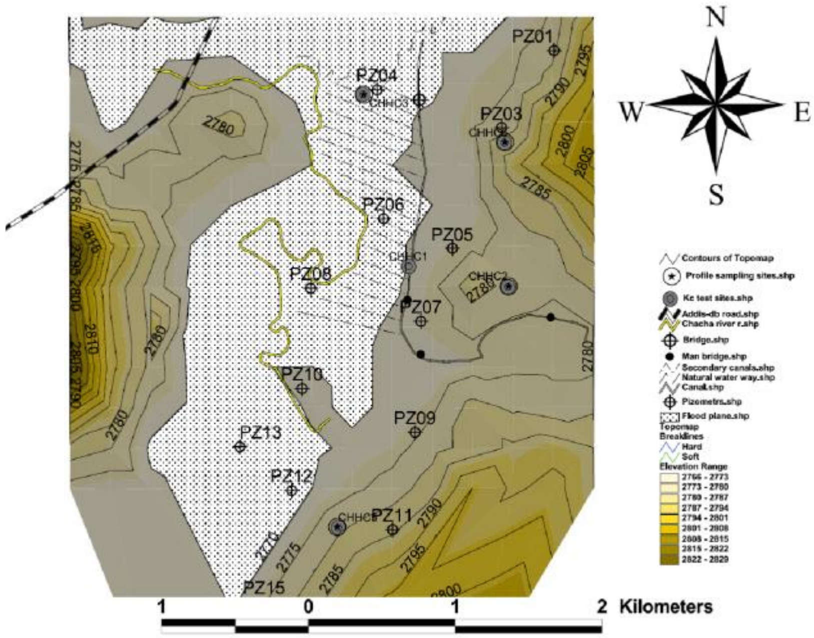

Figure 2. Details of the study area

An inverse auger-hole test was conducted to evaluate the hydraulic conductivity in the irrigation scheme and in the surrounding farms at different elevation and soil type. Five sites were selected in which the tests were performed. Hydraulic conductivity in a inverse auger hole method is given by Kh= 1.15r tan □ where Kh, r and tan □ are hydraulic conductivity, radius of auger hole and slope of time vs log (water level +r) graph.

Result and Discussion

The soil in the irrigation scheme was primarily clay textured and black in color. The water holding capacity is moderately high to high (180-240 mm/m) with low infiltration (Co-SEARAR, 2002). The soil reaction was in the near neutral to basic range (table 1). Hydraulic conductivities were found to be 3 cm day^{-}, 238.5 cm day^{-1}, 11.9 cm day^{-1}, 9 cm day^{-1} and 6 cm day^{-1} for tests 1, 2, 3, 4, and 5 respectively.

Tests 1, 3, 4, and 5 conducted with in the irrigation scheme were with values were less than 10 cm per day. These areas entertain a huge amount of water by the rain and flood. Test 2 however, which was conducted at higher elevation and different soil type was with high conductivity. This area represents the farms which are currently being cultivated in the rainy season.

Table 1. Soil properties by profile and depth.

Field No	Depth [cm]	pH 1:2.5	EC [dSm^{-1}]
Profile One	0-20	6.40	0.089
	20-50	6.84	0.055
	50-75	8.90	0.251
	75-140	7.88	0.172
	>140	9.10	0.333
Profile Two	0-20	6.44	0.035
	20-60	7.14	0.079
	60-80	6.93	0.165
	>80	7.84	0.084
Profile Three	0-15	5.58	0.155
	15-50	6.48	0.115
	50-95	8.13	0.063
	95-120	8.96	0.182
	>120	8.86	0.109
Profile Four	0-25	6.48	0.115
	25-47	6.48	0.056
	47-63	6.69	0.043
	63-98	6.88	0.058
	98-130	6.36	0.088
	>130	7.50	0.058
Profile Five	0-10	5.38	0.091
	10-50	6.24	0.045
	50-80	6.88	0.071
	80-130	7.48	0.189
	130-160	7.25	0.221
	>160	7.25	0.149
Profile Six	0-12	6.22	0.045
	12-60	6.95	0.063
	60-90	7.81	0.130
	90-110	9.01	0.190
	>110	9.04	0.178

Excess water may occur on the surface or deeper in the soil profile. These are manifested in the form of surface ponding often combined with waterlogging of the top soil or rootzone waterlogging due to impaired percolation or high water tables. Piezometer observation proved there existed high ground water table levels starting late June to early November 2006 and during late April and early May 2007. It is also depicted that some land was inundated during August to September.

For most perennial crops the root zone is said to be 1.5 m. Having this as a critical water table depth, crop production during March, April, early May, late June, July August, September, October and early November will face waterlogged condition. However, since the commonly produced crops are cereals and crop yields and water table depth relationship for clay soils minimum yield decrease is at a depth of 1 meter (Smedema and Rycroft, 1983), crop production is expected to be hampered mostly in July, August, September and early October. Lands which were submerged and with high water levels were with in the Chacha irrigation project area. It is evident from the observation that it was difficult to cultivate the farms with in the above stated times with out proper drainage system installed.

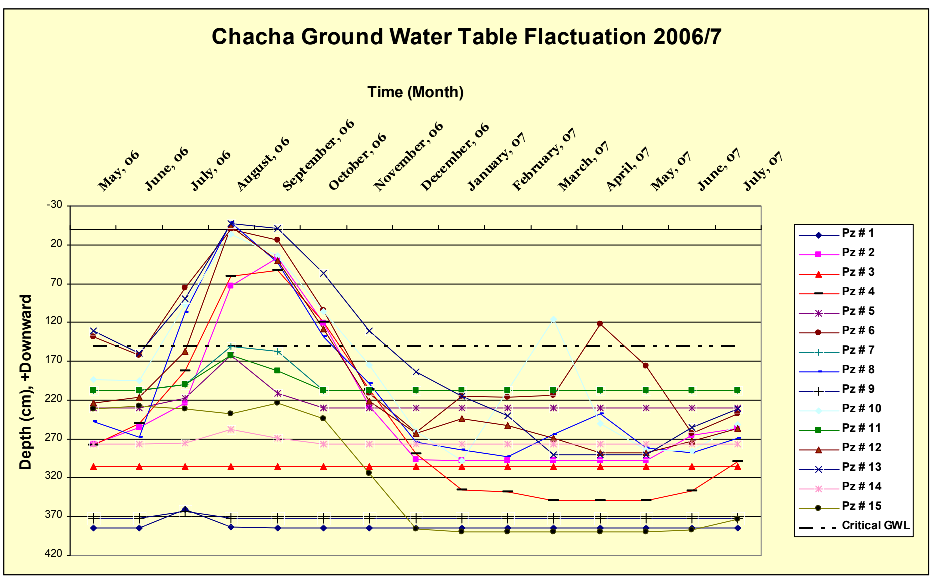

Figure 3. Water table fluctuation in the 15 piezometers

The Chacha irrigation project was established in the flood plane of Chacha river basin around Chacha town. The river Chacha originates in the eastern high lands of the wereda, Megezez area. It also drains the flood plane of the nearby plateau. There are reports of frequent flooding in Chacha town. The rainfall amount in the experimental year was relatively lower than the previous years. In the rainy season the plane is often flooded as a result the scheme is submerged. As seen in fig 1, the scheme has similar elevation as its surrounding and the down stream of the river. This makes draining the water very difficult. Hence, it could be easily seen that utilization of the scheme in the rainy season is still difficult even with the presence of drainage system.

In the light of the experiment results, the cause of waterlogging in the scheme is believed to be attributed to high water tables caused by floods coming from the upper lying lands. Poor drainage system of the area as a whole and due to topographic condition, the rainwater cannot smoothly discharge, and the accumulated runoff remains stagnant in low laying retention areas and surrounding the river thereby creating severe waterlogging problem.

The reason of long lasting waterlogging situation in the area is owing to inadequate drainage capacity of the river, meaning lack of enough inlets to the receiving water bodies and natural drains helped in creating drainage congestion. Waterlogged pastures over winter and early spring are a common sight on many farms in high rainfall areas.

The Chacha river water has a good quality for irrigation in terms of its electric conductivity.

Conclusion and Recommendation

In conclusion, the Chacha irrigation area was characterized by black heavy clay soil which was regularly inundated during the main rainy season. The area has low hydraulic conductivity and infiltration capacity. It is situated on a flat flood pain drained by the river Chacha. It had water tables above and close to the surface during March, April, early May, late June, July August, September, October and early November. Cultivation was practiced after the rains when the natural drains reduce the water table.

Based on the study results, it is recommended that the natural drainage capacity of the river be enhanced, since waterlogging was brought about by lack of sufficient drainage, in order to cultivate the area during the rainy season. The enhancement must concentrate on the receiving water bodies or ways found to the west of the town. However, it may require huge investment. Without this, surface or subsurface drainage could not result in making the area produce more than it is currently doing. Therefore, the current production system should prevail taking note of the expected flood and waterlogging period.

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Investigation on Salinity Problem of Efratana Gidim and Kewet Weredas

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Abstract

Among the methods of agricultural production intensification, irrigation is considered prominent. However, in order to harvest the virtues of irrigation sustainabley, the production system must be enhanced towards the potential use of resources maintaining it without causing waterlogging and salinization. Often times, irrigation is associated with salinization in many parts of the world. In North Shawa, Salinity problem has manifested itself to the extent that farmers are experiencing tremendous yield losses, especially on vegetable crops, and some farms had to be abandoned or farmers had to switch to producing more salt tolerant crops. Methodical approaches towards reclamation of these salt-affected soils and/or prevention of development of non-saline soils to saline or alkaline soils is very essential in transforming rainfall dependant traditional agriculture to sustainable irrigated agriculture. Soil and water qualities of Yellen and Jeweha areas were investigated to support the decision making process and to benchmark the problem of salinity. Soil profile and surface samples and temporal water samples were analyzed. Soil types in the study area were mainly black and brown. The samples from the black Vertisols of Garda were found to fall in the saline range while the samples from the brown soils were non saline. The lower layers of the excavated profile were saline showing the potential alkaline soil development. A wide area of salt affected soil as well as shallow ground water was found in Wacho. Most of irrigation sources fall in the high salinity class but were low sodicity and safe to marginal residual sodium carbonate content.

Key words: Cation exchange capacity, Electrical conductivity, exchangeable sodium percentage, soil profile

Introduction

Land is one of the basic resource bases of production in agriculture. While demand is increasing as a result of growing human and livestock population, the vital land resource is finite and there is a limit to its expansion. With growing claim for land from non-agricultural sectors, such as residence, industry and infrastructures, bringing new land under cultivation might not be feasible in the future. Accordingly, appropriate means to intensify agricultural production will spin around upon our efforts to manage the existing soil and water resources for maximum production.

It is known that, one method of intensification of agricultural production is through irrigation. However, irrigation should be managed well to derive the merits out. In order to harvest the virtues of irrigation sustainabley, the production system must be enhanced towards the potential use of resources maintaining it without causing waterlogging and salinization. Incorporation of water of any quality adds salts to the soil. In the long run this results in the accumulation of soluble salts which will cause salinity problems mainly in arid and semi arid regions.

Large amount of salt-affected areas are found worldwide in places where precipitation to evaporation ratios are 0.75 or less (Brady and Weil, 1999). In Australia, Africa, Latin America, and in the Near and the Middle East countries these soils are widely present. About 951 million hectares of land is affected world wide and 80.4 million hectare of it is shared by Africa (Abrol et al., 1988). Ethiopia is not an exception to the problem although irrigation is not widely developed compared to the potentially irrigable area. In fact it stands first in acreage of saline soil in Africa (Abrol et al., 1988). According to FAO (2005), Ethiopia has 10.61 million ha saline and 425,000 ha sodic land. The semi-arid and arid lowlands and valleys have major problems of salinity and alkalinity. Tamirie (no date) reported that 44 million ha is potentially susceptible to be salt affected. Out of the 44 million ha, 75 % have dominantly salinity problems, 18 % have combined salinity and alkalinity problems and 7 % have dominantly alkalinity problems.

According to Tamirie, out of the 170,000 ha under irrigation by state farms in Awash Valley and in Central Rift-Valley lake area, almost 10 % (11,000 ha) are feared to have been salinized and have already gone out of production. Likewise, in North Shawa, Salinity problem has manifested itself to the extent that farmers are experiencing tremendous yield losses, especially on vegetable crops, and some farms had to be abandoned or farmers had to switch to producing more salt tolerant crops. For example, in Efratana Gidim Wereda at Negesso Kebele, about twenty farmers lost their fields to salinity (Yonas, 2002).

Methodical approaches towards reclamation of these salt-affected soils and/or prevention of development of non-saline soils to saline or alkaline soils is very essential in transforming rainfall dependant traditional agriculture of the locality to sustainable irrigated agriculture. Assessing soil and water qualities for salinity and suggesting remedies are fundamental in management decision options. Therefore, this experiment was initiated to assess salinity status of water and soils of Yellen and Jeweha for future management or economic reclamation options.

Materials and methods

The study area is found at 10^{o}5'32" N Latitude and 39^{o}54'51" E Longitude at about 1197 meter above sea level average elevation within the Awash river basin in the East African Rift Plateau. This area is administered by two weredas, to be precise Kewet and Efratana Gidim. Yellen kebele belongs to Kewet while Jeweha is to Efratana Gidim. It is located at a distance of about 235 km to the north east of Addis Ababa. The annual average rainfall from 18 years record at Shewa Robit town was 1007.8 mm and the temperature ranges from 16.5 ^{o}C to 32 ^{o}C (Kewet Wereda Bureau of Agriculture, unpublished data). Koch *et al.*, (1990) reported that the annual evapotranspiration is 1517 mm.

The study area is one of the widely irrigated areas of North Shewa Zone having various springs, the river Jeweha and its tributary Sewer as sources of irrigation water. The area is mainly cropped with tef, sorghum, onion, maize and tobacco.

Soil and water samples were gathered to appraise the importance of salinity. Point surface soil samples were collected by auger sampling to the depth of 30 cm at 15 cm intervals from localities; Wacho, Negesso1, Negesso2, Goleguadisa, Garda, Godguadit, Abunu and Negesso Chaka within the study area. Water samples were taken from springs and rivers. Rivers were also monitored for temporal fluctuation in salt contents. A soil profile was opened at Wacho to a depth of 1.7 m to see the vertical distribution of salts. Samples were collected at 30 cm interval.

The soil samples were first air dried, ground and passed through 2 mm sieve to undergo the physical and chemical properties analyses. Texture was analyzed by the hydrometrical method. Soil bulk density was evaluated by taking core samples. Soil reaction (pH) was by pH meter. Electric conductivities were measured by compensating EC meter. Soil quality was assessed in terms of its electrical conductivity or the total dissolved solids

(TDS) of the saturated extract while water quality was assessed based on the salt content of the water sources. Irrigation water quality is primarily related to salinity and sodicity in terms of the total dissolved salts, the sodium adsorption ratio and residual sodium carbonate content. These criteria were used to assess the quality of the soil and irrigation water in the area. In this study the detailed profile soil and water investigation data were obtained from a similar thesis work [Yonas, 2006].

TDS content or the amount of soluble salts in the water is generally estimated by determining its electrical conductivity (ECw). Water salinity has four classes: C1, C2, C3 and C4 accounting for the low (0.1-0.25 dS m^{-1}), medium (0.25-0.75 dS m^{-1}), high (0.75-2.25 dS m^{-1}) and very high (> 2.25 dS m^{-1}) salinity levels (US salinity laboratory, 1954).
The sodium hazard of irrigation water is estimated by the sodium adsorption ratio, SAR. This is the proportion of sodium to the sum of calcium and magnesium in the water used for agriculture ($SAR = Na^{+}((Ca^{2+}+Mg^{2+})/2)^{-1/2}$). Water with SAR in the range 0 to 6 can generally be used on all soils with little problem of a sodium buildup. When SAR range from 6 to 9, chances for soil permeability problems are increased. Soils should be sampled and tested every 1 or 2 years to determine whether the water is causing a sodium increase (Hergert and Knudsen, 1997). The USSLS (1954) classify irrigation water into four sodium hazard classes as S1, S2, S3 and S4 to signify low, medium, high and very high hazard levels based on the amount of SAR content. The ranges in this system are <10, 10-18, 18-26 and > 26 for the low, medium, high and very high hazard levels respectively. High CO_3^{2-} and HCO_3^{-} tend to precipitate as calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) thereby essentially increasing the sodium hazard of the water to a level greater than that indicated by the SAR (Gupta and Stewart, 1990).

The carbonate and bicarbonate hazard criterion is appraised by the residual sodium carbonate content ($RSC = ((HC_3O^{-} + CO_3^{=}) - (Ca^{2+} + Mg^{2+})))$. RSC of less than 1.25 meq lt^{-1} guaranty a safe irrigation water while amount exceeding 2.5 results in an unsafe situations. Amounts ranging in between the two extremes are marginal (USSLS, 1954).

Result and discussions

Soil type in the study area was mainly black and brown soil known by the local names Tikure Mererie and Boda Afer respectively. All the samples from the black Vertisols of Garda were found to fall in the saline range while the samples from the brown soils were non saline. In Goleguadisa though the soil was tikur mererie the soil was none saline except two of the samples collected. The soil in Negesso 1 was partly saline. A wide area of salt affected soil as well as shallow ground water was found in Wacho. As a result, it felt important to look in to the profiles and detailed physical and chemical composition assessment.

Table 1. Saturated extract chemical composition

Depth (cm)	pH	EC_e dS m^{-1}	Cations (meq/ 100 gm Soil)				Anions (meq/ 100 gm Soil)				BSP
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	
0-30	9.2	0.51	0.33	0.01	0.09	0.04	0.21	nil	nil	0.25	101
30-60	9.3	0.77	0.65	0.01	0.06	0.04	0.24	0.18	nil	0.33	100
60-90	9.2	1.49	2.45	0.01	0.06	0.04	0.75	0.97	nil	0.80	102
90-120	8.9	6.99	3.86	0.02	0.84	0.04	3.83	nil	nil	0.72	104
120-150	8.9	7.98	4.55	0.02	1.00	0.05	4.37	nil	nil	1.07	103

Soil Profile Characterization

The saturated extract chemical composition and Densities, texture and Exchangeable cations of excavated profile are indicated in tables 1 and 2. The layers had high bulk density and clay percentage, which could be attributed to the dispersing ability of high exchangeable Na^+. This may be an indication of soil structure deterioration. The chemical analysis showed that soluble sodium to be the dominant cation in the profile.

Table 2. Selected physical and chemical properties of the soil profile

Depth cm	Bulk Density gm cm^{-1}	Textural Class	pH 1:2.5 H_2O	EC 1:2.5 dS m^{-1}	Exchangeable Cations meq/ 100 gm Soil				CEC meq/ 100g Soil	ESP	BSP
					Na	K	Ca	Mg			
0-30	1.46	Clay	9.80	0.43	5.53	2.95	33.14	8.77	60.00	9.22	84
30-60	1.48	Clay	9.60	0.69	11.45	1.93	33.62	6.80	64.36	17.79	84
60-90	1.62	Clay	9.50	0.94	14.38	1.68	36.17	7.20	66.36	21.67	90
90-120	1.54	Clay	8.30	5.02	16.56	1.52	34.55	8.85	64.86	25.53	95
120-150	-	-	8.30	5.81	20.00	1.47	34.83	9.66	67.36	29.69	98

In the profile, the ECe buildup with depth increment dictated by the washing down of the ions by irrigation. ECe value abruptly increased beyond layer three (60 - 90 cm). Sodium was still the dominant soluble cation followed by Ca^{2+}, Mg^{2+} and potassium. Soluble SO_4^{2+} dominated the top three layers while the last two layers were Cl^- conquered, from the anion point of view.

Calcium was the leading ion in the exchange complex in this profile. Sodium followed Ca, except in the first layer. Soil pH of the extract was also high. The ESP increased down the layers. Looking the salt distribution in the layers it could be said that salt mobilization may have resulted from irrigation. However, the fact that this profile had black, highly clayey and deep soil which indicates failure of soil structure, there is high probability that salinization was from below and reoriented by irrigation water.

Irrigation Water Quality Characterization

Irrigation water sources were also analyzed to asses their contribution in the salinization process. Irrigation water quality is primarily related to salinity and sodicity in terms of the total dissolved salts, the sodium adsorption ratio and residual sodium carbonate content. These criteria were used to assess the quality of irrigation water in the area.

It was observed that the pH in the investigated water samples was high. This is because of the presence of alkali ions mainly bicarbonates (Table 3). An increase in alkalinity is accompanied by an increase in pH (Gupta and

Abrol, 1990). Majority of electrical conductivities of the samples were also high. Therefore, most of these samples contained appreciably high concentration of dissolved salts sufficient enough to change salt free soils into saline and sodic conditions up on the continued uses of these water sources for irrigation. The dominant soluble cation in the irrigation waters was Na^+ while the dominant anions were HCO_3^- and SO_4^{2-}.

Table 3. Soluble chemical characteristics of irrigation water

Site location	pH	E.C dS m^{-1}	Cations (meq/lt)				Anions (meq/lt)			
			Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-
Ambo Spring	8.8	1.06	1.17	1.83	0.15	7.78	1.44	2.00	1.40	5.40
Bira Boy Minch	8.6	0.90	1.20	3.16	0.17	5.51	1.29	1.45	1.40	5.79
Tikure Diversion	8.5	0.89	2.72	1.44	0.17	4.51	1.59	3.47	0.40	3.00
Tikure Water Well	8.5	1.84	5.77	2.78	0.19	5.40	4.44	5.41	0.60	2.85
Kuribri at Monopol	8.6	0.22	0.87	0.40	0.10	0.84	0.27	0.11	0.50	1.55
Profile One	8.6	5.92	5.21	9.97	0.37	41.76	2.91	42.71	0.80	9.84
Eddo Chekecheq	8.6	0.35	0.97	0.68	0.12	1.51	0.39	0.33	0.40	2.70
Sewer Wenz	8.6	0.96	1.89	1.00	0.17	6.19	1.38	3.35	0.40	3.05

The stream water coming from Menz escarpment, Jeweha (kuribri), proved non-saline (0.22 dS/m) at the gate of the Tobacco Industry. However, as it led down stream it was contaminated with salt (0.9 dS/m at Tikure diversion). The Sewer River water was investigated as high saline at the diversion point as a result of amalgamation with Gola spring water and drainage water from the above irrigation scheme.

Table 4. Salinity hazard classes of investigated irrigation water

Site location	SAR	RSC	Salinity Class	Sodicity Class	RSC Class
Ambo Spring	6.35	3.79	High (C3)	Low (S1)	Marginal
Bira Boy Minch	3.73	2.83	High (C3)	Low (S1)	Marginal
Tkure Diversion	3.13	-0.76	High (C3)	Low (S1)	Safe
Tkure Water Well	2.02	-10.9	High (C3)	Low (S1)	Safe
Kuribri at Monopol	1.05	0.78	Low (C1)	Low (S1)	Safe
Ground water Dug	15.16	-4.54	Very High (C4)	Medium (S2)	Safe
Eddo Chekecheq	1.66	1.45	Medium (C2)	Low (S1)	Marginal
Sewer Wenz	5.15	0.56	High (C3)	Low (S1)	Safe

All irrigation water sources investigated were found to be non-sodic (table 4). Nonetheless, with regard to residual sodium carbonates criteria of the USSLS (1954) classification, 61 percent (RSC < 1.25 meq lt^{-1}) were safe for irrigating crops while 39 percent (RSC between 1.25 and 2.5 meq lt^{-1}) were marginally acceptable. It has been mentioned that the majority of irrigation water in this area were derived from springs. Besides, these springs were concentrated in and near Wacho village. Therefore, application of these saline spring waters without caution for irrigation in the traditional and modern irrigation schemes installed with poor drainage facilities must have contributed to the development of saline soils in the study area.

River water was monitored at four locations in the main Jeweha and tributary Sewer rivers namely Asmak, Balchi, Jeweha and Sewer. Observed seasonal fluctuation trends show, electrical conductivities of river waters in the wet regime were lower than the dry regime. The main rainy season, *Meher* (*Hamle and Nehase*), and the minor rainy season, *Belg* (*Tir*) had the smallest electrical conductivities while the rest had relatively higher salt contents in terms of electrical conductivity (Figure 1). The reason for this could be due to the dilution effect of non-saline surface run off during the wet seasons.

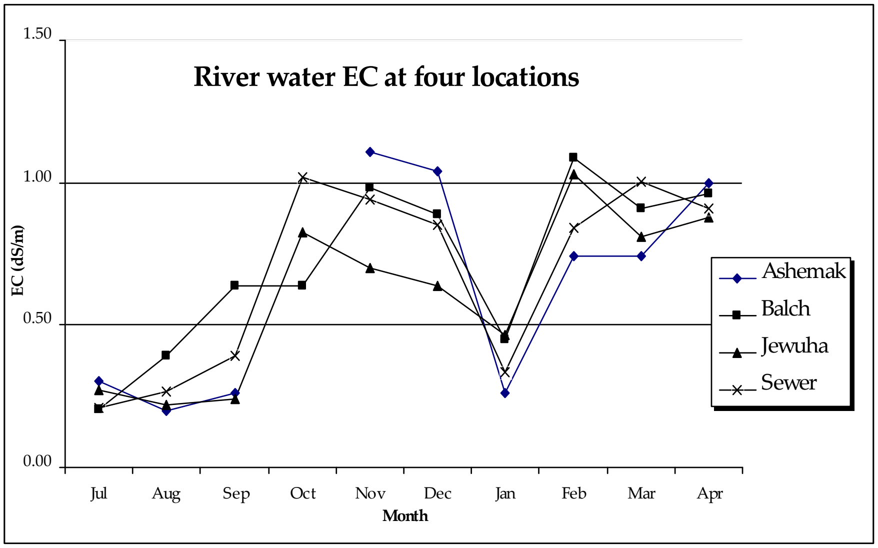

Figure 1. Electrical conductivity fluctuations with time

Conclusion and Recommendation

This study confirmed the importance of salinity and sodicity hazards of the district. Point soil sample tests indicated that there was salinity problem in a substantial coverage. As a result, salinity in overall has emerged as a threat for irrigation development. It was possible to investigate that majority of irrigation source springs were saline.

However, the salinity problem in the area can easily be avoided by leaching reclamation. Education and demonstrations can increase farmers' awareness and adoption of preventive measures than seeking cure after serious problem (sodicity) emanates. Moreover, further investigations and researches in the area of leaching requirement for the locality should be done.

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Evaluation of Different Water Harvesting Techniques in Improving the Survival Rate of Tree Seedlings in Drought Affected Woredas of the Waghimira Zone, Amhara Region

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Abstract

Moisture stress is the major limiting factor which highly reduces the survival rate of tree seedlings in semi-arid areas in the region. One of the approaches to overcoming such problems in semi-arid areas is use of different water harvesting structures. In this experiment, four water-harvesting techniques arranged in RCBD with three replications were used in three sites. The treatments were half-moon micro-basin (HM), eyebrow basin (EB), water collection trenches (TR), and a control i.e., normal pit (NP). Most adaptable and multi-purpose tree species (Schinus molle) for the area were planted in July 2003. Grasses, shrubs and tree species were regenerated throughout the experimental period. As a result, HM and EB gave significant results ($P \leq 0.05$) to root collar diameter (RCD) of the trees as compared to the control. On the other hand, a significant result was obtained in tree height ($P \leq 0.05$) for EB as compared to the control.

Survival rate of trees were also taken as the critical indicator for efficiency of the water harvesting structures (WHS). The trench structure gave the higher survival rate percentage, whereas eyebrow and half moon ranked second and third, respectively. From easiness of the construction and from farmers perspective HM was outsmarted over the other moisture conservation structures.

Keywords: Moisture stress, water harvesting, half moon, eyebrow, trench, micro-basin

Introduction

Water stress is the major limiting factor which highly reduces the survival rate of tree seedlings in semi-arid areas in the Amhara Region. The rain fall in Wag Hmira Zone is low in amount and erratic in nature (Hershfield, 1961). Occasionally, high intensity rain produces high runoff and less soil water storage. This excess runoff could have been temporarily stored by creating artificial micro water storage basins around tree seedlings. The harvested water will be used for the tree seedlings, which suffer from moisture stress during most part of the year, mainly due to dry spells.

One of the recent approaches to overcome such problems in semi-arid areas is the use of different water harvesting structures. This includes the methods able to increase water availability to plants such as rainfall multiplier systems and micro runoff storage mechanisms (Volli Carucci, 1996). In Ethiopia, there is limited information and experience on the potentials of water harvesting techniques and its possible uses. In most cases tree seedlings are planted without any water harvesting methods or without using the common half-moon (micro-basin). Despite the structures are used in some places, in most cases they are not constructed carefully following their appropriate designs. The intention of this experiment, therefore, was to evaluate efficiency of the different water harvesting techniques that can store rainfall and runoff water to increase survival rate of tree seedlings in semi-arid areas.

Materials and Methods

Description of the Study Area

The study areas, North Wollo zone and Waghimera zone, are found between $11^0 18^{'}$ and $13^0 16^{'}$ North of latitude and $38^0 20^{'}$ to $40^0 05^{'}$ east longitude in North-eastern part of the Amhara Regional State. North Wollo and Waghimra zones cover an area of 309,432 ha.

The North-eastern part of the Amhara region has a bimodal rainfall; there is a short rain or *belg* in periods of February to May with main rains or *meher* falling in June to September. The Western part of North Wollo and Waghimra zones as a whole is uni-modal rainfall zones where crops are cultivated in *meher* or *kiremt*.

Mean annual rainfall varies from 600 mm to 1300 mm with eastern part of North Wollo receiving the most rainfall and North-eastern part of North Wollo and Waghimra receiving the least. The mean annual temperature in both zones generally ranges from 8 ^oC to 21 ^oC. The poor soil and vegetation cover is the descriptive nature of the study area.

The two zones constitute three major ecological zones: highland (*dega*), midland (*weinadega*), and lowland (*kolla*) which constitutes 12.3, 44.2, and 43.5 and 4.6, 29.2, 66.2 percent of the total area of North Wollo and Waghimra Zones respectively (DHV Consultants, 2001; SERA, 2001).

Sites on hillsides (45-61% slope) where their soils are not too rocky and void of soils were selected in Lalibela. Four water-harvesting techniques arranged in RCBD with three replications and adjacent abandoned lands were used for each site. The treatments were half-moon (micro-basin), eyebrow basin, water collection trenches, and a control. The construction techniques described by Volli Carucci (2000) were adopted for this study. The dimensions of the area for one treatment were 18 by 24m^2 and the area between treatments was 2 meter square. The total area for one replication was 24 by78m^2 including the space between treatments. The most adaptable and multi-purpose tree species (Schinus molle) for the area was planted in July 2003. Each site was fenced with locally available material and was guarded to avoid uncontrolled factors. Baseline data of the site was collected at initial stage of the experiment supported by photographes and video recordings. Experimental data were also collected every three months starting from establishment.

Layout and design:
Slope gradient: 45-61%.
Size of one block was 24 by78m^2.
Area between the blocks: 3m
Size of each treatment (plot size): 18 by24m^2
Area between treatments: 2m^2
The treatments were replicated into three and these include:

- Half moon (micro-basin)
- Eyebrow basin
- Water collection trenches
- Control

Data to be collected were:

- Base line data:
  - Available grass and tree/bush species
  - Surface topography
  - Photograph and video documentation

- Survival rate of tree seedlings
- Height
- Root collar diameter
- Type and density of undergrowth vegetation

- Tree and grass biomass around the seedling
- Regenerated tree or bush species

Results and discussions

As shown on Figure 1 and Table 1, RCD was found significantly increased *($P \leq 0.05$)* for the half moon in the 30th month.

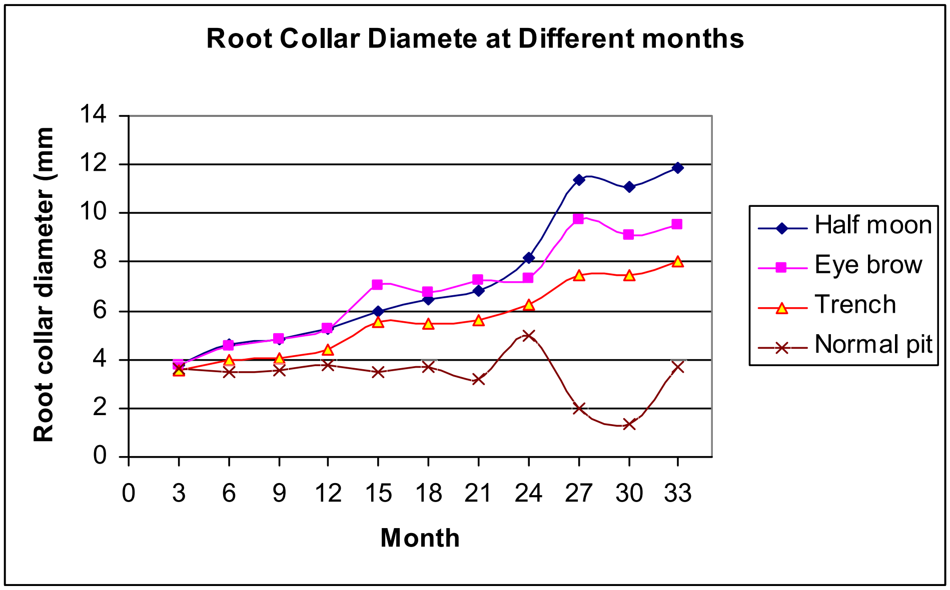

Figure 1: Mean root collar diameter (RCD) for the trees grown in the individual water harvesting structures

When comparing the performance of structure by height of tree seedling growth, similar to the performance indicated above for RCD, half moon, eyebrow and trench were found to be ranked in their order of importance (Figure 2 and Table 2). Almost the increment in heights of the trees is uniform or steady for the period covered in all the three structures. However, both height and RCD were exceptionally found to be higher for the period between 30-33 months. This might be due to high percentages of survival rates were recorded in these months.

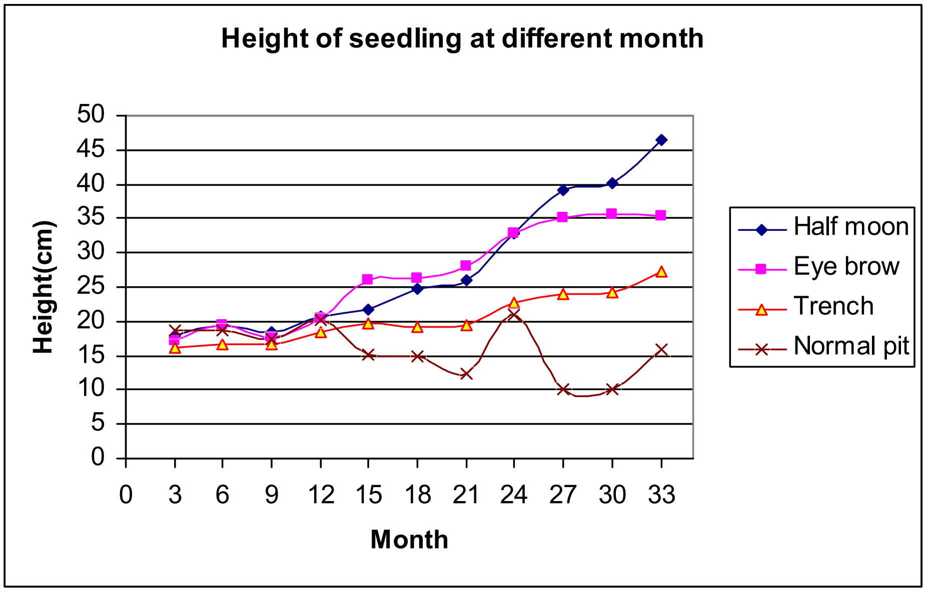

Figure 2: Mean heights of the trees (cm) along the individual water harvesting structures

Survival rate of trees were also taken as the critical indicator for efficiency of the water harvesting structures (WHS). And as shown on Figure 3 and Table 3, the trench structure gave the higher survival rate percentage, whereas eyebrow and half moon ranked second and third, respectively. Survival rate of the tree seedling were found to be decreased at a rate for the period between the 9^{th} and12^{th} months, which were the driest time of the year in the area. However during the rainy season of July to October (12 to 15 months) the dead trees were able to regenerate and the survival rates were found to be improved.

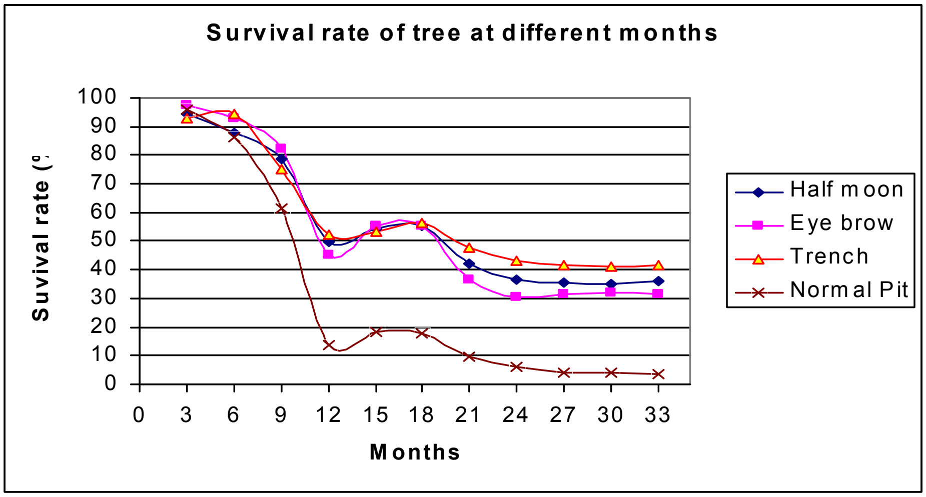

Figure 3: Mean survival rates of trees along the individual water harvesting structures

Table 1. Mean root collar diameter (RCD) in three months interval along the individual water harvesting structures

Treat-ments	RCD (Root Collar Diameter)										
	3	6	9	12	15	18	21	24	27	30	33
HM(1)	3.76	4.61	4.81	5.26	5.96	6.44	6.79	8.15	11.38	11.05	11.84
EB(2)	3.76	4.51	4.84	5.28	7.04	6.76	7.23	7.32	9.76	9.09	9.50
NP(3)	3.60	3.45	3.57	3.78	3.48	3.68	3.16	4.94	2.00	1.33	3.66
TR(4)	3.53	3.96	4.06	4.42	5.57	5.45	5.64	6.28	7.48	7.49	8.06
Mean	3.66	4.13	4.32	4.69	5.51	5.58	5.71	6.67	7.65	7.24	8.26
CV	8.62	14.69	13.24	16.84	14.15	11.59	27.58	11.23	29.66	23.46	32.06
LSD	0.63	1.21	1.14	1.57	1.55	1.29	3.14	1.49	4.54	3.39	5.29

Table 2. Mean heights of trees in three months interval along the individual water harvesting structures

Treat-ments	Height										
	3	6	9	12	15	18	21	24	27	30	33
HM(1)	18.02	19.51	18.35	20.82	21.61	24.69	26.05	32.70	39.13	40.04	46.41
EB(2)	17.16	19.50	17.65	20.45	25.93	26.20	28.14	32.87	35.07	35.59	35.40
NP(3)	18.65	18.63	17.52	20.21	15.15	14.77	12.50	20.88	10.00	10.00	15.83
TR(4)	16.18	16.65	16.71	18.31	16.68	19.14	19.44	22.69	23.90	24.26	27.17
Mean	17.50	18.57	17.56	19.95	20.59	21.20	21.53	27.29	27.02	27.47	31.20
CV	11.52	15.24	13.29	20.28	16.42	13.33	31.72	22.09	34.88	37.47	37.66
LSD	4.03	5.65	4.66	8.08	6.75	5.65	13.65	12.05	18.83	20.57	23.48

Table 3. Mean survival of trees in three months interval along the individual water harvesting structures

Treat-ments	Survival Rate										
	3	6	9	12	15	18	21	24	27	30	33
HM(1)	94.44	87.63	78.75	49.58	54.16	55.55	42.36	36.52	35.69	35.00	35.83
EB(2)	97.22	92.91	82.36	45.27	55.54	55.55	36.66	30.55	31.38	32.08	31.25
NP(3)	95.83	86.25	61.25	13.47	18.05	17.77	9.44	5.97	4.02	4.02	3.75
TR(4)	93.05	94.16	75.00	52.08	53.32	56.38	47.63	43.19	41.52	41.25	41.52
Mean	95.13	90.24	74.34	40.10	45.27	46.31	34.02	29.06	28.15	28.09	28.09
CV	5.46	6.36	9.45	22.48	26.05	23.13	31.95	37.18	36.84	36.12	39.65
LSD	10.38	11.46	14.04	18.01	23.56	21.40	21.72	21.59	20.72	20.27	**22.25**

From the appendix tables below (Appendix Table 2- 5) grasses, shrubs and tree species were regenerated throughout the experimental period. Some of shrub species were *Keshelo*, *Mentesie*, *Ensosula*, *Doret*, etc. and some of the tree species were Acacia lahi and Dodonea angostifolia. After each rainy season the grass was cut and distributed for the society with their bylaws by cut and carry system.

Conclusion and Recommendation

In conclusion, Half-Moon and Eyebrow were found to be significantly different in root collar diameter (RCD) as compared to the control, whereas the water trench (TR) structure showed no difference from the control. Regarding height of trees, it was only Eyebrow structure that significantly different from the control structure. Generally, all the treatment structures (HM, EB, and TR) were found to be significantly different from the control in most of the measured variables, whereas there was little or no difference among the treatments. So rather than trying to grow trees and shrubs with out any moisture conservation structures, it is by far better practicing moisture conservation structures for a better survival and growth of trees and shrubs in the drought areas.

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Documentation of successful traditional farmers' practices and innovations in agricultural water management in Amhara Region, Case: North Shewa

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Abstract

Farmers' have been innovating new practices since the dawn of agriculture to adjust to their circumstances so that they can maximize or optimize benefits from the use of their natural, human and financial resources. Results of such innovations lead to practices, which are in most cases sustainable, practical and within the limits of their capabilities. Such practices may include areas of soil and water conservation, abstraction and conveyance of water for irrigation, methods of application and scheduling of irrigation water to crops, choice of crops, other agronomic practices for irrigated crops, and management of the water users in making decisions to share water, maintain irrigation schemes, resolve conflict and the like. Farmers in north Shewa have been managing agricultural water for long and have developed practices and innovations. Such successful practices can be made available to farmers in other areas with similar environments for adaptation and adoption to assist the Region's endeavor on developing irrigation-based agriculture to attain food security at household and state levels. This paper tries to describe the traditional farmer innovated and successful practices and assess the potential these practices for the betterment of water management.

Key words Checkdam, Indigenous knowledge, yewuha abat

Introduction

Farmers around the world are aware that farm-level land and water management practices are of prime importance for satisfying the needs of field and vegetable crop. Sufficient water must be present in the root zone for germination, growth and soil microbiological and chemical processes that aid in the mineralization of nutrients. Therefore, they endeavor to optimize the water supply of their crops within the limits of their knowledge and the farming operations practiced. They have developed some sort of on-farm water management practices as a result of continuous experimenting.

They have been innovating new practices since the dawn of agriculture to adjust to their circumstances so that they can maximize or optimize benefits from the use of their natural, human and financial resources.

Results of such innovations lead to practices, which are in most cases sustainable, practical and within the limits of their capabilities. Such practices may include areas of soil and water conservation, abstraction and conveyance of water for irrigation, methods of application and scheduling of irrigation water to crops, choice of crops, other agronomic practices for irrigated crops, and management of the water users in making decisions to share water, maintain irrigation schemes, resolve conflict and the like. Some innovations and adoption may take place on individual farms quite often community action leads to large-scale adoption.

The Amhara National Regional State is emphasizing on developing irrigation-based agriculture to attain food security at household and state levels. To this effect various irrigation projects have been implemented. Therefore, it is important that appropriate technologies are available for adoption by the farmers. The status of formal research in Amhara is in its nascent stage despite the fact that farmers in the State have been practicing irrigation for centuries, which requires documentation and understanding farmers' knowledge of irrigation water management and the practices used successfully. Such successful practices can be made available to farmers in other areas with similar environments for adaptation and adoption. This can significantly reduce the time usually needed for formal research to come up with appropriate solutions. On the other hand, understanding the principles behind the successes of the practices can help researchers and extension officials in evolving new technologies or practices. Over all, the process can reduce the time and cost involved in developing appropriate and sustainable technologies to the farmers. It can also facilitate improving some of these practices through infusion of knowledge of scientists and extension officials. Therefore, this experiment was conducted with the objectives of describing the traditional, farmer innovated and successful practices in detail, context of their development, benefits from such practices and their strengths and weaknesses and assessing potential to improve the performance of such practices through formal on-farm and/or on-station research

Materials and Methods

For this study, the following definitions and perceptive of terms are pertinent for common understanding.

Water management Is defined as the planned development, distribution and use of water resources in accordance with predetermined objectives while respecting both the quantity and quality of the water resources. It is the specific control of all human interventions concerning surface and subterranean water. Every planning activity relating to water can be considered as water management in the broadest sense of the term (International commission on irrigation and drainage, ICID, 2000).

Traditional practices are the ones developed and followed by farmers and passed from fathers to children, whether they are best performers or not.

Farmer innovations are meant to be those that farmers have developed in the recent past in response to their needs and circumstances. These could be the results of their own experimentation at the site or adaptation of a technology they have seen somewhere else or of a technology or practice recommended by research or extension system. Such adaptations are usually made to fit to their circumstances.

Successful practices are meant to be the ones which farmers and communities are practicing successfully generating different types of benefits – social, economical, physical, agronomic, environmental, etc. Again such practices could include successful farmer innovations, traditional practices, adaptation of a research recommendation or of a practice practiced by farmers elsewhere.

Indigenous Knowledge is meant to be the knowledge of the farmers developed from the perception of their circumstances, environment, culture, social norms and values, etc. and experiences gained from their traditional practices.

This activity tried to document successful traditional practices and farmer innovations and adaptations related to agricultural water management and short comings in effective utilization of irrigation through semi-structured interview schedule. The schedule covered areas akin to irrigation methods and practices, agronomic practices, farming systems, improved operation and maintenance approaches, abstraction methods, conveyance and distribution, management of the water users, conflict resolution, input supply, marketing of farm products, conservation of natural resources, equity and the likes.

The study was conducted in weredas of North Shewa zone of the Amhara region, where traditional Irrigation schemes were present and traditional innovation and practices were believed to have been widely in practice. The weredas were namely Ankober, Ansokiya Gemza, Basona Werana, Efratana Gidim, Kewet, Merhabete and Tarmaber representing the high, mid and lowland irrigation areas. Specific schemes were selected based on information from the bureau of agriculture of the respective weredas.

A semi-structured interview schedule, interviews with experts and field visits were used to document successful traditional farmers' practices and innovations in agricultural water management in the study schemes.

Results and Discussion

Irrigation water sources in North Shewa zone were mostly rivers and springs. Although few irrigation schemes were established recently, most traditional schemes in Kewet, Efratanagidim, Antsokiyagemza and Baso weredas were established long ago that farmers were observed to have difficulties remembering when they were operational. Some have lasted for more than three generations (more than 100 years). The present day traditional irrigation techniques therefore, had the touch of their fathers and forefathers.

Newly established schemes were built with the aid of NGOs and government interventions. For example, Lutheran church helped the construction of Melkajebdu irrigation scheme in Aliyu-amba, Ankober Wereda. The regional government has also constructed many schemes in North Shewa Zone. Among them are the schemes in Yellen and Wacho (Kewet wereda), Chacha irrigation scheme and others in Baso and other weredas. The traditional schemes were developed and maintained by the communities' participation. The new schemes which were developed employing modern abstraction and conveyance technologies were constructed by peoples' labor contribution and in some by employed labor. It was pointed out that there was little work under taken by the implementing agencies of the new schemes to educate and capacitate farmers to fully utilize irrigation. The reforms were mainly focused on structural improvements that the practices in the so called 'modern' or preferably 'improved' schemes were similar.

In the visited traditional schemes the structures used in water abstraction were stone masonry stabilized by mud or soil and plant residues. Broad leaves were used to reduce seepage. Farmers indicated that river water abstraction took two forms depending whether the river is narrow and do not bring much eroded materials as well as bigger stones and/or the river is wide and come along with stones of varying sizes.

In the first case, a kind of check dam is constructed across the river to divert water in to the sides of the river. Some times the abstraction could have certain angle of inclination from the river sides. Although this form of abstraction requires regular maintenance especially in the beginning of irrigation seasons, the damage encountered is minimal due to the size of river flow and eroded material coming. Moreover, the water can easily over top the structure and flow without major damage. The check dams were usually constructed in places where the river course was narrow to reduce the time and material used for construction. Farmers also select the site considering whether or not the abstracted water could reach the command area they need to irrigate.

Figure 1. Checkdam type water abstraction on small streams (Majete)

In the case of wider rivers like Jemma, Jare and Jeweha, traditional abstraction is very difficult. Abstractions are constructed annually following the reduction of flow volumes. The place of diversion may also change positions annually. Since the rivers have huge discharges and come with a lot of eroded materials the water diversion structures are often washed away. In addition, every year the direction of flow is changed with in the river width. As a result, position of diversion could go upward or downward based on flow direction in the streams. Once the water is diverted it would be lead to the sides of the river and gradually rose to the ground level. In some places long canals must be constructed along the river sides to get the water on the field. This method was found to be very laboriously tiresome by the farmers but had to be done annually for survival.

Figure 2. Wide river abstraction techniques (Jemma)

Main canals were often times earthen. However, recently, cement lined canals were observed in the traditional schemes. The size of earthen main canals depends on the number of villages or irrigation schemes available. Traditionally, the size of secondary and tertiary canals was judged by the size of water it carry, that is, the number of furrows or 'Boy' it can feed. These measurements were also applied for water distribution, for instance, it was observed and pointed out by farmers that water is measured by 'boy wuha' in Majete. It is the same as saying water amount which satisfies optimum flow in a number of furrows. Although volumetric discharge measurement were not observed, proportioning of water gives an entry point in introducing formal water measurement systems for economizing the use of the resource.

Farmers clean and maintain main canals and compact canal beds to reduce seepage. Canals face different obstacle in reaching the irrigated field. Especially in the high lands due to the topography, canals encounter steep slops, valleys and gullies. Farmers employ various methods to overcome the encountered obstacles. In case of steep slops, farmers either dig into the sides of the slope or build a stone masonry wall parallel to the slope on top of which water flows. Valleys, gullies or natural water ways are escaped using logs formed into canal like shape, metal sheet and in some cases concrete structures are used.

Figure 3. Irrigation canal crossing hill (a-Bakelo) and water way(b-Shewarobit)

Crop choices in the surveyed schemes vary according to the climate they were found. Onion, tef, pepper, sweet potato were crops widely under irrigation in the low and mid altitude areas while wheat, barley and garlic were in the highlands. Recently, cropping pattern changes were observed in traditionally irrigated areas. For example, long season sorghum planted late

April was replaced by irrigated onion and other vegetables in Mekoy, Antsokiya and irrigated wheat production has been almost band in Bakelo area in basso wereda. These, changes were mainly due to introduction of high valued crops like onion, driven by the market as in most of the lowland schemes, and disease and pest problems occurring in the dry season as in the highlands. In age old highland schemes however, since the practice of irrigation was in place for long and the crop choices were limited, farmers were using cropping patterns of their fathers.

Most of the farmers in the studied irrigated areas do not use released improved varieties; rather they kept using their own varieties by selecting the best plants. Moreover, commercial fertilizers were rarely applied to irrigated crops. This was mainly because of fertilizer prices and for fear of water shortages which might result in crop burns by fertilizers. In those who apply fertilizers to irrigated crops, the rate was less than the amount they incorporate to the rainy season crops. Although commercial fertilizer use was low in all schemes, the lowland schemes were batter than the highland and mid altitude schemes. Farm yard manure was used in Tach Sar Amba, Efrata wereda, for banana and papaya plantations.

Crop yields in all the surveyed schemes were reported lower in irrigation production than the rain fed production. This indicates the need to improve traditional schemes in terms of water productivity.

Table 1. Fertilizer usage in irrigated crops in some of visited schemes

Wereda	**Scheme Name**	**Water Source**	**Production System**	**Crop**	**Fertilizer (rate)**
Antsokiya Gemza	Lay Jare Mesno	Jare River	Rain Fed	Tef	**Urea** 2qt/Ha **DAP** 40-48 Kg/Ha
				Onion	Urea 2Qt/Ha
				Tomato	Urea 0-48 Kg/Ha
			Irrigated	Tef	-
				Onion	Urea 1Qt/Ha
				Tomato	Urea 0 -48 Kg/Ha
	Tach Jare Mesno	Jare River	Rain Fed	Teff	-
				Onion	Urea 2.4 Qt/Ha DAP 1 Qt/Ha
				Tomato	Urea 1Qt/Ha
			Irrigated	Teff	Urea nil DAP nil
				Onion	Urea 1.6 Qt/Ha DAP 1 Qt/Ha
				Tomato	Urea 0-1 Qt/Ha
Efratanagidm	Tachegnaw Sar Amba Mesno	Lisha Wuha Nazero River	Rain Fed	Onion	Urea 1 Qt/Ha DAP 50 Kg/Ha
				Corn	Urea 1 Qt/Ha DAP 1 Qt/Ha
				Banana	Farm Yard Manure
				Papaya	Farm Yard Manure
				Cabage	Urea 1 Qt/Ha DAP 48 Kg/ha
				Bit root	Urea 1 Qt/Ha DAP 48 Kg/ha
				Tomato	Urea 1 Qt/Ha
			Irrigated	Onion	Urea 2Qt/Ha DAP 1 Qt/Ha
				Corn	Urea 2Qt/Ha DAP 1 Qt/Ha
				Banana	Farm Yara nure
				Papaya	Farm Yara nure
				Cabage	Urea 2Qt/Ha DAP 1 Qt/Ha
				Bit root	Urea 2Qt/Ha DAP 1 Qt/Ha
				Tomato	Urea 2Qt/Ha

Wereda	Scheme Name	Water Source	Production System	Crop	Fertilizer (rate)
Ankober	Melka Jebdu Mesno	Melka Jebdu River	Rain Fed	-	-
			Irrigated	-	-
Tarmaber	Arid Amba Wonz	Arid Amba River	Rain Fed	-	-
			Irrigated	-	-
Tarmaber	Batug Mesno	Batug River	Rain Fed	Wheat	Urea 1Qt/Ha
				Teff	Urea 1Qt/Ha DAP 20 Kg/Ha
				Garlic	Urea 144 Kg/Ha
			Irrigated	-	-
Basona Worana	Gunagunet Mesno	Gunagunet River Dedot Spring	Rain Fed	Wheat	Urea 2Qt/Ha
			Irrigated	-	-

Flood irrigation was widely used method of water application. Furrow irrigation was seldom used for row cropped onion. According to the interviewed farmers these methods were selected due to lower labor requirement.

Farmers indicated that there were complementarities in irrigated and rain fed production systems. The first form was starting crops with the rain and finishing them by irrigation. This mode of production was practiced especially where farmlands were temporarily inundated by the summer rain especially in the highlands. Wheat, lentil, field pea fenugreek are mostly cropped in such a practice. The second form was to plant using irrigation and let it mature by the rain. Long maturing sorghum and corn were best examples of such production system in the lowlands.

Amount of water application depends on the farmer's judgment. It is said that the crop is well watered when the field is wet and there is accumulated water over the surface. Farmers had optimum watering frequencies when water is in surplus and in scares. But still the amount of application had unquantified variations from farm to farm and farmer to farmer.

As water is the most important resources in irrigation, its equitable use is very essential for a healthy scheme. As a result, farmers had different water management bodies. The most famous water administration body was the

"*Yewuha'abat*" or "Father of water". *Yewuha'abat* is an elected member of the community whom the farmers agree upon to be in charge of all water issue. On the bases of the scheme's area, he may have local administrators, especially if the scheme comprises of two or more villages. The *yewuha'abat* is recognized by the kebele's "*limate budin*". Water dispute and other water distribution issues are solved by the *yewuha'abat*. If things get out of the capacity of this body the kebele administration and elders will join to solve the problem. Other wise, the matter will be handed to the formal court. Most of the cases however, are taken care by the *Wuhaabat*.

There is also a similar institution to administer irrigation water in some areas (Jeweha area). This institution is known as "*Yewuha budin*". Elected members of the scheme are delegated to settle all water related issues for the equitable use of the resource by the community. The community formulates bylaws on scheme maintenance, annual fee, water use rules and charges upon defaulters. Although the charges vary from scheme to another, could reach 50 bir to water denial.

Water allocations were based on the size of the farm irrigated and the type of crops grown. Sensitive crops like vegetables were given frequent supplies. Priorities are also given to vegetables than cereal crops in case of water shortage. In addition, smaller farms were supplied in smaller fraction of the coming water. It is to be recalled that water is measured in 'boys', if the water coming in the secondary canal can supply certain boys and there are two farms being irrigated at the same time, the big sized farm will take the greater portion.

Farmers have established irrigation frequencies for their crops. Based on the availability of water these frequencies were adjusted. Cereals were generally irrigated less frequently than vegetables (Table 2). Generally speaking, farms were observed to be over irrigated once the supplies were on. However, frequencies seem to be in most cases low, for cereals in particular, implying longer irrigation intervals which might result in stress related yield losses. The frequencies happened to be consistent for a crop in similar agro-ecologies.

Table 2. Irrigation frequencies in some of visited schemes

Wereda	Kebele	Scheme Name	Crop	Frequency of Irrigation when water is	
				Sufficient	Scarce
Antsokiya Gemza	Agla Majete	Lay Jare Mesno	Onion	3-4 Daya	8 Days
			Tomato	2 Times/Season	2 Times/Season
			Tef	Once/Season	Once/Season
	Agla Mageta	Tach Jare Mesno	Teff	2times/Season	-
			Onion	6days	9days
			Tomato	15days	20days
	Mekoy 03	Gudaber	Onion	8 Days Interval	In 15 Days Interval
			Sweet Potato	Once In A Month	Once In The Season
			Chat	4 Days Interval	8 Days Interval
			Banana	8 Days Interval	In 15 Days Interval
			Tef	7 Days Interval	In 15 To 30 Days
			Fruit Trees	8 Days Interval	>20 Days Interval
			Papper	15 Days Interval	25 Days Interval
Efratanagidm	Tach Sar Amba	Tachegnaw Sar Amba Mesno	Onion	4-5days	8days
			Corn	8days	10-15days
			Banana	8days	15days
			Papaya	8days	10days
Ankober	Aliyu Amba Zuria	Melka Jebdu Mesno	Onion	3 Days	5 Days
			Tomato	5 Days	10 Days
			Banana	7 Day	-
Tarmaber	Yitta	Arid Amba Wonz	Wheat	Once/Week	Once/Week-Month
			Fenugreek	Onece /season	-
	Koste Amba	Batug Mesno	Wheat	Twice/Season	Once/Season
			Garlic	3days	8days
			Onion	3days	8days
			Fenugreek	3times/Season	Once/Season
Basona Worana	Bakelo	Gunagunet Mesno	Wheat	Once/Season	
			Barley	Twice/Season	Once/Season
			Lenti	Once/Season	
			Beans	3times/Season	Once/Season
			Grlic	20days	30days
			Fenugreek	Twice/Season	Once/Season

Irrigation water was free of charge in most schemes studied. In some schemes where water users' cooperations exist, annual water fees were paid usually for expenditures in scheme maintenance. Farmers consider water as a free commodity and unanimously believe that it should not be traded. Moreover, farmers indicated that scarcity of water in the critical season makes it difficult to be traded since it is only given to those who need it critically.

Most of the irrigation schemes studied were accessible to local markets. Furthermore, they were located close to the main asphalt road. As a result it was possible to market their products in bigger markets earning better values. For example, Majete and Shewarobit farmers provide their produces to as far as Mekele. However, despite the opportunities, individual farmers had market price problems. Due to the lack of organized associations, the currently benefiting actors were the middle men and some aware resourceful farmers. Although it was encouraging to see farmers going beyond their local markets and sell products in far markets as Mekele and Addis Ababa (as seen in Majete) the majority were resource poor and producing in small scales which limited them to be the beneficiaries of these opportunities.

Nevertheless, encouraging marketing innovation was seen in Majete. Taking lessons from the trading community, few farmers have stopped supplying local traders. Instead, they produce on their own farms and collect produces from the scheme by a better price than the traders offer, rent vehicles and sell it by taking it to bigger markets. This has created opportunities for the emergence of new community which we called trader-farmer. The presence of these farmers has improved the local prices and some times stabilize good prices for the local farmers.

In any of the schemes studied neither sign of health hazard brought about by irrigation, nor complaint by the users was come upon. This was mainly because the irrigation water is scarce. However, in Wacho kebele, Kewet wereda, it was observed that malaria was evidently important disease in relation to irrigation projects.

Conclusion and Recommendation

The study realized that farmers in North Shewa Zone had numerous traditional practices, innovation and indigenous knowledge in the management of agricultural water. As irrigated agriculture entail water abstraction, conveyance, application to the agricultural fields and administration of water for equitable utilization for successful production systems farmers own valuable knowledge through continues experimenting and experience on which modernization endeavors should be based and ready made techniques be transferred to similar locations.

Farmers also possess successful water administration techniques and organizations developed through years of experiences. They had formulated workable bylaws to equitably administer their water resources and avoid possible conflicts. It was possible to find strong social atmosphere on which irrigation and other agricultural modernization could depend on. Farmers were found to adequately utilize their agronomic practices in the irrigated agriculture as well. Crop choices for specific locality depending on the available resources was practiced in every traditional scheme surveyed.

In the area of marketing agricultural produces however, limited awareness was found. Lack of organized approach to derive the best out of the production system had resulted in subsistent incomes which kept the development of the sector behind.

Areas in which improvement was keenly required include method of application and management of excess water, when and how much to irrigate and enterprise choice for profitable production system. The other important intervention part is the irrigated agriculture development. The development work requires huge investment which the farmers could not afford. Government and non-government organizations should play an important roll in developing the sector.

In the light of the study results it is recommended that;

1. Water abstraction and conveyance indigenous knowledge and techniques should be adopted to similar localities
2. Irrigated agriculture agronomic practices should be verified and adopted to similar localities
3. Water administration indigenous practices and knowledge should be transferred
4. Method of application and management of excess water should be addressed by the research system to improve the sector
5. When and how much to irrigate and enterprise choice for profitable production system should also be answered by research.
6. Marketing of agricultural produces should be supported by concerned government and nongovernmental agencies and efforts to organize producers should be continued by the same and the research system.

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International Commission on Irrigation and Drainage (ICID); Multilingual Technical Dictionary on Irrigation and Drainage; CD Version. New Delhi, India; 2000.

Forestry

Farmers' Tree Preferences: an Assessment of Constraints and Opportunities in Selected Watersheds in East Amhara

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Abstract

Agroforestry is very ancient and dominant land use practice in eastern ANRS. These practices are numerous as the area covers a larger area and wider agroecology. However, little scientific information is available about the major agroforestry practices in order to improve and optimize the productivity of the land and the land user. With respect to this, the challenge in these areas is to diversify and avail to farmers a whole range of tree species for various purposes, with alternative spatial and temporal arrangement. In most cases, assessment of farmers tree needs, uses, interests and priorities is essential to determine germplasm acquisition and plan species to be raised in nurseries and to define extension methods. Therefore a research was conducted in north and south Wello and Oromiya zones with the major objectives first to assess farmers' tree needs, identify constraints and opportunities for agroforestry research and development activities, identify tree products that farmers are most interested in, determine tree planting niches and tree management practices of farmers, assess factors influencing farmers' decision in the selection of species and niche. Stratified systematic and random samplings were used in order to select the target household. Hence; Bati, Kemisse, Jamma, Wuchale, Haik, and Sirinka were selected. The identity, diversity and growing niche of each tree species was recorded together with household characteristic. The Shannon diversity index H, Simpson diversity index D-1 and inverse Berger-Parker index d-1, and Rényi diversity profile was used during analysis. In addition Linear Redundancy Analysis (LRDA) and pair wise ranking were used in order to analyze the relation between species and other variables. The results showed, tree preferences and species diversity vary across agroecology and household characteristics. Hence, list of the most desired species for different locations was suggested. Based on the diversity of tree species and availability of tree growing, different agroforestry interventions such as tree diversification, introduction of new species, alternative uses and new growing niches have been recommended.

Key words: agroecology, agroforestry, diversification, domestication, germplasm

Introduction

North and South Wello and Oromiya zones occupy the major part of eastern part of ANRS. There is extreme land degradation in this area due to historical, demographic and environmental reasons. The forest and woodlands have already disappeared long ago. As a result land productivity is very low. The cropping system is rain fed agriculture, where irrigation is practiced in very limited areas. The rain fed Agricultural has always a poor performance as the rainfall distribution is getting erratic and scanty in amount. Farmers in the area grow trees in combination with crops and livestock in order to avert and mitigate the vagaries of bad environmental conditions. Although it is an age old practice, technically speaking this land use system is called agroforestry.

Agroforestry is a collective name for a range of land use practices in which trees or shrubs are grown in association with herbaceous plants (crops or pastures), in a spatial arrangement or a time sequence, and in which there are both ecological and economic interaction between the tree and non tree components of the system (ICRAF, 1997). The economic interaction is the production of fuel wood or fruit for cash or income; and the ecological interaction, which is the distinctive feature of agroforestry, the biogeochemical cycle in the system. For example combining tree fodder with grasses in the nutrition of livestock and returning farmyard manure to arable land, with benefits of improved livestock productivity, higher income and soil fertility maintenance.

There are numerous agroforestry practices and systems in Ethiopia. An agroforestry practice is an arrangement of components (trees, crops, pastures, and livestock) in space and time, and system is a distinctive local example of a practice, characterized by environment, plant species, management, and social and economic functioning.

The agroforestry practice and system in the area has not been well studied in order to improve and optimize the productivity of the land and the land user. It has been believed that tree domestication diversifies agro-ecosystems and make them more productive and stable, as there is positive relationship between ecosystem diversity, and ecosystem stability and productivity (Elton, 958; Hutchinson, 1959; Frank & McNaughton, 1991; Tilman & Downing, 1994; Tilman, 1996; Rodríguez & Gómez-Sal, 1994; Naeem et al., 1994; Hooper & Vitousek, 1998; Hector et al.,1999; Loreau & Hector, 2001; Smith & Rushton, 1994).

Domestication covers a wide area and defined to encompass accelerated and human induced evolution to bring species into wider cultivation through a farmer-driven or market-led process. In tandem with individual tree, domestication of landscapes by investigating and modifying the uses, values, intraspecific diversity, ecological functions, numbers, and niches of both planted and naturally regenerated trees is an approach that is getting promoted recently (Kindt; 2001).

With respect to this, the challenge in these areas is to diversify and avail to farmers a whole range of tree species for various purposes. Lack of seeds, seedlings and other planting materials is frequently identified as the most important constraint to a greater adoption of agroforestry technology/practices. Therefore there is a need is to develop and apply better methods to forecast germplasm needs, and to facilitate establishment of sustainable seedling production and distribution systems that draw on the strengths and capabilities of the farmers and private sectors.

Assessment of farmers tree needs, uses, interests and priorities is essential to determine germplasm acquisition and plan species to be raised in nurseries and also to define extension methods. In other words, this is essential to determine agroforestry tree choice for farmers. Moreover, identifying farmer's top priority products and species that brings highest benefits and understanding the way how farmers currently manage trees on-farm is important in defining the principal tree species.

Therefore this research has been initiated and executed with the objectives first to assess farmers' tree needs, preferences for MPT species and identify constraints and opportunities for agroforestry research and development activities. Then, identify tree products that farmers are most interested in and that may best meet their needs and determine those species producing them. Side by side determine tree planting niches and tree management practices of farmers and assess factors influencing farmers' decision in the selection of species and niche. Finally, help target project activities at solving farmers' priority problems with appropriate interventions

Materials and methods

The study was conducted in Eastern Amhara, mainly in North and South Wello and Oromiya zones. A combination of random and systematic sampling approach has been used. The survey area was stratified in to three, based on traditional agroecology classification: Dega, Woina-Dega and Kolla. For the Kolla agroecology, Bati and Kemisse taken in to consideration; for the Dega Jamma was chosen; and for the Woina-Dega Wuchale and Haik taken. For reference purpose, the Sirinka catchment was taken. In the selected watersheds every third household during farm walk was selected. The principle of functional ecological groups was the guiding rule in the data collection process. Functional groups can be defined as clusters of species that play the same role in maintaining and regulating ecosystem processes (Gitay et al. 1996). Norberg et al. (2001) define functional groups as clusters of species that share similar resources and predators.

For every tree species encountered on a farm, information was collected on the presence in particular on-farm niches by interviewing household members involving farm walks, and data recording using pre-tested questionnaires. On-farm niches for trees refer to the location on the farm and the establishment pattern of trees at the location. The niches that were distinguished were trees in the homestead area, trees mixed in cropland, trees on contours in cropland, trees on boundaries of the farm, live fence, trees in woodlots, and trees in degraded lands.

Use-groups were defined as groups of species providing similar products or services to the farm household. Studying use-groups is similar to studying functional groups. Free responses on tree uses were obtained on a species-by-species basis. These answers were post-coded during data entry in the databases that were created for data analysis and storage (Table 1).

Respondents were also requested to name the main use of the species on the farm. Information was provided by the farming household on the source of seedling or germplasm of each tree species. Origins of germplasm were post-coded in categories including the own farm, from neighbor or from government nurseries. Farmers were also interviewed to prioritize desired species and modifications in tree composition and niche.

Several farms × species matrices were formed by inserting abundance > 0 in a specific matrix cell. Use-groups (i.e. matrices) defined by species occurrence and use as recorded at individual farms. Abundance > 0 was recorded for a cell in case the specific farmer (listed in rows) had communicated to use the particular species (listed in columns) for the particular use (product or service). Niche matrices were formed in an analogous way.

In order to prioritize each species for a particular purpose to grow on a particular niche, pair wise ranking was employed.

Table 1. Summary of sampled watersheds and household characteristics

Location of watershed	No. of HH visited	Average land holding (Ha)	No. of Female HH
Bati	32	0.69	4
Jama	25	0.62	6
Chefa	25	0.84	3
Kalu	25	0.46	5
Ambassel	25	0.39	7
Tehuledere	25	0.5	5
Sirinka	25	0.54	8

Measuring diversity for comparison

Usually ecosystem diversity is measured with species richness. Species richness (S) refers to the number of species that were encountered on a specific farm, in a specific watershed. Alpha diversity was analyzed by taking the average number of species per farm. Gamma diversity was analyzed by the total number of species in each category of use or niche in respective agroecology.

The Shannon diversity index H, Simpson diversity index D^{-1} and inverse Berger-Parker index d^{-1}, which are all values at specific scales of the Rényi series H_a were calculated directly from information on species' presence and absence. The Rényi series provides diversity profile values (Ha) based on a scale parameter value a, which varies from 0-10 (Tóthmérész 1995; Legendre & Legendre 1998; Rennols & Laumonier 2000):

$$Ha= \log (\sum p^{a}_{i})/1-\alpha,$$

Where pi = proportion of item i, α variable to be determined by maximum likelihood method, a=0-10.

The Renyi profile gives information about the diversity and evenness of an ecosystem and therefore more efficient for diversity analysis. This is because some ecosystems may be diverse but less even. For instance, if there are ecosystem a and ecosystem b, in the Renyi profile, system a is more diverse than system b if all values of the diversity profile corresponding to system a are larger. Systems that have intersecting profiles consist of one system that is richer but not more evenly distributed. H_8 is only determined by the proportion of the dominant species, therefore the value of evenness that correspond to H_8 (i.e.E8) provides an insight in the contribution of the dominant species to evenness. Therefore, systems with larger E8 have a more evenly distributed dominant species. Systems with intersecting evenness profiles consist of one system where the dominant species is more evenly distributed but the other species less evenly.

Shannon H (Magurran 1988; Condit et al. 1996, Legendre & Legendre 1998)

$$H1= -\sum p_i \log p_i$$

Simpson D^{-1} (Magurran 1988 ; Legendre & Legendre 1998)

$$H2 = \ln (D^{-1}) = \ln (\sum p_i^{2})^{-1}), \text{ and}$$

Berger-Parker d^{-1} (Magurran 1988)

$$H = \ln (d^{-1}) = \ln (p^{-1}_{max}),$$

Diversity indices are also used for comparison purpose.

Results and Discussion

Detailed information has been gathered on the diversity of each agroecology in terms of trees and tree growing niches, the distribution of uses over species, diversity characteristics of niches, diversity characteristics of use-groups, constraints of tree growing, and priority use and niche of existing tree species. The tree species grown by farmers is annexed to the text.

Gamma diversity analysis based on Shannon diversity index showed, Sirinka is the most diverse (3.33) followed by Kalu and cheffa with values 3.24 and 3.2 respectively. Jama is the least diverse agroecosystem with value of 1.93. In general there is a pattern that as elevation increased, diversity of the agroecosystems observed decreased (Table 2).

Comparing evenness and the contribution of the dominant tree, that is the most widely planted tree species, for diversity; Kalu is the most diverse, followed by Cheffa and Sirinka. The high elevated area Jamma is both less diverse and even (Figure 1). Important to mention may be, Sirinka is the most diverse agroecosystem, but the contribution of the dominant species for the observed diversity is very low.

Table 2. Gamma diversity values of the watersheds

Woreda	Shannon	Simpson	J	E	Berger-Parker	Menhinick	Margalef	McIntosh
Bati	2.97	15.96	0.95	0.84	0.16	3.22	5.60	0.87
Jama	1.93	5.49	0.84	0.69	0.27	1.49	2.36	0.67
Chefa	3.20	17.95	0.89	0.66	0.11	3.34	7.48	0.84
Kalu	3.24	19.53	0.88	0.66	0.08	3.20	7.59	0.84
Wuchale	2.87	11.93	0.83	0.57	0.15	3.15	6.56	0.79
Tehuledere	2.96	13.36	0.85	0.59	0.17	2.71	6.40	0.79
Sirinka	3.33	19.43	0.89	0.65	0.13	3.24	8.12	0.84

Analysis of species by sample matrix by taking the occurrence of use group over species, occurrence in terms of the number of times the use was mentioned showed, growing trees for construction has the highest frequency. It has been mentioned 876 times. This may be due to many tree growers who have diverse tree species grow the trees mainly for this purpose. The other uses were mentioned on average from 214-298, except forage use group which was mentioned 57 times. On the other hand, farm occurrences, the number of households where the use was mentioned, showed fuel wood is the most important use group followed by construction. Interestingly, fuel wood has the highest result in species average, number of species per farm and per use for those farms where the use was mentioned. That means farmers have different alternative for fuel wood or diverse plant species are used as fuel wood (Figure 1). On the contrary extremely low species average value for forage shows, farmers have little or no alternative woody plant that can be used as fodder (Table 3). That means the average number of tree species that can be used as fodder on each household is less than one and there is a possibility that fodder trees are not planted on the farm.

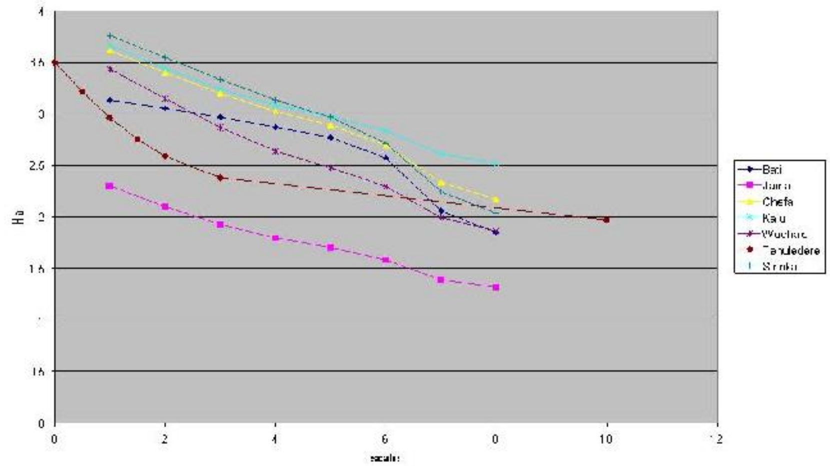

Figure 1. Diversity profile values of the selected watersheds

Table 3. Characteristics of the seven use-groups

Use group	Occurrence[1]	Farm occurrence[2]	Species average[3]
Construction	876	139	2.69
Fuel wood	221	181	10.69
Farm implement	214	117	2.61
Fence	298	161	3.28
Market	221	124	3.63
Lumber	269	128	2.69
Forage	57	55	0.70

[1]*Occurrence: number of times the use was mentioned;*
[2]*Farm occurrences: number of households where the use was mentioned;*
[3] *Species average: number of species per farm and per use for those farms where the use was mentioned*

Analysis of species by sample matrix by taking tree growing niche and the associated plant species showed, homestead areas being the most important tree growing niches followed by trees scattered inside own farm. Live fences and farm boundary is also moderately important tree growing niches. In terms of farm occurrence, number of households where the tree growing niche was mentioned also showed homesteads being the best and preferred niches followed by live fencing and scattering trees in side own farm (Figure 2).

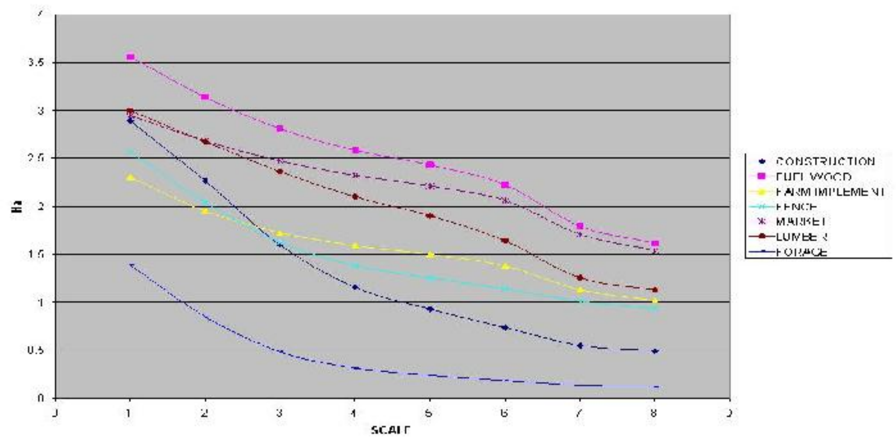

Figure 2. Diversity profile values for the seven use-groups

Note only are homesteads important tree growing niches, they are also diverse as they have higher species-average result, that is the number of species per farm and per niche for those farms where the niche was mentioned (Table 4).

Table 4. Characteristics of the 8 tree growing niches

Tree growing niche	Occurrence[1]	Farm occurrence[2]	Species average[3]
Homestead	746	166	8.88
Live fence	279	163	3.34
Farm boundary	125	77	1.51
Scattered inside farm land	371	121	4.39
Degraded hills	63	24	0.75
Gully	29	15	0.35
River banks	51	15	0.62
Soils conservation structures	31	24	0.38

[1]*Occurrence: number of times the use was mentioned;*
[2]*Farm occurrences: number of households where the use was mentioned;*
[3] *Species average: number of species per farm and per use for those farms where the use was mentioned*

Diversity and productivity of niches and watersheds

Extremely low species- average value for degraded hills, gully, river banks, and soils conservation structures; shows, these tree growing niches are not utilized for growing trees. This may be due to free grazing as these areas are common properties utilized without any regulation, or due to security problems as trees need relatively longer time before being ready for harvest, and the uncertainty during this time who will take the benefit (Figure 3).

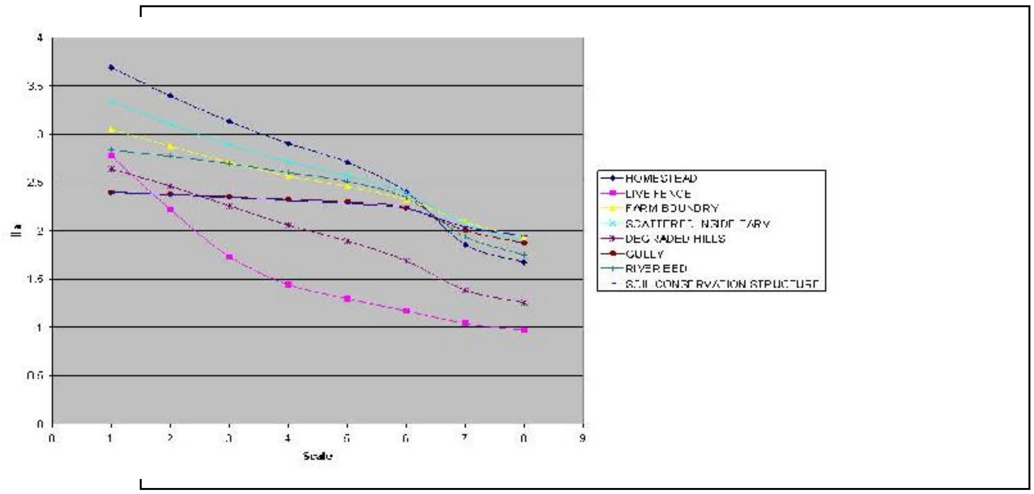

Figure 3. Diversity profile values for the different tree growing niches

The same diversity and evenness pattern is evident from the analysis of diversity and evenness by taking niche across agroecologies. The most important niches for Kolla agroecology are homesteads and scattered trees in own farm. Scattered trees in side farm as tree growing niche got lesser importance in high elevated agroeocologies such as Jamma. Therefore, project that aim to increase diversity should focus on first introducing new species in the area so that to increase diversity. Second, using tree growing niches some how away from the farm where food crops are grown (Table 5).

Table 5. Alpha diversity values across agroecologies

Niche	Watershed	H	J	E	S	Berger Parker	Menhinick	Margalef	McIntosh
Homestead	Kalu	2.93	0.85	0.60	12.73	0.18	3.16	6.57	9.08
	Tehuledre	2.99	0.86	0.62	13.45	0.19	2.81	6.37	0.80
	Ambassel	2.78	0.89	0.70	11.95	0.19	2.21	4.70	-9.68
Live Fence	Kalu	2.00	0.80	0.62	5.08	0.37	1.95	3.02	5.61
	Tehuledre	1.32	0.64	0.47	2.53	0.59	1.21	1.85	0.44
	Ambassel	1.31	0.67	0.53	2.83	0.49	1.07	1.59	0.48
Farm Boundary	Kalu	1.95		1	7	0.14	2.65	3.08	1.32
	Tehuledre	2.51	0.93	0.82	10.45	0.17	2.5	3.91	0.83
	Ambassel	1.78	0.91	0.85	0.80	0.31	1.94	2.34	0.77
Inside farm	Kalu	2.62	0.89	0.72	10.13	0.2	2.19	4.17	3.63
	Tehuledre	2.55	0.92	0.80	10.96	0.17	2.18	3.76	0.81
	Ambassel	2.39	0.88	0.73	8.40	0.22	2.47	3.88	-5.43
Degraded hills	Kalu	0.69	1	1	2	1	1.41	1.44	0.40
	Tehuledre	1.92	0.93	0.86	5.83	0.31	2.22	2.73	0.81
	Ambassel	-	-	-	-	-	-	-	-
S.conservation	Kalu	1.33	0.96	0.95	3.57	0.4	1.79	1.86	1.14
	Tehuledre	-	-	-	-	-	-	-	-
	Ambassel	-	-	-	-	-	-	-	-
River bank	Kalu	-	-	-	-	-	-	-	-
	Tehuledre	2.44	0.98	0.96	10.89	0.14	3.21	4.15	0.95
	Ambassel	2.04	0.98	0.96	7.36	-	-	-	-
Gully	Kalu	-	-	-	-	-	-	-	-
	Tehuledre	-	-	-	-	-	-	-	-
	Ambassel	1.39	1	1	4	0.25	2	2.16	-1.5

Farmers get planting materials from different sources. For instance source of seedling by ownership shoed 66.70 % of the respondents got their seedling from government nurseries and 50.94% from their neighbor and the rest from their own.

The most valued tree or shrubs (in order of decreasing importance) *Eucalyptus globules, Eucalyptus camaldeulesis, Chata edulis, Acacia seyal, Psydium guava, Mangifera indica, Persea Americana, Citrus sp., Cordia Africana, Albizia gummufera, Grewia ferruginea, Ehretia cymosa, Erythrina abyssinica.* The list of species encountered during the survey is annexed to this text.

The most important tree management activities (in order of decreasing importance) are side pruning, lopping, hoeing, weeding, manuring, and fencing. Thinning, that is reducing the stocking number as the tree grows in size, was not mentioned as a management activity.

Major tree diseases or pests include termite on Eucalyptus and Khat; unidentified worm on Coffee, Khat, Citrus, and Eucalyptus; wood pecker birds on Cordia; insects on Ziziphus; and beetle on mango. The extent of the damage in all instances was reported to be high.

Gender segregation in to male and female headed households for diversity of niche and tree species showed, male-headed households had highest species richness values than the female headed house holds. In terms of niche, *homestead* and *scattered inside farm* are important tree growing areas and *live fence* and *boundary planting* for the female headed ones. This may be related to security to farm and home.

Wealth as determined by the number of cattle, seem to have no impact on the species diversity characteristics of the studied house holds. The results do not show consistent results (Table 6).

Table 6. Percentage (%) of respondents as their source of wood for various purposes

	Farm	Homestead	Near Forest	Market	Neighbor	Other
construction	9.67	83.33	0	7	0	0
farm implement	3.33	91.67	3	2	0	0
fodder	72	25	3	0	0	0
fruit	0	100	0	0	0	0
fuel wood	50	46	8.30	5.70	0	0
medicine	16	75	9	0	0	0
For sale	40.01	2.09	57.9	0	0	0

Pair wise ranking of tree growing niche by the use or function of the tree showed, homestead is the source of supply for 83% of construction, 92% of farm implement, 25% of fodder, 100% fruit, 46%fuelwood, 75%medicine, and 2% for sale. This further substantiates our previous observation that homestead being the most diverse and important tree growing niches, followed by own farm and wood lands in the given watershed.

Homesteads are more diverse and important because they are under strong and secured ownership feeling of the household owner. Besides, they are near settlement and are always under the direct supervision of member of the household; again they will be managed well and easily as they are watched.

The most important limitations for tree growing were very low seedling survival, due to drought and free grazing. On the other hand, seedling availability has been mentioned as an obstacle for tree growing by only 7.8 % of the respondents. This may lead to the assumption that, although there is seedling supply, the quality is poor. Therefore, decentralization of nursery at the household and village level is an important intervention. This approach is important from two perspectives, first it gives flexibility to produce the desired woody species, and second quality seedlings will be produced. This can be achieved by giving training to farmers engaged in tree growing.

Pair wise comparison of a tree species against its use showed that 80 % prioritize fuel wood the most important use, followed by fruit 12%.

Conclusion and Recommendation

In general low diversity is observed in high elevated agroecologies, *fodder* in the use group, and *gully, river bank,* and *degraded areas* in the niche analysis.

Low diversity compels diversification by means of addition of a new species or adaptation of a species performing well in similar conditions. The first possibility to increase diversity might be making more germplasm available to farmers. Another possibility is that some socio-economic factors such as wealth, gender and access to information and resources, should be taken in to consideration in the form of subsidy or special program for the poor or female.

With decreasing diversity, tree diversification may become more relevant. The diversity profile values points to potential interventions. One strategy could be to increase the frequency of some tree growing niches or use-groups in the landscape where they do not occur. Groups of medium occurrence could be selected for wider distribution. A combined strategy could involve also targeting those farms with a low total number of niches or use groups and establish additional niche or use for the farms. Such interventions would increase the alpha diversity of the household; this will also increase gamma diversity provided that new species contribute to the addition.

In our case, in the Dega areas introduction of species will be important, and at the same time increasing the abundance of the existing native species as *Olea, Dombiya torrida, Hypericum quartinianum, Hagenia abyssinica, Senecio, gigas* will be important. In the Kolla and Wona-Dega areas increasing the niche (tree growing areas) will be important. Most farmers satisfy their wood demand from trees grown either in the homestead or inside farm or from the adjoining forest or woodland. Very small fraction of the wood supply comes from other tree growing niches.

The average numbers of uses per species and use-group frequencies highlight the potential value of extension messages on alternative uses of species. Widespread extension of information on potential uses of species that do not occur on all farms at present could result in increased on-farm diversity if this information would encourage farmers to incorporate new species in their farm.

Niches or use groups with low diversity should be targeted for diversification. The gamma diversity provides suggestions on how alpha diversity can be improved. For niches or use groups with higher gamma diversity, a wider distribution of existing species within the area would offer one method of enhancing alpha diversity.

For low gamma diversity niches or use groups, for instance forage, the solution would be to introduce new species or to promote alternative uses for species that are already present. Increasing gamma diversity could also result in increased stability and productivity at the landscape level.

Diversification could be targeted towards more important use-groups, rather than targeted towards those groups which have low diversity. The major emphasis should be on economic importance and importance for the household food security

The major points that need attention when a new niche and/or use is introduced should, first the quality of production of these species for a particular niche or use; second the complementarity in production in the existing land use system for instance compatibility with crops and grazing situation; and third, the characteristics of the species. The decision could be made not to promote all uses. Decreasing the number of uses per farm could result in higher profitability per farm.

An analogy is the criterion introduced by Van Noordwijk et al. (1997) on the relationship between biodiversity and profitability. If initial diversity loss would result in large gains in profitability, then these authors suggest that a segregation (specialisation) approach may be more appropriate – if increment of profitability is the major goal for the landscape.

Similarly, Van Noordwijk & Ong (1999) indicated that the value of diversity in agroecosystems strongly depended on the ability of farmers to derive value from a large number of components, and not from one dominating component.

Reduction in the number of species for a particular niche or use-groups per farm could result in substantially greater risks to individual farmers, therefore needs great care.

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Annex 1. Species list in each agroecology

No.	**Woina- Dega**	**Kolla**	**Dega**
1	*Acacia decurrens*	*Carisa edulis*	*Acacia decurrens*
2	*Acacia saligna*	*Eucalyptus camaldulensis*	*Buddleja polystachya*
3	*Carisa edulis*	*Coffee*	*Cupressus lusitanica*
4	*Catha edulis*	*Catha edulis*	*Chamaecytisus palmensis*
5	*Calpurnia auria*	*Euclea recemosa*	*Dombeya torrida*
6	*Chamaecytisus palmensis*	*Calpurnia auria*	*Erica arborea*
7	*Cupressus lusitanica*	*Delonix regia*	*Eucalyptus globulus*
8	*Coffee*	*Acacia etbaica*	*Hagenia abyssinica*
9	*Eucalyptus globulus*	*Jejeba*	*Hypericum quartinianum*
10	*Euclea recemosa*	*Karor*	*Juniperus procera*
11	*Juniperus procera*	*Kombocha*	*Maesa lanceolata*
12	*Lomi Citrus*	*Ziziphus spinachristi*	*Olea africana*
13	*Maesa lanceolata*	*Lomi Citrus*	*Salix subserata*
14	*Mangifera indica*	*Mangifera indica*	*Senecio gigas*
15	*Moringa stenoptela*	*Papaya*	*Vernonia amygdalina*
16	*Olea europea ssp. cuspidata*	*Acacia saligna*	
17	*Papaya*	*Sebansa*	
18	*Sesbania sesban*	*Sesbania sesban*	
19	*Syzygium guava*	*Moringa stenoptela*	
20	*Salix subserata*	*Woyiba*	
21	*Senecio gigas*	*Zeitun*	
22	*Vernonia amygdalina*		

Agro meteorology and Remote Sensing

Rainfall Variability and Farmers' Copping Strategies: the case of Kobo Woreda

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Abstract

This study examines rainfall variability and farmers coping strategies in North Wollo: the case of Kobo Woreda. Historical rainfall data of the recent past records of kobo meteorological station was statistically analyzed on annual and monthly basis. Rainfall characteristics such as the annual total rainfall, the mean monthly rainfall, the coefficient of variation (C.V) of rainfall, and the precipitation concentration index were assessed. The result show that there is greater variability in rainfall distribution and amount and it is considered to be one of the most limiting factors in Agriculture. Farming systems survey was also conducted at five Peasant associations (PA's) of the study area to investigate the effects of erratic rainfall and farmer's coping strategies to weather related risks. The result showed that rainfall variability has a significant impact on crop and livestock production. Farmers have learned to cope with the current variability and have adapted a range of management strategies to ensure at least a minimum yield. But coping strategies are only risk avoiding and there is a need to share knowledge about these traditional technologies and to critically evaluate modern solutions in terms of costs, environmental impact and long-term sustainability.

Key words: Erratic distribution, intermittent drought, precipitation concentration index, coping strategies

Introduction

Rain fed Agriculture is influenced and highly constrained by climatic variability. The agricultural productivity of dry land farming zones is particularly fragile and vulnerable due to a wide range of climate and thus, the efficiency of the agricultural productivity system is determined mainly by the local climatic conditions (ICRISAT.1978). Among the climatic elements, rainfall is the most important factors, as it largely determines the agricultural productivity of an area. It defines the availability of moisture and the limits of the growing season. Agricultural operations depend on the anticipated pattern of rainfall over different time and scales. Rains in dry land climates are, however, notoriously variable, not only from year to year but also within the season (ICRISAT, 1978). Usually, researchers refer to the total amount of rain when characterizing the farming systems of a given area (Surrender et al, 2004). Annual averages alone, however, are of little use. In addition to its absolute quantity, the characteristics of rainfall such as its distribution, intensity and variability play an important role. Dry periods for example often occur during the growing seasons in many locations. These can last several weeks and markedly reduce yields yet their occurrence does not show up all in averages taken over several years. Analysis of these characteristics is therefore, essential. When data on the main variables of rainfall are known and analyzed, it is possible to choose crops and verities, planting dates and input levels in such a way that water available during the crop season can be exploited to the maximum The probability of a certain amount of rain, which can be calculated statistically, can also provide valuable information in planning agricultural land uses. The level of risk of erratic and unreliable rainfall may differ from area to area and farmer to farmer. Assessing and identifying the main problem areas where the effects of erratic and unreliable rainfall on the farming system most felt (i.e. is it feed shortage? limited availability of soil moisture and risks of prolonged dry spells? need for optimal timing of ploughing and planting to use the limited rainfall period? and so on) need to be addressed for further studies on improved intervention mechanisms.

Farmers may have their own indigenous knowledge and coping strategies to reduce those effects. Statements by farmers about climate and rainfall are also a source of valuable information. They can provide detail information on local conditions, which cannot be picked up by the weather stations broad networks. Therefore, it is very important to identify the wealth of indigenous knowledge underpinning farmers' strategies to cope with a drought prone environment, as well as the potentials and constraints of the on-going external interventions that assist farmers in their copping strategies. Accordingly, farming systems survey was conducted in five kebeles at Kobo woreda to investigate the effects of erratic rainfall and farmer's coping strategies to weather related risks.

Materials and Methods

The study area

Kobo woreda is located at the northern tip of Amhara National Regional State. The main town of the woreda, Kobo, is located at about 54 kilometers north of Woldia town. The woreda borders with Tigray region in the north, Gubalafto and Habru Woredas in the South, Afar region in the east and Gidan woreda in the West. The woreda has an area of 251,405 hectares or 2514.05 km^2. Its altitude ranges from 1000 to 2800 masl. Kobo is divided in to 32 peasant associations. The agro climatic features of the woreda is inclined to be tropical as 7.9%, 37.2%, and 54.9% of it is *Dega*, *Woina Dega,* and *Kolla*, respectively. The human population in Kobo woreda is estimated to be 206,788. The livelihood of the population is dependent on mixed farming and crop production, with about 96% of its population engaged in a risky agriculture. Due to various constraints, Kobo woreda is one of the critically food insecure woredas of the Amhara National Regional State.

Methodology

Historical rainfall data from Kobo meteorological station during the period of 1973 to 2006 were analyzed on monthly and annual basis. Rainfall characteristics such as the annual total rainfall, the mean monthly rainfall, the extremes of rainfall during the historical record time, the coefficient of variation (C.V) of rainfall, and the precipitation concentration index were analyzed. Farming systems survey on the effects of erratic and unreliable rainfall and farmers' coping strategies was conducted at five Peasant associations (PA's) of Kobo woreda. Ten respondents from each PA were interviewed with a structured questionnaire in addition to informal discussion to identify the risks of erratic rainfall on agricultural production and indigenous knowledge to cope with the problem.

Results and Discussion

Agro-climatic conditions

Historical rainfall data analysis (1973 to 2006) showed that the average annual rainfall of Kobo area is 655.83 mm (Table 1). About 62 % of this amount is concentrated during the main rainy season namely July, August and September (Fig.1). The standard deviation is found to be 171 mm with coefficient of variation of 26 % and the precipitation concentration index is 17%. The value of precipitation concentration index showed that there is seasonal variation of rainfall distribution and the coefficient of variation indicates a greater risk in rain fed agriculture. Comparison of the annual rainfall with the normal rainfall also showed that there is greater deviation of rainfall amount in year to year distribution (Fig. 2).

Table1. Agroclimatic elements of Kobo (Altitude: 1470masl, coordinates: 12.09, N.L., 39.38)

Month	Rainfall (mm)	Max. Temp	Min. Temp	Humidity %	Wind speed (km/day)	Sunshine Hours	ETo-Penman (mm/day)
Jan	12.43	25.8	12.6	60.1	161	7.82	3.92
Feb	15.03	27.3	13.3	57.4	200	7.71	4.62
Mar	29.93	29.1	15.6	53.9	186	8.01	5.15
Apr	59.92	30.5	16.1	55.3	186	8.17	5.48
May	46.76	32.1	16.6	47.1	156	8.39	5.57
Jun	17.00	33.7	18	37	175	6.53	5.75
Jul	114.58	31.4	18	48.2	181	5.71	5.27
Aug	204.70	30.1	16.9	58.8	139	6.05	4.65
Sept	87.66	29.9	15.3	60.6	111	6.73	4.43
Oct	42.11	28.7	13.8	71.7	179	8.31	4.6
Nov	12.47	27.9	11.9	46.6	137	9.13	4.42
Dec	13.24	26.4	11.5	55.7	144	8.48	3.94
Year	**655.83**	**29.4**	**15**	**54**	**163**	**7.6**	**1758**

The result of questionnaire based discussion with farmers of the study area also showed that nature of rainfall is the main constraint to crop and livestock production. The most serious problem of rainfall variability is poor rainfall distribution (Table 2). The rainfall pattern of the area is mainly characterized as late start, dry spell between two rainfall events, absence in the middle and early setoff. Time series analysis of rainfall showed that there is a decreasing trend even in rainfall amount since the year 2001(Fig. 3).

The climatic water balance analysis (comparison of the monthly rainfall with the monthly potential evapotranspiration) revealed that the study area has very short growing period. Crops grow best when there is no shortage of water in the soil and this occurs when the potential evaporation rate is matched or exceeded by the rainfall, at least during the growing season of four months. For Kobo area, however, the rainfall exceeds the potential evapotranspiration for a period of less than three months (2nd week of July to end of September).

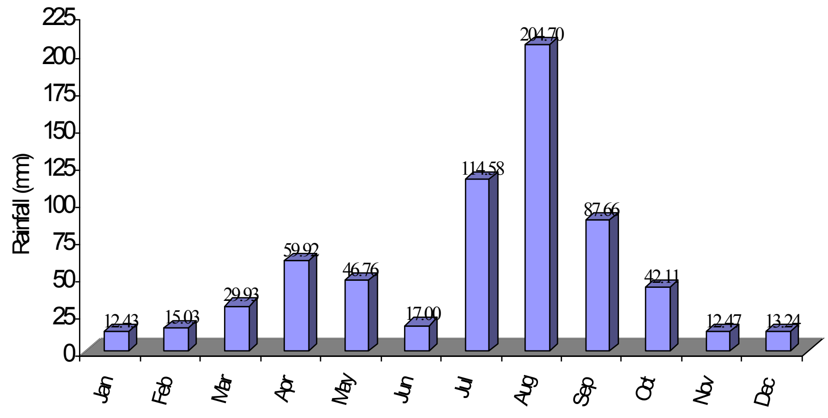

Figure 1. Mean monthly rainfall distribution at Kobo woreda

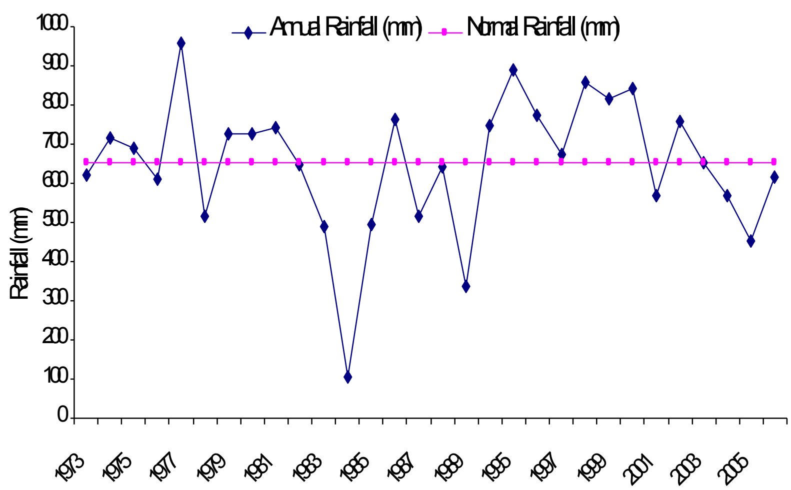

Figure 2. Comparison of annual rainfall and normal rainfall (mm) at Kobo woreda

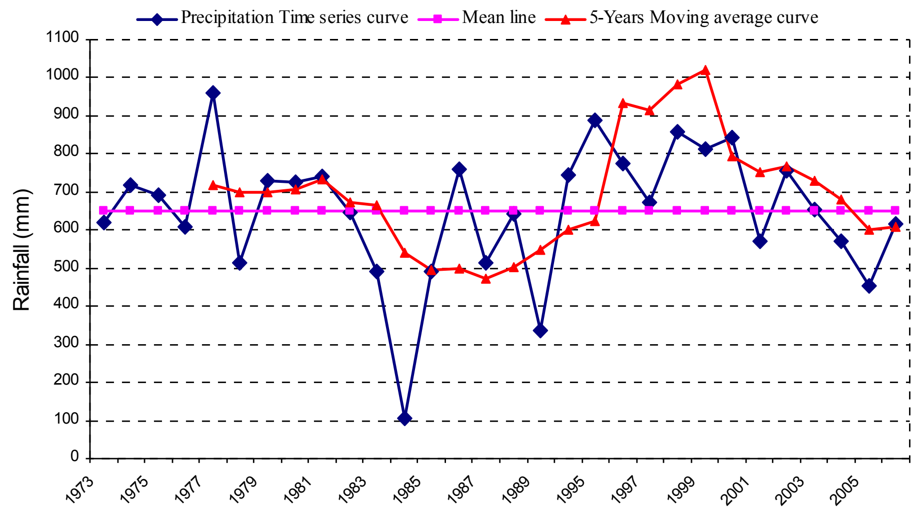

Figure 3. Time series analysis of rainfall at Kobo

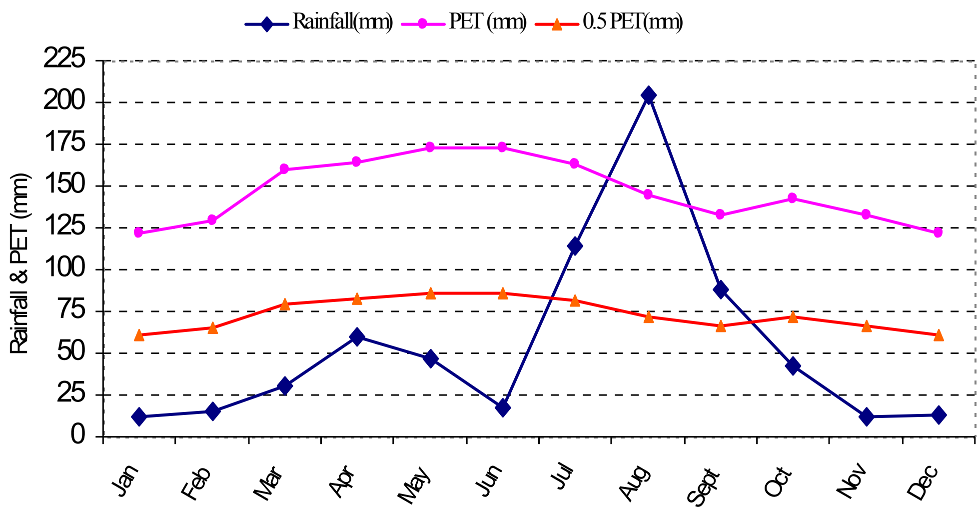

Figure 4. Comparison of annual rainfall and potential evapotranspiration (PET) at Kobo

Risks of erratic rainfall: Farmers' perception

Erratic rainfall is found to be the bottleneck for agricultural production of the study area. Farmers explained that the agricultural activity heavily depends on the timing, amount and distribution of rainfall. The nature of rainfall is, however, erratic in space and time and it significantly limits agricultural production potential of the area. Risks associated with rainfall variability identified in the study areas include:

- total or partial crop failure
- shift in crop types, and genetic erosion.
- pest incidences
- shortage in feed availability
- prevalence of animal disease

Table 2. Problems associated with rainfall variability as indicated by respondents.

No	Major problems	Percentage of Respondents
1	**Rainfall variability is the main constraint to crop and livestock production**	100
2	**Most serious problem of rainfall variability**	
	Poor rainfall distribution	70
	Inadequate rainfall amount	2
	Both Poor rainfall distribution and inadequate amount	28
3	**Trend of variability in rainfall Distribution**	
	Late start, Absence in the middle and early set off	34
	Late start and absence in the middle	26
	Late start and early setoff	16
	Late start	12
	Absence in the middle and early set off	4
	Early setoff	4
	Late start, absence in the middle and too much rain in specified period	2
	Late start and too much rain in specified period	2
4	**Increase of inter seasonal drought occurrence**	96
5	**Shift in crop types related to rainfall variability**	96
6	**Loss of long cycled local crop varieties (Genetic erosion) due to successive drought**	52
7	**Pest incidence in association to rainfall variability**	90
8	**Disease prevalence related to rainfall variability**	96
9	**Incidence of frost**	54
10	**Effect of rainfall variability on livestock feed availability**	100

Local Coping strategies and Technologies for adaptation

Various coping mechanisms and adaptive strategies have been adopted by the rural households in the study area to reduce the impact of unreliable rainfall events (Table 3 and 4)). Some of them are individual measures;

while others are community based requiring group action. The coping mechanisms can be visualized as a network to maximize utility of resources from both livestock keeping and agriculture. The adopted strategies and coping mechanisms are depending on households' perception on extreme events and the problem associated with it.

A common response to erratic rains is to change the type of crop grown or to modify planting dates. Local communities have developed a knowledge base of what crops can succeed in their location, including the choice of crop species that would be suitable under drier conditions. Dry planting during late start of the rain and replacing with another crop when the rain do not persist after planting is the main strategy to cope with the effects of rainfall variability. For instance, farmers of the study area usually use dry planting of long cycled local sorghum varieties and when the rainfall is not persistent, they replant short cycle varieties of the same crop but if the rain is delayed for long time and if they felt that the season is not favorable for sorghum varieties, they used to replace it with teff and some leguminous crops like check pea.

Farmers have a practice of diverting flood to their farmland whenever there is rain which is scientifically known as runoff farming and some of them have a tradition of plowing strips of sorghum seedlings , locally known as 'shilshalo' so as to increase the soil moisture status of their farm.

During livestock feed shortage; they reduce the number of animals, exchange oxen power fro straw, and use uncommon feed sources such as leaves and pods of trees.

In addition to the aforementioned coping strategies, farmers have their own indigenous forecasting and early warning systems. They forecast the condition of the coming rainy season based on observation of migratory bird species, blooming of flowers and abnormal behavior in animals and used this information to adjust their farming systems to some extent.

Table 3. Farmers coping mechanisms to effects of rainfall variability

No	Type of Risk	Coping strategies	Percentage of respondents adopting these strategies
1	Poor rainfall distribution and lack of on time rain	Dry planting and shifting to early maturing varieties	62
		Dry planting of local varieties	28
		Using high seed rate	6
2	Absence of Rain in the middle (Limited soil moisture immediately after planting)	Replacing with another crop (for example if sorghum is planted but can not grow due to limited moisture then the land will be replanted with chickpea)	94
		Replanting the same crop	6
3	Pest incidence	• Plowing the land in June and early July to kill the eggs of the pest, • Cleaning the boundaries of the farmland, • Killing some insects using mass family labor	34
4	Livestock feed shortage	Reducing the number of animals	40
		Exchange of oxen power for straw /crop residue	22
		Using uncommon feed sources such as tree leaves and pods	10

Table 4. Possible rainfall scenarios, associated challenges and potential strategies for adoption

Possible Rainfall Scenarios	**Associated Challenges/problems**	**Potential Strategies to be adopted**
Low amount (Skewed to the left of the mean)	Insufficient to meet crop water requirements (high actual evapotranspiration)	• Selection of drought tolerant crop varieties • Moisture conservation measures • Reduced seed rate /lower plant population • Protective/life saving irrigation and extension of LGP
Low predictability of onset date (cessation date of effective rainfall not known)	Difficult to adopt fixed date of sowing, crop/varieties and management practices	• Off season tillage to capture early rains that comes any time • Development of crops varieties of wider plasticity
Short duration(short growing period), late onset, early cessation	Potentially high yielding long cycle crops cannot be grown	• Development of early crops varieties • Adjust plant population (e.g. Within 30 days after onset) • Development of crop varieties of wider adaptability
Erratic distribution (high intra and inter season coefficient of variation)	Difficult to adopt fixed date of sowing, plant population and fertilizer rate	• Develop different crop varieties of wide adaptability
Intermittent drought		
Early season stress	Reduced Stand establishment, vegetative growth hang over	• Selection of short duration crops and varieties • Use of reduced plant population
Mid season stress	• Premature switch from vegetative to reproductive stage • Reduced pollination and fertilization	• Thinning down by certain percentage • Protective irrigation • Soil and moisture conservation • Mulching
Late season stress	• Shortened grain filling period • Reduced yield	• Thinning, weed removal, mulching (and other soil and water conservation) • Repeated inter cultivation(hoes have water) • Protective irrigation(life saving irrigation
High intensity index over short time	• Rainfall exceeds infiltration rate • Accelerated Runoff • Soil erosion and increased sedimentation load at the down reaches	• Increase opportunity time for concentration and infiltration • Runoff/water harvesting inter row, inter plot, on farm pond

Conclusion

Statistical analysis of historical rainfall data showed that the rainfall is highly variable both in distribution and amount. Farmers have learned to 'cope' with current variability though a range of strategies (crop, water and livestock management practices).Coping strategies are largely local processes and actions taken by those directly at risk. However, they are very similar across communities and hence it may be possible to develop a frame work for adoption based on strategies that have generally been successful. A broader awareness of coping strategies beyond the community can also contribute to the policy process and facilitate the replication of good practices. The causes of vulnerability and livelihood decisions that people make based on their access to resources, are important in designing adaptation strategies. A systematic review of coping strategies may also reveal the limits of current coping, and where longer term impacts might require new measures. As evidenced by those cases where people are only managing to survive rather than effectively cope with extreme events, it is clear that not all traditional techniques are appropriate for dealing with disasters. There is need to share knowledge about these traditional technologies, and to critically evaluate modern solutions in terms of costs, environmental impact and long-term sustainability. To make food security more robust , the impact of climate variability require a number of strategies such as adaptation of new crop varieties , efficient land management ,mitigation of the effects of drought , improved seasonal climate prediction and so on. Exchange of experiences between regions facing similar climatic threats and risks would help broaden the knowledge base on such adaptations. Climate risk management tools are now readily available (climate analyses software: crop, soil and water management and pest simulation models: spatial weather generators: satellite imagery, seasonal climate forecasting: GIS systems etc). The uncertain impacts of climate variability must be seen in the context of, and integrated into current development priorities.

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Natural Resources Characterization

Inventory and Characterization of Potentials and Management of Wetlands in Eastern Amhara

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Abstract

Even though wetlands are biologically diverse and hydrologically important features, they are among mis-managed natural resources in our Region. There is no policy for the sustainable use of them. Even, there is no information and study about the nature as well as the potential of wetlands. Raising awareness on the value of wetlands is therefore, essential for achieving an appropriate recognition of the role that these areas play at present and contribute to the development of the region. This study is aimed at to see the extent, distribution and threats of the major wetlands in Eastern Amhara to investigate sustainable wetland management techniques and institutions based on local and external knowledge systems. A formal survey with a preliminary informal survey was conducted in addition to field observation for the identification of the bio-physical characteristics and socio-economic values of wetlands in Eastern Amhara (North Wollo, South Wollo and Oromia Zones). Thus, wetlands of Chefa, Borkena, Gerado, Alashameda and the margins of Hardibo and Lego lakes have been assessed. The study showed that most part of the wetland is used as temporary grazing for animals during the dry season and there is few practice of early cereal harvesting on the uplands during the belg season. Some needy local people also generate income by selling grass species from the wetland which can be used as house roofing, thatching house floors and for different cultural ceremonies like coffee ceremony. Ealderly people witnessed that the wetland was a house for various types of flora and fauna but currently most of those bio-diversity resources are disappeared. Cheffe *(Cyprus latifolius)* and Tatie *(Wattled Ibis)* are the dominant flora and fauna respectively, which adapt the environment and exist for long years. In general, most of the communities consider the wetlands as a wasteland that has no significant value other than dry season grazing. There is no social attitude to protect and utilize them on a sustainable manner. This indicates that the area is neglected despite its significant role in ensuring environmental stability and food security. Hence, it requires urgent regional policy, management priority and awareness creation.

Key words: Wetlands, fauna, flora, biodiversity

Introduction

wetlands are defined as ``areas of marsh, fen, peat land or water whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters(Davis , 1994). For an area to be a wetland, water does not have to be at the surface, but it has to be close enough to the surface and for long enough to allow anaerobic conditions to develop in the soil (Adrian, 2001). Some wetlands may be permanently flooded, whilst others may have water close to the surface for only a few months in a year.

Ethiopia's wetland resources, which include swamps, uplands bogs, flood plains and the margin of natural and artificial lakes, are widely distributed through out the country. Currently it is estimated that 1-2 % of the landmass of the country is categorized under wetlands. Theses wetlands provide a range of functions and products, which are both environmentally and socio-economically beneficial to local communities. They help to regulate water flows, are essential habitats for many species of flora and fauna and support traditional land use practices.

Even though wetlands are among the most biologically productive ecosystems, their value and significance is often neglected. They are seen in a negative light of wastelands, habitats for pests and threats to the public health. Globally, awareness of the needs for the importance and sustainable utilization and conservation of the wetlands, in 1971, the representatives of 18 countries went to the small town of Ramsar in Iran to put their signature to the convection as it has become known. The Rasmar convection is the only environmental treaty dealing with a particular ecosystem and currently has 134 contracting parties (Davis, 1994). Ethiopia despite the fact that it has got many types of wetlands that are highly threatened is not yet a contracting party to the convection.

Wetlands in Amhara Regional State cover about 3.7% of the area and include areas of seasonally flooded grassland, water bodies and permanently flooded papyrus grass swamp (Abay, 2001). Presently, there is no policy for the sustainable use and conservation of wetlands in country in general and in Amhara region in particular. This study is aimed at to see the extent, distribution and threats of the major wetlands in Eastern Amhara to investigate sustainable wetland management techniques and institutions based on local and external knowledge systems.

Material and Methods

A formal survey with a preliminary informal survey was conducted in addition to field observation for the identification of the bio-physical characteristics and socio-economic values of wetlands in Eastern Amhara (North Wollo, South Wollo and Oromia Zones). Soil samples were taken from 0 to 40 cm and 40 to 100 cm depths of wetland fields and laboratory analysis of physical and chemical characterization of the soil samples had been carried out.

Results and discussion

Location, Distribution and Soil characteristics

Eastern Amhara is located in the North East escarpment of Ethiopia, which comprises Oromia, South Welo and North Welo administrative zones of Amhara region. Geographically the location is bounded in 10.10^0 to 12.36^0 N latitudes and 38.50^0 to 40.40^0 longitudes. The land area covered by the wetlands is estimated to be 23250ha, which is 0.42% of the total area of the sub region. The wetlands of this area are distributed into five different areas and categorized in Riverine, peat lands, depress ional, and fringe wetlands (Table1). Out of the five-wetland area the chefa wetland is the largest wetland area that share 75.3% of the wetland areas of the sub region and located in two Weredas of Oromia zone. The other four wetlands are located in three different weredas of south welo. There are no significantly registered wetlands in North welo administrative zone except few small ones in spot areas.

Table 1. Location, size and category descriptions of wetlands in Eastern Amhara

Name	Location	Area (ha)	Categorical description
Chefa	Artuma and chefa Dawa werdas of oromia Zone	17500	Dominantly Riverine wetlands but also consist of peat lands and depressional wetlands.
Borkena	Kallu wereda of South welo Zone	2500	Riverine wetlands
Gerado	Dessie Zuria wereda of South welo Zone	1500	Peat lands and riverine wetlands
Borumeda and Alasha	Dessie Zuria and Kutaber werdas of South welo Zone	1000	Purely peat lands
Hardibo	Tehulederie Woreda of South welo Zone	750	Fringe wetlands

Analysis of soil samples taken from 0 to 40 cm and 40 to 100 cm depths indicate that the wetlands have clay soil texture with organic carbon content of 0.9 to 2.3 %. The soil pH is in the range of 6.5 to 8.0.

Table 2. Some physical and chemical characteristics of soils in the wetlands

	pH		% N		% OC		% OM		Texture	
Wet land	0-40	40-100	0-40	40-100	0-40	40-100	0-40	40-100	0-40	40-100
Chefa	7.4	7.7	0.2	0.1	1.4	0.9	2.4	1.5	clay	clay
Borkena	8.0	7.3	0.2	0.2	MR	1.2	MR*	2.1	clay	clay
Gerado	7.5	7.4	0.7	0.3	2.5	1.8	4.4	3.1	clay	clay
Borumeda	6.5	6.6	1.1	0.5	MR	2.6	MR	4.4	clay loam	clay
Hardibo	7.4	7.3	0.3	0.3	2.3	1.8	4.0	3.1	clay	clay

* MR = more than the expected range

Bio-physical features of wetlands

Chefa wetland

Condition of inlets and outlets of the wetland:

The main rivers and streams that cross chefa wetland are Borkena, Betho, Tuluberie,Workie, Dolu, Yigebehal, Habaya, Arfatu, Salons. These rivers discharge water to the wetland particularly during the main rainy season and water in excess of Borkena River, which is the outlet for all these rivers, will cover the wetland surface for about two to three months. Thus, during the rainy season, Chefa wetland would be roofed by water. The wetland has both inlets and an outlet. But during the rainy season, the amount of water discharged in by the inlets is much greater than the amount discharged through the outlet and hence the area would be roofed by water.

Bio-diversity

Chefa wetland is an important habitat for many species of flora and fauna. It is observed that various wetland dependant and wetland associated as well as wetland independent plants and animals use it as their habitat. But detail identification and classification of the flora and fauna was not possible. However, local names of very dominant species were recorded. The major floras available in the wetland are Filla, Senbelet, Delecho, Cheffe (*Cyprus latifolius*), Qetema, Qeqeba, Qewie, and Wonz Admik (*Salix subserrata)*. Balo (mogne fakir) and Benj are also widely distributed wetland independent species which are transported from other areas by water and adapt to the wetland.
According to information by local communities, chefa wetland was forest area several years ago. It was an essential habitat for various tree species mainly Girar *(Acacia spp.)*, Bisana *(Croton macrostachus)*, wanza *(Cordial africana),* Warka *(Ficus species)*, Aregalo Shashatie and Gilo. All these species are now disappeared from the wetland due to dynamic land use changes.The major fauna available in the wetland include Kakisa (birds with long legs and bikes), Tatie *(Wattled Ibis)*, Dakiye, Kebero *(fox)*, Beyeme and fish. Animals like Agazen, Tota *(ape)*, Kerkero, Gureza, Sala were common several years ago but now they disappeared.

Current land use type and economic values

Most part of the wetland is used as temporary grazing for animals during the dry season. It is used as a communal grazing land and any body can use the wetland as a means of feed source for animals during the dry season. Even the nomads from remote areas like Afar region migrate with their animals and settle with in the wetland in temporary huts to use the wetland for grazing during acute feed shortage seasons which is locally called Wuren Mawetat. The grazing land is poorly managed and no local bylaws are applied over its utilization except the ELFORA site. Only about 1648 ha of grazing land is under best management by ELFORA.
The second type of land use is an early cereal harvest on the uplands during the belg season. In some parts of the wetlands and edges, farmers harvest crops like maize and teff using belg rain and supplementary irrigation near Borkena River. But according to farmers' information, inmost cases, there is crop failure due to lack of rain during the belg season and water logging when too much rain comes.

Starting from the mid of June, the wetland will be roofed by water and hence, livestock grazing and crop production activities will stop till the next September. The duration of water logging problem depends on the condition of the rainy season.

The wetland has various economic values other than grazing and cultivation. Local communities use filla (long green grass) for house roofing. Some needy people made dibora or Gadeta from filla and sold it up to 5 birr per unit price. Debora is used as house floor roofing. Some poor families also get income by selling cheffe to towns dewellers, which is used for thatching house floors and for different cultural ceremonies like coffee ceremony. Nomads, who migrate to the wetland, use Filla and other grass species for building temporary huts. Traditional fishery is also a means of income for some people.

Major threats and Farmer's perception to the wetland

Grazing by domestic stock is the major threat to the wetland. The wetland is used by a large number of livestock, which is beyond its carrying capacity, during the dry seasons. Intensive grazing makes wetlands lost their natural features. Drainage problem (water logging) followed by Weed infestation is another threat to the wetland management. During the rainy season, the wetland is roofed by excessive surface water and when water drains, weeds transported with sediments from other areas start to grow. The wetland is now being invaded by transported aggressive weed species like *mogne fikirr*.

Hazard of epidemic disease on animals is a common problem and malaria infestation associated with the wetland is a threat to public health.

Most farmers consider the wetland as a wasteland that has no value other than dry season grazing land. They need it to make fully cultivated land and hence they do not consider other economic values of the wetland. Some farmers, however, are aware of it as a potential natural resource that can be beneficial if its management is improved. Few farmers, around Kemissie, for example, attempt to cultivate rice by their own initiation. They suggest that if it is possible to build dikes to improve the drainage problem, the wetland can be a productive area (both for cultivation and grazing).

The grazing land is a common resource (Community owned) and the wetland used for an early cereal harvest is privately owned. There is no social rule and by-laws to protect the community owned wetland. Every one can utilize the wetland without any limitations.

Borkena (Tekaki and Mar bete) wetland

Condition of inlets and outlets of the wetland

The wetland has both inlets and an outlet. But during the rainy season, the amount of water discharged in is by far greater than the amount discharged through the outlet and hence the area would be roofed by water.The main rivers and streams that cross chefa wetland are Borkena, Tuluba Jibo, Dirma, Felana and Harbu. These water bodies discharge water to the wetland particularly during the main rainy season and water in excess of Borkena River, which is the outlet for all theses rivers, will cover part of the wetland during the rainy season.

Bio-Diversity

Borkena wetland is an essential habitat for filla (wobello), delecho, cheffe and qetema. Shewshewie and shenbeko (Arund donax) are the main plant species which disappeared from the wetland. Dominant fauna currently available are Wutala, white birds, and Dakiye while Agazen and Tota (ape) are extinct animals from the wetland.

Current land use and economic values

Upland of the wetland is under cultivation during the belg season and some part of it is also under meher season cultivation but this part is in risk when the rainy season is heavy. The most central part of the wetland is marshy and no cultivation can be operated but it is used as source of animal feed during the dry season.

Harvest of grass spp. like filla for the roofs of rural houses, fishery (traditional) and selling of grass spp. like filla to the towns are important means of income for some poor families.

Major threats and Farmer's perception

The land is utilized under its capacity due to water logging problem. Malaria infestation that is due to the presence of the wetland causes human health problem.

Some farmers perceive that the wetland is potential for crop cultivation if it is possible to control the water-logging problem. Most farmers consider the temporary grazing wetland as a wasteland that has no value other than dry season grazing.The grazing land is a common resource (Community owned) and the wetland used for an early cereal harvest is privately owned. The community applies no bylaws to protect the communal wetland and the commons tragedy guides its utilization.

Gerado wetland (Merfeta, Ambo chefe and Bilen meda)

Condition of inlets and outlets of the wetland:

This wetland is located in south Wollo zone of Dessie Zuria woreda. It is extended from Kelina in the southeast to Gerado in the northwest. Altitude of the area ranges from 2210 to 2250 m.a.s.l. It is estimated to be 12 km length by 1km width or about 1200 hectares (this is a rough estimation). The main rivers and streams that cross chefa wetland are Gerado (Qelina), Bilen, Legeworkie, Jegola, yenege woli, and Yito. The wetland has both inlets and an outlet. Gerado river is the outlet but during the rainy season, this river can not drain all the water discharged in and hence the area would be roofed by water.

This wetland is not rich in its bio-diversity. Gerado River are chefa, qetema, gicha and cheffe. Some bird species such as white birds and Ziye (Dakiye) also exist.

***Current land use* and major threats:**

Almost all part of this wetland is under cultivation but it is a problematic farmland. The water level is high and it is impossible to harvest crops during the meher season. Only an early cereal crop harvest can be operated and it will left fallow during the rainy seasons. Main crops that can be cultivated are maize, barley, wheat, and Abish. Land preparation will start in November and planting is in January. Farmers attempt to provide supplementary water to crops by diverting nearby rivers, particularly during the initial growth stages. Part of the wetland along the edges of Gerado river, is used as animal feed source under cut and carry feeding systems.Harvest of grass spp. like Filla for the roofs of rural houses, selling of cheffe and qettema to the towns is important means of income for some poor families. Some marshy sites with in the wetland are sources of theses grass species.

Water logging is the major threat. The land is potential for crop production but it is a problematic area. Starting from June, the area will be under the problem of drainage and during the rainy season, the area will be roofed by water. Farmers are aware of it as a potential farmland despite its water logging problem.

Margins of Hardibo and Lugo Lakes

Condition of inlets and outlets of the wetland:

Runoff from hillsides and Water from rivers such as Anqerka, Fecha, Gido, Wulawul, and Gendetre cross the wetland and enter to the lakes, which have no outlet.

Bio-diversity

The lakes are rich in their bio-diversity particularly in their fauna composition. Some of the major bird species recorded in their local names are Yebahir Dero**,** Aliquada (birds with long leg and bikes), hawsew amora, white birds (sabisa), qetie boleche, kakisa, harie gobit and Assa(fish).Some of the dominant grass species in their local name are Hebelo, Qetema, Dilcho, Chefe, Qebero ageda.

Land Use

These lakes and their boundaries are under the category of wetland. The farmland around the lakes, locally called "bahire sheshi meret", is utilized for crop production but it is under stress of water logging. Farmers around lake Hardibo harvest sorghum. According to farmers view, sorghum is relatively better to cope with the problem of water logging but other crops like maize cannot resist it. Farmers around lake Lugo on the other hand, produce perennial crops like orange in addition to cereal crops.

Local Community use Hebelo (long green grass spp.) for house roofing. They also use Delecho to make *Gesso (rain protective material).* Fishery is experienced at theses lakes. There is legally organized union of fishery at Haike Town. Members of the union harvest fish from the lakes. Lake Hardibo is used as a source of irrigation scheme established by SAERAR.

Boru and Alensha Meda

Boru and Alensha Meda *are* communal grazing lands and farmlands to the north and west of these wetlands are under the problem of high water level. Wheat and Barley crops are being cultivated only during the belg season and left fallow during the rainy season.

Conclusion and Recommendations

Wetlands are natural habitats for many types of flora and fauna. On the one hand they keep the biodiversity resources and on the other hand they maintain the balance of the ecosystem. They also have socio-economic values. However, currently they are mismanaged and are under threat. First of all they are community owned and there is lack of awareness of users on the significance of these resources. There is no rule and by-laws to use the wetlands properly. Every one attempts to get the maximum benefit from these resources with out taking care of their management and hence tragedy of the commons rule is applied on them. If the current land use and management system continues, there will be time that these resources totally distorted leading to environmental imbalance. Hence, there is a need to devise a strategy for better management and sustainable utilization of these resources. Policy needs to be devised to consider and protect theses resources and their ecological functions and socio-economic advantages need to be recognized and valued. This study focuses on preliminary investigation of wetlands as initiation but further investigation and detail study using satellite images to identify the major aspects and mapping the wetlands is strongly recommended for proper monitoring and management.

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Natural Resources Limitations and Potentials in Amhara Regional State: The Case of Lay Gayint Woreda

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Abstract

A survey was conducted in Lay Gayint Woreda, South Gonder Zone of the Amhara Regional State in 1999 to investigate the natural resources base of the area for agricultural development intervention. The survey method used was Participatory Rural Appraisal (PRA) technique. Results of the survey revealed that the area is highly degraded due to severe water erosion, deforestation, continues cultivation and improper farming practices. Drought is regarded as the leading yield-limiting factor. It prevails quite frequently and in some seasons, farmers remain with out crop harvest. The unreliable and erratic rainfall usually accompanied by hail also makes agricultural production a difficult exercise. Very limited surface and underground water is available. Most of the rivers are located in deep gorges and are difficult to be used for irrigation. Natural forests are extinct in the area. Only some remnant traces of natural trees are available on farmlands, on communal grazing lots and riverbanks. From the survey result, it is possible to conclude that Lay Gayint woreda is highly degraded, infertile, overpopulated and drought prone. Therefore, the following recommendations could help to alleviate the problem: practicing physical and biological soil conservation practices on sloppy lands and on active gullies; practicing alley cropping systems on hilly farmlands; area closure of highly degraded lands for rehabilitation; practicing in-situ and ex-situ moisture conservation practices; exploiting available underground and river water; encouraging farmers to use organic and inorganic fertilizers; introducing pulse crops in crop rotation systems; and finally voluntary resettlement of the population to areas with less population, fertile soil and having reliable rainfall.

Key words: Drought, deforestation, erratic rainfall, soil erosion, soil fertility depletion

Introduction

The Amhara National Regional State has 105 woredas, of which 49 woredas are regarded to be drought prone. About 2.5 million people living in these woredas are food insecure or require food aid at least some time in the year.

This number accounts for about 17.3% of the region's population (Akalu Teshome et al, 2000).

According to the first five years development plan of the Amhara National Regional State, top priority was given to the agriculture sector mainly to ensure food security at the household level. However, the effort was not successful in drought prone areas. It is mainly attributed to lack of appropriate agricultural production technologies. Moreover, previous agricultural research efforts focused on high potential areas. Although the agricultural production constraints in drought prone areas are numerous and interwoven with each other, it did not received research patronage and even the problems were not identified and prioritized in a systematic manner. Hence, previous development efforts in drought prone areas did not give the desired results.

Recently, awareness among researchers in the region have grown that with out understanding the natural resources base and the farming systems of the Woreda, it is impossible to think about any research activity or to device any agricultural development intervention. To this effect, a survey was conducted to assess the natural resources base and the farming systems of the woreda to identify the problems and recommend some research, development and policy interventions. In this paper, result of the survey on natural resources potentials and limitations of Lay Gayint woreda is presented. The results and suggestions presented in this paper could be valid to similar degraded and drought prone woredas of the Amhara Regional State.

Materials and Methods

The Study Area

Lay Gayint Woreda is located in South Gondar Administrative Zone of the Amhara National Regional State. It borders with Estie and Farta Woredas in NorthWest, Ebinat and Meket Woredas in the North, Simada and Tach Gayint Woredas in the South and Tach Gayint and Meket Woredas in the East (Fig 1).

The total area of the Woreda is 132, 031 hectare (Woreda Office of Agriculture, 1991 E.C). The altitude of the Woreda ranges from 1300-3500 meters above sea with varied toposequence across the height, which extends from Tekezie basin to Guna peak. Nefas Mewicha is capital of the Woreda. It is located 175 and 75 kms away from Bahir Dar and Debre Tabor towns, respectively. The approximate global position for the capital of the woreda is 11.77^{0}N and 38.5^{0}E (Intergovernmental Authority on Drought and Development (IGADD) et. al, 2000). The population of the Woreda is estimated to be 200,951. Of this, 91.8% are living in rural areas (Woreda Office of Agriculture, 1991 E.C).

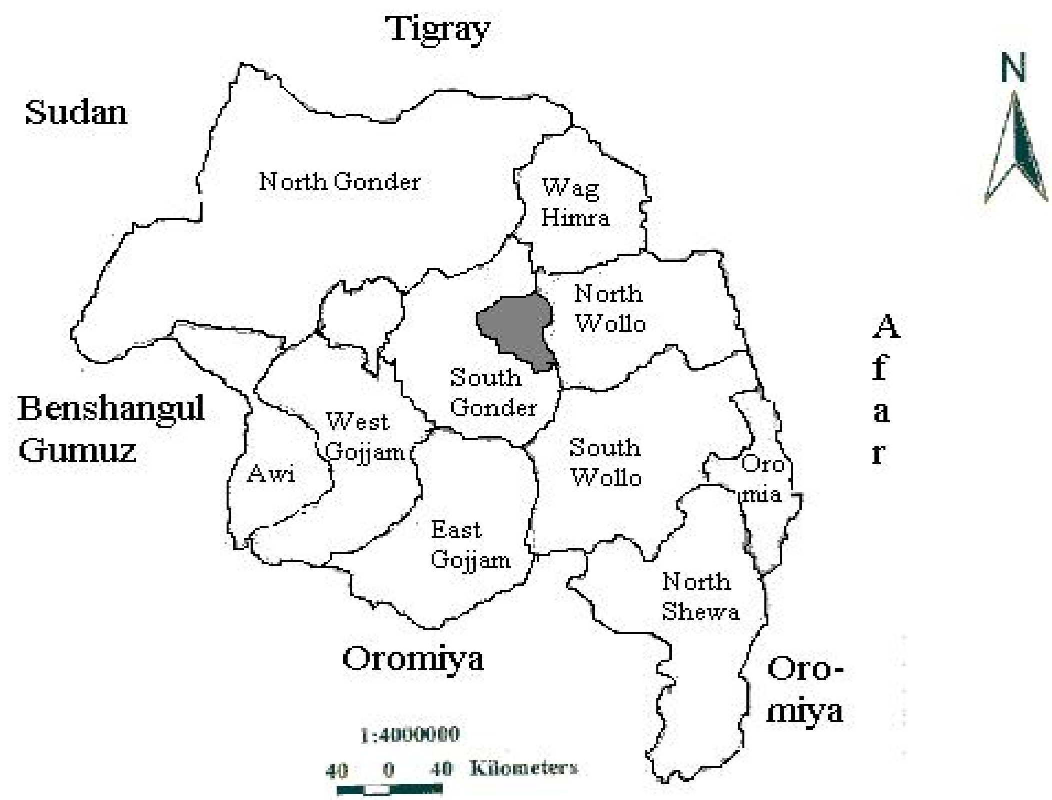

Figure 1. Approximate location of Lay Gayint Woreda (shaded) in the Amhara Regional State (ANRS)

Based on altitude, the Woreda can be divided in to four major climatic zones. These are low land (Kola), intermediate (Woina Dega), high land (Dega) and extremely high land (Wurch). Kola, Dega and Wurch, and Woina Dega contribute 28%, 41% and 31% of the total area of the Woreda, respectively. With regard to topographical distribution, about 70% of the Woreda is rugged terrain, 15% is mountainous, 10% is flat land, and the remaining 5% is valley (Woreda Office of Agriculture, 1991 E.C). The most rugged topography is found in the Kolla and Woina Dega areas while relatively plain topography is found in the Dega and Wurch areas. Although much of the land is rugged and unsuitable for cultivation, farmers continued to cultivate it for the last several years. Therefore, the topsoil of most lands is washed away by water erosion and land sliding.

According to the Woreda Office of Agriculture, the average annual rainfall ranges from 600-1100 mm and the average minimum and maximum temperature is 9 and 19^0c, respectively. The effective rainy season extends from mid June to first week of September. If the rainy season starts in March, farmers grow potato and barley in woina dega and dega areas, and sorghum in kolla and Woina Dega. Belg rainfall is crucial to overcome seasonal food shortage. According to farmers' report, if rainfall fails to happen in March and May, farmers encounter serious food shortage. The rain shower from September to October is also crucial to grow residual moisture crops such as chickpea, grass pea and barley. However, the rainfall is erratic in distribution and the amount and duration is not dependable for crop production. Late onset, uneven distribution and early cessation are some of its features. The climate varies from year to year and favors pest and disease development.

Survey Methodology

The survey was conducted in a sequential fashion using the following steps: secondary data collection and analysis, representative site selection, participatory rural appraisal (PRA) and individual and group interviews on general themes.

Collection of secondary data was carried out by reviewing several reports and interviews of representatives of the Woreda Office of Agriculture, Woreda Administrative Council, Woreda Cooperative Office and non-gove-

rnmental organizations (NGOs). After analyzing the secondary data, the previously designed checklists of the participatory rural appraisal was readjusted by incorporating new findings.
To study the agroecology and physical characteristics of the area and select a representative site for each ageoecological zone, transect drive was made together with representatives of the Woreda Office of Agriculture. Based on this, Kola, Woina Dega, Dega and Wurch climatic zones were identified in the Woreda. Two representative peasant associations (PAs) from each Dega and Woina Dega and one PA from each Wurch and Kola climatic zones were selected. Transect walk was made from the highest to the lower point of the village. Along the route, observation on soil types, existing vegetation cover, settlement, crops grown and other relevant information were gathered.

Problem identification and prioritization were made in each climatic zone by using pair-wise ranking. Farmers identified and prioritized their problems logically and systematically with out external interference.

Participatory rural appraisal (PRA) technique was used to collect and analyze primary data. This method gave a chance for the community members to participate in problem identification and prioritization. After PRA technique, small groups were formed and thorough discussion was made which helped to generate basic data and cross-check the available information.

Results and Discussion

Soil and Water Degradation

Kola Domain

The kola domain is the leading one in the intensity of erosion among all the four domains studied (kola, woina dega, dega and wurch). About 95% of the area are vulnerable to erosion. Farmers speculate the following causes of erosion in the area:
1) Deforestation: The area is highly deprived of vegetation cover and this situation generally exposed the area to serious water erosion.
2) Topography: Steep slopes and ruggedness of the topography accelerates speed of run-off collected from the uphill.

3) High and erratic rainfall: Heavy and erratic rain, which is usually coming after the land is tilled, causes the soil surface to be eroded. This situation besides eroding lands on the uphill causes heavy siltation on the bottomlands and makes production a difficult exercise.
4) Population pressure: Average family size is nine people and a household has two "Timad" of land (1 Timad =50x25m). The high number of human population per unit area brought about continues cultivation and eventually loosening of the soil surface. Moreover, hilly areas are always intensively grazed by animals and the grass cover is totally absent. Therefore, the area is vulnerable to erosion.

Some activities are being undertaken by the government and non-governmental organizations like CPAR, FHI and GTZ to conserve soil and moisture in the area. The soil and water conservation practices focus on constructing physical conservation structures like stone and soil bunds, cut-off drains, check dams on gullies and waterway ditches. Only some "Imbacho" and "Ret" plants are seen on the bunds. The effort on conservation using physical structures is encouraging. This intervention was started after much of the topsoil was washed away in many instances, which suggests that biological conservation activities should be integrated with the physical ones to rehabilitate the soil fertility of the area. This will assist in supplying the farmer with organic fertilizer (which will restore the soil fertility status), fuel to the family and feed to his animals.

Woina Dega Domain

The woina dega area is less degraded than the kola area but more degraded than the dega and wurch. In this domain, soil degradation is regarded as major production constraint next to drought. About 90% of the area is exposed to erosion. Causes of soil degradation in this area remain to be the same as that of the kola area. However, two more causes are added here. The first one is, drainage ditches opened during road construction are dissecting farm lands and cause serious gully formation. The other one is land sliding, which in some cases is taking away the entire village, is reported to be serious treat to the farmers of the area. As soil and water conservation methods, soil and stone bunds, check dams, cut-off drains, drainage ditches and planting grass stripes like vetivar grass are practiced in the area.

Dega Domain

Soil erosion in the dega area is less severe than the Kola, Woina dega and the Wurch areas. It is mainly because there are more flat lands in this domain which minimize the intensity of erosion. In kebele 4 for example, 75% of the land is flat or has gentle slope, 23% is sloppy and 2% is stony. Moreover, the relatively intensified livestock husbandry in the area paved the way for leaving more grass covered grazing lands. Nevertheless, about 75% of the total land area are still exposed to erosion. Among soil conservation methods, stone and soil bunds, fanyaa juu, cut-off drain, check dams and biological soil conservation methods like planting vetch and tree lucern are practiced.

Wurch Domain

The wurch area is the starting point for most of the rivers. Therefore, there is always downward movement of soil and water resources from this area. This eventually caused serious degradation of land. The topography is unique in that there is no flat land surface and about 85% of the area are exposed to erosion. Some soil conservation structures such as stone bunds are available. Farmers reported that, soil bunds are not effective in this area. Because, the topography is very steep and such structures cannot withstand the runoff coming down with very high velocity.

Soils and Soil Fertility

Kola Domain

Soils in the kola area can be classified into three major groups:

1) "Walka" soils. These are heavy black soils (Vertisols) distributed in the valleys, near rivers and springs. On such soils farmers grow tef and chickpea. These soils are regarded as the most productive soils of the area.

2) "Serbola" soils. These soils are a mixture of red and black soils (Cambisols). These are situated in the middle of the hillsides. On this soil types major crops grown are wheat, faba bean and field pea. These soils are regarded to be second after walka soils in their fertility status.

3) "Keyatie" soils. These soils are loam red soils (Luvisols) found on the top of the sloppy catchments. On such soils lentil and linseed are cultivated. They are identified as the least fertile soils of the area.

Soil fertility problem is a serious problem, which attributed for low crop productivity in the area. Some times, even rock fragments that do not satisfy the criteria to be called "a soil" are being cultivated. Major causes for poor soil fertility status of the Kola area of Lay Gayint Woreda are: physical erosion of the top fertile soil, continues cultivation of the same land with out fallowing, high mineralization rate of organic material (which is related to high temperature), mono cropping, and overgrazing (which causes low nutrient return).

Farmers do not use artificial fertilizers. They have many reasons for it. Among others, farmers speculate that burning effect of fertilizers on dry seasons, high cost of artificial fertilizers and absence of subsidy when crops fail due to unfavorable weather conditions and the steep nature of the cultivated land are regarded as the major ones. They apply some manure in their homestead farms to produce maize if at all left after satisfying their fuel demand. Farmers apply ash and some decomposed feed leftovers on some fields.

Woina Dega Domain

Soils of the woina dega area can be classified into four major groups:
1) "Walka". On such soils crops like tef, sorghum, grass pea and chickpea are cultivated.
2) "Serbola". On such soils crops like barley, fababean, wheat, barley and lentil are the major ones.
3) "Keyatie". On such soils farmers grow crops like linseed, lentil and noug.
4) "Nechatie". This are sandy loam gray soils (Regosols), which cover the top of mountains and contain many stone and gravel particles. These soils are usually used to produce linseed and lentil.

Most of the soils of the woina dega area are virtually infertile. Linseed and noug are the dominant crops in this area. The change in the farming system from "Magie" barley to barley varieties like "Embudiy", "Nechita" and "Embedat" which can survive on degraded lands are good sines of soil fertility deplition. However, in relative terms, "Serbola" soils are regarded as the best soils of the area followed by black, red and gray soils. In area coverage, the 'Walka" soils dominate followed by "Serbola", "Keyatie" and "Nechatie". Unlike the Kola domain where artificial fertilizers are rarely used, in woinadega domain urea and DAP fertilizers are applied for tef and wheat production. However, due to high purchasing cost and the risk of crop failure when rain fails, farmers have some reservations in using mineral fertilizers. Besides artificial fertilizers, farmers apply some manure on potato, onion, and barley, which are cultivated as homestead crops. Ash is also used as fertilizer on waterlogged soils.

The soil types in the dega area are also classified into four, i.e., "walka" (produces tef, guaya, and fenugreek), "serbola"(produces barley, wheat, and faba bean), "nechatie"(produces linseed, field pea, wheat and lentil) and "keyatie"(produces wheat and linseed).

According to farmers, the sharp decline in soil fertility status started when redistribution of land was made in 1971E.C. This situation brought fragmentation of land. Small land owning per household caused continues cultivation with out fallowing practices, which generally made the land to be exhausted. There is a limited attempt by farmers to apply artificial fertilizers like DAP and Urea on wheat and tef. However, as in the case of other domains, farmers are complaining of high fertilizer costs. Fertilizer costs in "Kebele 4" for example, was 246.65 and 215.50 Birr per quintal in 1991/92 E.C, and 271.00 and 182.00 Birr per quintal in 1992/93 E.C cropping seasons for DAP and urea fertilizers, respectively. Poor fertilizer use efficiency of crops was also reported usually attributed to limited moisture availability and cold weather condition. In this area, farmers are complaining of poor solubility of white colored DAP than the gray ("guaya melk") one. Some manure and ash are applied in homestead crops like brassica and onion production. Crop residues are not left in the fields because farmers use crop residues as animal feed and to cover the roof of their houses.

The soils of the Wurch area are classified into “Serbola”, “nechatie” and “keyatie” that are covered only by potato and barley. Although the “serbola” soils take the lion's share in area coverage and are considered as the most productive soils in other domains, they are here considered as least productive. This soils occupy the top flat surface of the mountains and permanent freezing during the cropping season generally hinders crop production. Artificial fertilizers are not totally applied in the area. Farmers are justifying it by the coldness of the weather which generally diminishes fertilizer sue efficiency.

Water Resources

Kola Domain

Moisture is the most serious limiting resource of crop production in the kola area. It is scarce both for human and animal use. Insufficient rainfall, and

above all its erratic distribution, is limiting crop and feed production. Rainfall starts late in June and ends early at the beginning of September. Some small and medium sized rivers are available in the area. However, because of the ruggedness of the topography, most of them are flowing through deep gorges and could not be used for irrigation. Some activities are being undertaken to harvest water. In situ water conservation is practiced using hillside bunds; however, due to sloppiness of the area and poor infiltration rate, it is difficult to maintain as much moisture as needed, which can sustain annual crops. Tree species, however, may successfully grow in this area.

Woina Dega Domain

Rainfall is unpredictable in woina dega area too. In most cases, it comes late and ends early. Besides, rain usually accompanied with hail cause serious damage on crop production. There are some ponds, streams and deep wells dug by the Food for the Hungry (FHI) non-governmental organization which are being used as source of drinking water. Some farmers who have lands in the vicinity of springs also use the water to irrigate their lands. Farmers are reporting that, there are some rivers in the area which can be used for irrigation. However, it was observed that it is very difficult to find large command area for irrigation which may payback the investments to be made. There are some possibilities of implementing in-situ moisture conservation and growing perennial crops. Tie- ridger is demonstrated by Canadian Physicians for Aid and Relief (CPAR) in the area. CPAR also had a plan of introducing hard pan braking plough (sub-soiler) to increase infiltration rate and conserve moisture in the area.

Rainfall shortage is also critical in the dega domain. In this area also rain starts in June and ends in early september. Erratic and heavy rain is sometimes causing serious flooding problems which is devastating large landmass. Moreover, hail damage and frost are serious problems of the area. However, it seems that there is better chance of developing irrigation schemes in this domain than elsewhere in the woreda. Because, there are more flat lands and rivers which can be used for irrigation.

Erratic rainfall, hail, frost and freezing of soil water are among the most serious problems for crop production in the wurch area. Farmers reported that there are rivers, which start their way from their villages but are unable to use them. Because stopping the rivers means that the down stream people will not have anything to drink and eventually will create a conflict.

Vegetation

Kola Domain

Natural forests are extinct in the kola domain. There are only some remnants of natural trees such as “Dedeho” (*Eulea schimperi*), “akakima”, “imbacho”, “wanza” (*Cordia africana*), and “imbis” (*Allophylus abyssinicus*). These trees are found on hill sides, river borders and deep valleys, which are in most cases inaccessible. Some eucalyptus trees are planted near homesteads on "Serbola" soils. Farmers use eucalyptus as major source of fuel wood, building material and construction of farm implements. Farmers call eucalyptus "wulletaw beza" meaning a tree with high merits. Agroforestry systems are not practically seen. Most of the farms are cleared from trees and shrubs.

Woina dega domain

In the woina dega area, the dominating natural tree species are acacia (*Acacia spp*.), “imbacho”, “imbis” (*A. abyssinicus*), “woira” (*Olea africana*), “kitkita” (*Dodonia angustifolia*), “bissana” (*Chroton macrostachys*), “kega” (*Rosa abyssinica*) and “agam” (*Carissa edulis*). From artificial plantation eucalyptus, “yabesha tid” (*Juniperus procera*) and “girangire” (*Sesbania sesban*) are dominating. However, the dominant tree species is “imbacho”, which is growing on the degraded lands and on terraces. Other trees are located on mountainsides, riverbanks and rarely within the field. Farmers are willing to plant trees in their field boarders. However, the free grazing system prevailing in the area is argued to hinder this intervention. Area closure is being implemented in the area to preserve trees, and some promising results are achieved in some kebeles. However, desired achievements in this domain generally could not be achieved due to the limited land resources per household and the free grazing system.

Dega Domain

In the dega domain from natural tree species acacia (*Acacia app*.), “kosso” (*Hagenia abyssinica*), “amija”, “woira” (*O. agricana*), “imbacho”, and “kega” (*Rosa abyssinica*) are available in trace amounts. Among manmade plantations, eucalyptus, “yabesha tid” (*Juniperus procera*), and “gesho” (*Rhamnus prinoides*) are the major ones. There are very few protected forests.

Wurch Domain

In the wurch area among the natural tree species “asta” (*Erica arboria*), “amija” (*Hypericum roeperianum*), and “jibira” (*Jiant lobilia*) are the major ones covering. Some eucalyptus manmade plantations are there. On some mountain tops there are protected forests with asta trees.

Generally, farmers have identified the following to be the major natural resources related problems in of Lay Gayint Woreda in a descending order of importance (Table 1):

Table 1. Major natural resources related problems in of Lay Gayint Woreda in a descending
order of importance based on the PRA

Kola	Woina Dega	Dega	Wurch
1) Moisture shortage	1) Land shortage	1) Soil fertility depletion	1) Land shortage
2) Soil erosion	2) Moisture shortage	2) Soil erosion	2) Soil fertility depletion
3) Land shortage	3) Hail damage	3) Hail damage	3) Soil erosion
4) Soil fertility depletion	4) Deforestation	4) Land shortage	4) Moisture shortage
5) Deforestation	5) Soil erosion	5) Moisture shortage	5) Deforestation
	6) Land sliding	6) Deforestation	6) Frost
	7) Soil fertility depletion	7) Frost	

Conclusions and Recommendations

From the survey result, it is possible to conclude that the area is highly degraded, infertile, overpopulated and drought prone area. Therefore, the following recommendations can be drawn to alleviate the problems related to natural resources conservation and utilization.

1) Voluntary resettlement of the population to less populated, more fertile and having reliable rainfall areas.
2) Practicing physical and biological soil conservation practices on sloppy lands and on gullies. Biological measures should focus on planting multipurpose tree and grass species and fruit trees with high cash value.
3) Practicing alley cropping systems on hilly farmlands.
4) Area closure of highly degraded lands for rehabilitation.
5) Development of appropriate excess water disposal technologies like cut-
6) off drains, and accumulating the water for reuse.
7) Giving policy and legal support for the construction of paved drainage ditches in all road construction activities.
8) Practicing in-situ and ex-situ moisture conservation practices including introducing tie-ridger and sub-soiling equipment.
9) Practicing integrated watershed management approach.
10) Introducing treadle pumps to exploit underground and river water.
11) Development of small springs, rivers and ponds for irrigation purposes.
12) Encouraging farmers to use artificial fertilizers by devising mechanisms for securing the farmers not to be disappointed by crop failure due to drought, hail and frost damage.
13) Encouraging the use of compost and other organic fertilizers.
14) Introducing pulse in crop rotation systems.

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Agricultural Mechanization

Modification of Rural Technology Model Multi-purpose Animal Drawn Cart

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Abstract

Animal drawn carts are popular transport tools in the region. However, their production cost and selling price is becoming prohibitively expensive, reducing their popularity and adoption rate. Perceiving the urgent need to stabilize the market for carts, existing multi purpose 2nd generation animal drawn carts were modified mainly for reducing their production cost. As the wheel-axle assembly is the most important part taking about 40 to 70% of production cost of any cart, more emphasis was given to modify this component. As the result, low cost and easy to produce wheel-axle assembly was developed and produced in the center's workshop. Two carts were then produced using these assemblies (splitting-type rim with hub and spindle), with other body parts similar to that of the previous cart type. The carts were tested in different conditions on a test track to evaluate their suitability and impact strength. Passing this test successfully haulage test was then conducted by distributing the carts to farmers and monitoring for any premature failure while operating under normal working conditions. Both carts extensively worked for about three months in this situation. During all these test periods, the carts and the new assembly performed satisfactorily without any significant failure. As an achievement, the new developed component enabled to reduce production cost by more than 50%.

Key words: haulage test, hub, Impact test, integral rim

Introduction

Access to an effective means of transport is an inevitable tool for promoting the economic and social development of rural community of any country. This is particularly true for small-scale farmers who are living far from main roads. It enables them to have access to agricultural inputs such as fertilizer and improved seeds, paves the way to use manure to improve their yield, allows them to market more produce, and to reduce time and effort spent in household activities as collecting firewood and water. In Amhara region, where the topography is not suitable and road networks are at lower level, access to motorized vehicle is generally very low. This indicates that it is not in a level to satisfy those farmers who are far from the main roads. Animal drawn carts are hence the most appropriate implements to satisfy most of rural transport needs, as it is possible to be owned by average farmers and are able to operate under most rural road conditions, including serving between farmlands.

In the absence of any other alternative, rural people transport their goods by carrying on their backs or heads. When transporting heavier loads, especially for moving goods and agricultural produce from the farm or homestead to the nearest town or main road is considered, pack animals such as donkeys and mules are usually used. These methods are backward and unduly tedious for human and animals. It demands more labor time per load and exposes the material for post harvest losses. Evidence from many regions, however, shows that animal drawn transport has many economical and social advantages over these traditional methods for farmers of rural communities. Furthermore, animal drawn carts are more suited to farmers who are supposed to transport agricultural products and other goods all year round in all whether conditions. Besides, they are also regarded as additional income sources, generating considerable income for the family by hiring of the carts for haulage of goods.

Considering the importance of using animals for relatively improved transport system, Bahir Dar Rural Technology Promotion Center (now Mechanization Research Center) has been producing and demonstrating multi-purpose animal drawn carts to farmers living in the western part of the region for many years. These carts have three major components, the wheel-axle assembly, the platform assembly and bracket. The cart body or platform is produced from wood and the bracket from available standard metal parts easily shaped in the center. However, the wheel axle assembly including the tire, which takes about 40 to 70% of the production cost of the cart (Dennis and Anderson, 1992) are imported from abroad. All those earlier imported wheels and axles are running out of stocks these days and could not be readily replace to satisfy the demand of farmers.

On the other hand, local artisans have good experience of producing lower quality animal drawn carts from scrap rear or front axle of old cars, usually obtained from central market. However, as demands created are very high and number of cars that have been put aside in the country road are progressively reduced, the supply of these components is very much limited. Besides, level of oldness of these scrap components differ from car to car and, as maintenance service rendered by the producers is usually very low, the carts may not give the required service, adding to the running cost due to increased break down frequency.

Therefore, producing and distributing carts relying up on imported wheel-axle assembly and scrap old car components could not bring the required progress in rural transport. Bahir Dar Agricultural Mechanization Research center, therefore, has to look for alternatives to produce the wheel-axle assembly from readily available materials in the market. This is foresighted to enable local artisans having small workshop facilities with simple tools to adopt it easily and deliver the carts with reduced price in sustainable manner. Hence, this study was executed with the following objectives:-

- Make possible of producing carts at merely 50% of their current price
- Reduce the manufacturing sophistication so as to make ease of manufacturing and repair of parts near to the areas of utilization; and
- Facilitate technology dissemination

Materials and methods

Design and manufacturing of wheel-axle assembly

Two types of integral rim and hub that fit on 7.5x16 tyres were produced. For easy removal and replacements of punctured tyre, the edge of the rims were made to be split type which enables disassembling by merely loosing of the nuts on it.

A 2mm thick sheet metal with 106mm width and 400 mm diameter was rolled and welded at the end. To protect the tyre from bulging out during inflation two types of edge formed over the two sides of the rim by welding.

From 16 mm diameter round iron, two 400 mm diameter rings were made. One of the rings was welded on one edge of the rim and the other attached over the other edge with bolt and nut for easy removal of the tire. Similarly, from 30x30x3 mm angle iron, 400 mm diameter rings were made and, as that of the round iron ring type, were attached with the rim edge. The hub was made from steel turned on lathe machine. It was then welded to 3 U-shaped spokes made from 14 mm deformed iron. Spokes are weld connected with the underside of the rim (Figure 1). Utmost care has been exercised when welding wheel components to avoid deformation of the rim while under load. Two 7.5x16 size pneumatic tires, inflated to appropriate air pressure, were used over the rim.

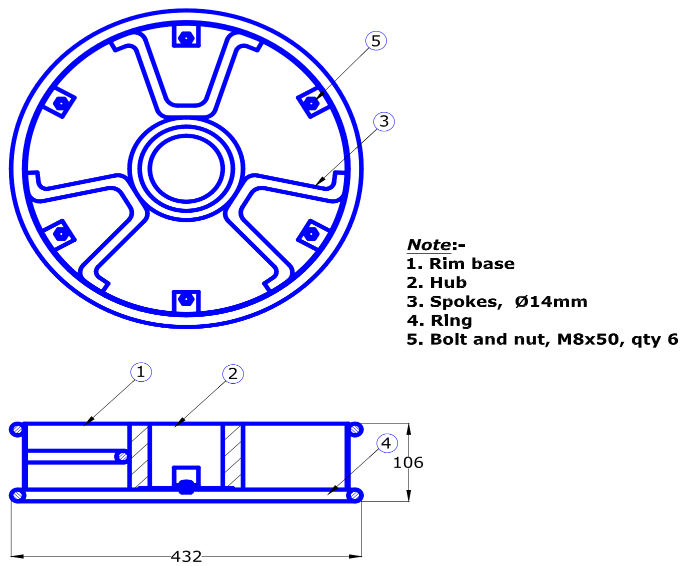

Figure 1. The Rim, Hub, Spokes and Rings.

Two spindles, made from 40 mm diameter mild steel bar, were machined on lathe and welded on the two ends of an axle, made of 2 inch galvanized pipe. Four roller bearings were fitted on the hub to complete the axle assembly (Figure 2).

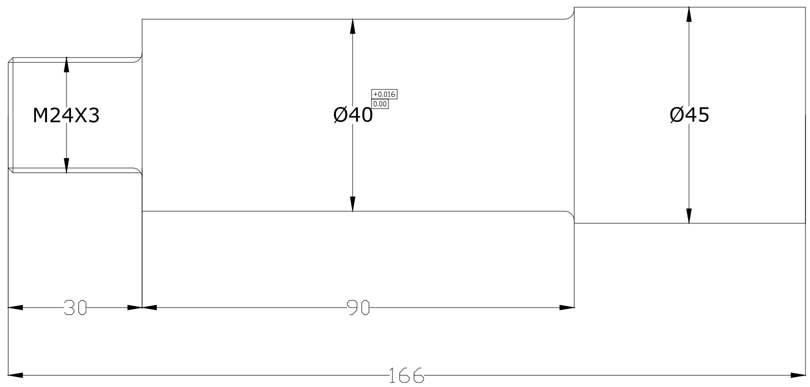

Figure 2. Details of a spindle in the Axle

Other cart components, including brackets, the body and beams were produced without any difference of the existing animal drawn carts, except introduction of deformed iron bracket with 32mm diameter, which is very much common in the local cart but new for the center cart.

Testing and evaluation

After completing of the whole components of cart, two carts where prepared, one with angle iron bracket and the other from deformed iron bracket.

Test bed, which is 25m in length having 20 cm high obstacle, was prepared to check fatigue strength of the cart. Impact test was performed by pulling the cart by a tractor moving at a speed of about 1 m sec^{-1} over this test track. During pulling, the cart was loaded with 50% (400kg), 75% (600kg) and 100% (800kg) of the rated load. At beginning and ending of the test track, the cart was subjected to the obstacle simultaneously. Then after, it faces the obstacle alternatively. It was pulled three times over the test bed before checking. The test procedure was taken from a procedure prepared by Wolelaw *et al,* (1999).

Haulage test was performed by distributing the cart to farmers around Merai for three months (Figure 3).

Figure 3. Modified cart in use

Results and Discussion

After producing the carts, impact and haulage tests were performed to confirm the good performance of the cart before promoting the carts.

Impact test

The manufactured cart operated successfully during the impact test. It has shown no sign of failure under 50%, 75% and 100% of the rated load, the normal load range a single animal can possibly pull.

Haulage (Field) test

The carts given to farmers in Merawi area who used them for transporting construction material, fodders, firewood and any other agricultural and construction material during the test period. Data was recorded progressively on types of loads transported, distance traveled, the road condition and failure occurred. The carts remained with the farmers for three consecutive months working exhaustively. According to the farmers record and expertise observation, no major failure has occurred during the three months.

Cost of modified wheel-axle assembly, excluding cost of tyre and rubber tube, is around 663.00 Eth Birr. However, cost of the imported wheel axle assembly, as it was imported through aid, though not available by now, is not less than 2,000 Eth Birr.

Conclusion and Recommendation

It has become clear that producing the wheel-axle assembly locally is more advantageous than importing readily available standard materials, as long as overall cart price is considered. This method will also pave the way to popularize the cart with reduced production complication and at an affordable price. However, it is recommended that more carts should be produced in the center and distributed to the farmers for further verification. Training of small businesspersons in the manufacturing methods will follow afterwards.

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Development of Chopper for Crop Residue and Hay

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Abstract

Engine driven chopper has been developed for chopping of crop residue and hay. The machine was designed with the following main components: feed hopper, rotating drum with swinging knives, casing with fixed knives welded on it, a screen, and stands. The machine was then tested in the center to evaluate its performance. The test was conducted using three levels of drum speeds; 960, 1200 and 1400 rpm and three feed rates; 420, 540, and 660 kg hr $^{-1}$. Maize stalk (at 6% M.C) and grass (at 78% M.C) were used as feed material. The test result showed that optimum drum speed and feed rate values for both maize stalk and grass were 1200 rpm 540 kg hr^{-1}, respectively. The average size reduction percentage using these optimum combinations was 92.0 and 79.5% for maize stalk and grass, respectively. The machine performed well with output rate ranging from 420 to 660 kg/hr and specific energy requirement of 11 to 20 KJ kg^{-1} output.

Key words: chopper fabrication, concave screen, drums speed

Introduction

Ethiopia stands first in livestock population in Africa. According to Alemayehu Mengistu (2002), livestock production contributes up to 80% of farmers' income and about 20% of the countries agricultural GDP. However, ever increasing human population accompanied with decline in land productivity resulted in an increased utilization of arable land for crop production. This, in turn, diminished available grazing land bringing about animal feed scarcity, the major problem threatening the countries huge cattle resource.

It is needless to say that, as grazing is the common practice in the country, traditionally livestock is dependent on natural pasture and crop residue for their daily feed requirement. However, grazing situation is exacerbated by the high density of cattle, with stocking rates about four times the recommended at global level. (Starkey *et.al* 1992). This decline in available livestock feed forced livestock owners to make use of crop residue mainly from cereals, especially in the latter part of the dry season. As residue is characterized by low nutrient content and poor digestibility and palatability, livestock tend to lose their weight, ending up with reduction in their market value, draft power, disease resistance, and amount of milk they produce.

In recent years, due to the opening of new commercial channels to external market as well as an increase in local consumption, many farmers are getting involved in cattle fattening activities and are getting good economic benefit from it. This shows that this activity deserves more attention so as to get better returns from the sector. One of the options to overcome a feed shortage, especially during long dry seasons when feed is in short supply, is to preserve excess fodder grown in rainy season in the form of silage. However, silage making has not been widely practiced in the country owing to lack of proper equipments for its preparation. Traditionally chopping is done manually using hand tools designed for other purposes. This makes the practice more burdensome and labor intensive for the farmers. Consequentially chopping will be incomplete making compacting the material difficult demanding even more labor and time.

Chopping of feed materials is known to have great advantage in silage making. In addition to assisting compaction while silage is prepared, it increases the surface area to volume ratio of fodder which, by making free of the cell juice and expelling the air, facilitates the fermentation process. Therefore, to make silage making attractive for farmers and enable them the benefit from it, chopping should be made in more user friendly ways, demanding less labor and time while the product maintains its quality. But availability of attractive chopping device has been the limiting factor for Ethiopian farmers to make silage and to chop farm residues , hence the objectives of this study was to develop and evaluate engine driven chopper which assists farmers in making more feed available for their livestock.

Materials and Methods

Design considerations

The main design aspects considered during chopper development were cost and complexity of fabrication, energy requirement, ergonomic factors, maintainability, material strength, kinematics, and style. Considering the above design aspects tangential feed type chopper (hummer mill) without blowing fan and conveyor was selected for this project. The machine utilizes the principals of hammer mill by which size reduction is accomplished by the cutting effects of rotating knives against small stationary knife plates welded in the casing. Since the knives are swinging, less danger will be occurred if hard inert material gets in to the chopper by accident. Feed enters into the chamber from top of the hopper and, chopped in to pieces by the rotating knives, will be discharged from the bottom of the machine. The knives cut the stover and other residue until it become small enough to pass through the bottom screen (Figure 1).

Figure 1. Developed motor driven chopper

Fineness of chopping is controlled by the screen size. It is obvious that the smaller the screen size the more work will be required to reduce the particles to the desired size. But during chopping grass wire mesh screen is removed. Generally the technology is simple in construction and easy to manipulate and requires little cost for the replacement of parts.

Chopper fabrication

The main body of the machine was constructed using parts that are found in the market. The drum was made from standard 3"G.I.pipe, rotating knives from 3mm steel sheet, fixed knife plates from 40X3 flat iron and the concave and screen from 6mm diameter deformed iron. The knives are punched on both sides and bolted with the drum using M10 bolts and nuts (Figure 2).

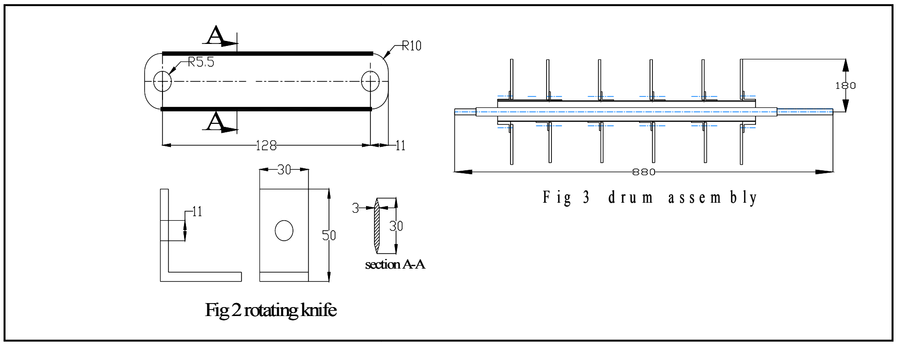

Figure 2. Assembly and details of drum component

The concave screen (Figure 3) was made from small bars welded on concave plates. The screen opening size is governed by the extent of the required size reduction and hence can easily be changed if required. Housing is made from 2 mm steel sheet. Machine design principles were used to determine the size of each component. Petrol engine 5HP rated power and 4000 rpm rated speed have been used for prime mover. Double grooved V belt and pulleys (ϕ90 and ϕ250mm) were used for power transmission.

Figure 3. concave screen

Testing and evaluation

Initially the machine was run with no load for about 6 hrs and its fuel consumption was measured. The material was then admitted uniformly to the machine and fuel consumption under load was measured using graduate cylinder and heat energy consumed for chopping unite kg of stover and grass was calculated by the outlined formula in FAO (1994).

$M = \rho * V$
$Q = M * C$
$E = Q/FR$

Where
M= mass of fuel per unit time (kg/hr)
V= fuel consumed for chopping (l/hr)
ρ= density(kg/m^3)
C= calorific value in(KJ/kg)
E = energy consumed (KJ/kg)
FR= feed rate (kg/hr)
Q= Heat transfer rate (KJ/hr

Material was fed at a constant rate manually when the machine is running. Length of the feed material was measured before and after chopping. The mass in kilogram and the time required for chopping the respective input was measured. Moisture content of the material (stover and grass) was determined using oven dry method and keeping the samples at 105c^o for 48 hours. Preliminary testing was conducted to select working ranges for feed rate and rpm for the test. Engine rpm was measured using digital tachometers while the following formulas were used to calculate capacity in dry bases, percentage size reduction (%), and moisture content (%).

$$\text{Capacity in dry bases (kg/hr)} = \frac{\text{capacity in wet bases (kg/hr) X (100\%-moisture content (\%))}}{100\%}$$

$$\text{Percentage size reduction (\%)} = \frac{Lb - La}{Lb} \times 100$$

Where
Lb =average length of the material before chopping
La= Average length of the material after chopping

$$\text{Moisture content (wet bases)(\%)} = \frac{Wb - Wd}{Wb} \times 100$$

Where
Wb =weight of material before drying (wet weight)
Wd =weight of material after drying

The following constants were used in determining the specific energy consumption of the machine (www.Kayelaby.Npl.Co.Uk/Chemistry/3-11/3-11-4.html)

- Density of petrol = 710 Kg/m^3
- Calorific value of Petrol = 45MJ/kg

Result and Discussion

Determination of optimum drum's speed and feed rate

The test was conducted to determine the optimum combination of drum speed (rpm) and feed rate and the results are summarized in Table 1. Average length of the fodder before chopping was 0.48m and 0.75m for maize stalk and grass, respectively.

Table 1. Test result on maize stock (6% MC) and grass (78%MC) using three shaft speeds and three feed rates

Trt. No	Shaft speed (rpm)	Type of fodder chopped							
		Maize stock				Grass			
		Feed rate (kg/hr)		Average length after chopping (m)	Average Size Reduction (%)	Feed rate (kg/hr)		Average length after chopping (m)	Average Size reductio n (%)
		moisture content 6%(wet bases)	moisture (dry bases)			Moisture content (wet bases) (78%)	Moisture content (dry bases)		
1	960	420	399.80	0.077	84.00	420.00	92.40	0.16	78.00
2	960	540	506.30	0.057	88.10	540.00	118.80	0.15	79.10
3	960	660	618.90	0.059	87.70	660.00	145.20	0.15	79.30
4	1200	420	399.80	0.086	82.00	420.00	92.40	0.15	80.00
5	1200	540	506.30	0.038	92.10	540.00	118.80	0.15	79.50
6	1200	660	618.90	0.050	89.60	660.00	145.20	0.15	79.80
7	1400	420	399.80	0.031	93.60	420.00	92.40	0.13	82.50
8	1400	540	506.30	0.048	90.10	540.00	118.80	0.12	83.00
9	1400	660	618.90	0.052	89.10	660.00	145.20	0.14	81.80

The result shows that as the feed rate increases, percentage size reduction increases at lower shaft speed and decreases at higher shaft speed. It was also observed that as the feed rate exceeds 660kg/hr unchopped stover passes through the sieve and the engine stops due to overloading. In addition, when the knife speed becomes 1400 rpm, very high vibration and back flow of the input materials to the hopper was observed. When the chopper works at knife speed of 1200 rpm and feed rate of 540 kg/hr, it was observed that no unchopped material passes through the sieve and the chopper was working without excessive noise.

Specific Energy requirement for chopping

The test was conducted to determine the energy requirement for chopping and the results are summarized in Table 2. By subtracting the fuel consumption with out load from fuel consumption with load the average fuel consumption for chopping 5.5 kg of maize stalk and grass is 0.117 ml/sec and 0.1 ml/sec, respectively. Using calorific value of fuel used and the fuel consumption rate average energy (specific energy) consumed for chopping a kilogram of stover and grass was found to be 20.38 KJ/kg and 11.59 KJ/kg, respectively.

Table 2. Amount of fuel consumed to run the chopper with load and without load.

Trt No	**Feed (kg)**	**Materials chopped**							
		Maize stock				Grass			
		Fuel consumed (ml) in 30 sec		Fuel consumption (ml/sec)		Fuel consumed (ml) in 20 sec		Fuel consumption (ml/sec)	
		Without load	With load	Without load	With load	Without load	With load	Without load	With load
1	5.50	12.50	16.5	0.416	0.55	7.10	9.20	0.36	0.46
2	5.50	12.00	15.8	0.4	0.53	7.10	9.10	0.36	0.46
3	5.50	13.00	15.7	0.3	0.52	6.80	8.70	0.34	0.44
Mean	5.50	12.50	16.00	0.416	0.53	7.00	9.00	0.35	0.45

Conclusion and Recommendation

The experiment has shown that developed chopper can successfully chop maize stalk and grass to the required level. It is also noted that optimum results could be obtained using540 kg/hr as a feed rate and 1200 rpm drum speed for chopping. However, more efforts should be made to evaluate the machine with farmers' participation for wide technology adoption.

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On Farm Evaluation and Demonstration of Lever and Screw Honey Presses

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Abstract

Honey is an important product of beekeeping with high nutritional and medicinal values. The other important product as well is wax. It is a valuable commodity, used by the beekeeper to form the foundation, but it also has high commercial value on the open market, both domestically and internationally. These two important products need to be properly handled and prepared for market. Among different ways of proper utilization of these products using of honey presses, like screw and lever types are some of them. During the experiment, screw and lever presses were evaluated. These honey presses were provided to farmers around Debre Worek wereda. Farmers and werada development agents were gathered to a training during which they were demonstrated the two honey extraction methods. Participants evaluated the methods using various parameters, such as, convenience of operation, knowledge, power requirement, extracting efficiencies, extracting rate, honey loss and maintenance condition.. The Farmers opinions and test results showed that the honey extracted by the screw press was better than honey extracted by the lever one. The average extracting rate, efficiency, and honey loses of screw honey press was 53.9kg/h, 96.8%, and 0.28kg whereas the lever type was 36.5kg/h., 90.6% and 0.42kg respectively. The statistical analysis of the data at 0.05level of confidence showed that significant difference between the two press regarding honey loss. Beyond technical capability, most farmers prefered the screw one because of less energy requirement and higher extracting capability. The overall observation showed that the honey extracted with the mechanical presses had acceptable qualities such as honey color, flavor odor, removing impurities as compared to traditional method using boiled water, cloth, and sun heat methods. Therefore, it is possible to recommend that the screw type honey press can be used by as additional income generating opportunity.

Key words: aluminium box, honey comb, steel box

Introduction

Beekeeping is one of the agricultural activities that farmers in the region are engaged in to produce the sweet food, honey. It is a useful sideline activity for many farm families in most parts of the region. Being a natural food collected by bees from nectar of flowers and processed by them, honey contains several vital constituents having nutritional and medicinal values. Viscous supersaturated sugar in honey is easily assimilated in the blood stream, deposited in liver as glycogen, and provides energy to our body. The calorific value of 1 kg of honey is very high as compared to other products.

Farmers in the Amhara region used fixed comb beehives, which is traditionally made from locally available materials such as woven reeds or grass. Estimates show that there are more than 0.6 million beehives in the region in which nearly 99% of them are traditional hives. The annual estimated honey production in the region is 334.243 tones with an average honey production of 5 Kg /annum from the traditional hives (CSA, 1994). This is a very low figure mainly attributed to lack of appropriate beekeeping equipment. Honey is usually squeezed out of the cut combs by hand, roughly filtered through cotton cloth, mosquito net, and stored in locally made containers. Mostly this method make the product get mixed with wax, pollen, dead bees and other foreign matter.

Beeswax is a product of the honeybee. It is produced from the bee's own body during the warm period of the day. The bee uses wax to build the comb cells in which its brood reared, and the cells in which honey and pollen are stored (Adjare, 1990**)**.Wax is a valuable commodity. It used by the beekeeper to form the foundation, but it also has high commercial value on the open market, both domestically and internationally (Draper and Duggan, 2001). The price paid to the beekeepers for unprocessed wax ranges from 10-15 birr per kilogram, while after processing it costs from three to four times in local markets. Most farmers do not sell beeswax since they do not have proper honey and it’s by product processing equipments.

In recent years, the introduction of improved Kenya model beehives with movable frames in some areas of the region increased the total honey production five folds when compared with the traditional beehives. Beside the honey production increments, there was also an increase of interest by farmers in participating on beekeeping activities and wax trade for additional income generation. Therefore, these facts forced the need of suitable honey pressing equipment.

In the Region, most farmers do not have the practice of extracting of pure honey and wax, rather they crushes honey with wax for market purpose. However, research output indicates that, traditionally the comb is collected and stacked on a wire mesh and container is put underneath the pile of combs. The heat from fire or sun begins to melt the honey, and honey and wax trickle down in to the container, the material collected is left untouched until the next morning. The bee wax, which will be hardened at the top of the honey, is removed and the honey is poured in to container.
The disadvantage here is that the honey looses nutritional value and quality when exposed to high temperatures. In addition, the smoky fire employed is full of ashes, charcoal and dust which contaminate the honey. Such honey tastes bitter and smoky (Adjare, 1990**)**. Therefore, using of heat for honey processing is not recommended (Gentry, 1982).

The conventional methods of extracting honey and beeswax are unsuitable and unhygienic. Extraction of honey by squeezing with the hand seems to be the quickest method for the average honey-taper who cannot afford a honey extractor or solar wax-melt. However, the hand contaminates the honey, and unripe honey ferments within a few days after extraction (Adjare, 1990**)**. Honey with high moisture content or "unripe" honey can deteriorate from the various yeast and bacteria that will thrive on the moisture available. Fermentation reduces the keeping quality and thus the life of the honey (Draper and Duggan, 2001).

There are different models of honey presses are in markets. The screw, lever, and hydraulic methods are some of them. All types of honey presses are not used by farmers due to equipment un availability and poor awareness. Preliminary observations show that these technologies need further studies on farmers' management for their suitable operation to extract better honey in both quality and quantity. Therefore, the objective of this study was to verify the performance of improved honey presses under farmers' local conditions and to increase awareness and access to improved honey presses among farmers, and extension/development workers.

Materials and methods

Description of Honey Presses

Honey is separated from the honeycomb under simple mechanical pressure applied by the use of a lever or a screw handle. Equipment of this kind is inexpensive and relatively easy to make. It is ideal for the small-scale honey processor, except the sieve and threaded screw, which are available and purchased from the market.

Honeycomb presses material should be made of aluminum (for those honey-contacted areas) and steel metal (for other parts). The pressing pad is made of wood and laminated by non-corrosive material. The press has a drilled chamber into which the combs are placed and squeezed. The honey is forced out through the round hole leaving the wax and any debris behind and collected in a draining tray. The mixture of wax and debris is subsequently separated and good quantities of high quality wax obtained. The models of honey presses used for testing purpose have the difference in driving mechanism and are described as follow.

Lever type honey press is modified at Bahir Dar Agricultural Mechanization Research Center. It is made of metals and wood. Cylindrical in shape and has cylindrical pressing pad located at the center of the basket. The pressing pad is derived by a hand-using long lever (Figure 1). It is easy to assemble and disassemble all components very quickly from the frame.

The screw honey press was purchase from the local market. It was copied from the original one that was made in Germany. It is made of metals and wood, cylindrical in shape and has cylindrical pressing pad located at the center of the basket. The pressing pad is derived by fine metric threaded screw lever (Figure 2). In the center, some parts like the base, the leg and the screw supports modified at bahir Dar Agricultural Mechanization Research Center.

For testing purpose both models were manufactured as a single unit with different driving mechanism. The base (leg) and the aluminum cylindrical basket are common for both honey presses. The honey pressing processes for each model are done by changing the driving unit alternatively.

Figure1

Figure 2

Evaluation Procedures

Screw and lever driven honey presses were the two-selected mechanical model, for the study. For both models except the perforated cylindrical containers and the screw parts, the other different parts of the models of manual operating honey presses were carefully design and manufactured at Bahar Dar Agricultural Mechanization Research center.

After checking of proper functioning of both honey presses in the center, criteria were set for selection of participant farmers and trail site. Numbers of farmers using local beehives, awareness about the improved technology among farmers, and area that is potential in honey production were some of the criteria. Site selection was made through discussion on the objective and merits of study with respective wereda Agriculture and Rural Development Office experts, development agents and farmers. Based on the criteria's and discussion, the trial site and participant farmers were selected. The selected sits were from E*ast* Gojjam zone, Debreworke wereda in three different kebeles.

In each kebele*,* three participants were selected. The selected farmers were practically trained on operation and handling of manual operating honey presses. The performances of mechanical and traditional honey extracting implements were discussed. Since the study was based on farmers' evaluation, discussion was made on the objective of the study and expectation form the participant farmers.

The presses were tested in two honey harvesting times, in November and June. Honey pressing time was recorded using stopwatch, crude, and pure honey measured by spring balance. During test time, farmers up to 80 Kg weight were used to operate the press. This helped to validate the selected materials strength**.** The net pressing time includes from the moment starting pressing and ends when it is necessary to turn over the pressed honey and clean the clogged holes. The losses of honey were determined by dissolving the remaining pressed honey in to water and separating it mechanically.

Both honey presses practically demonstrated in two ways for the farmers. The first method provided theoretical explanation of the use and benefit of the machines for over 250 farmers, and secondly practical demonstration was done. All participants forwarded their opinion regarding the presses, performance and other to be improved. Finally, in all trail site discussion was held among farmers, development agents and wereda expert on merit and demerit of honey presses relative to local honey extraction practices and their performance. Information was collected and recorded on required improvements, effectiveness, and suitability of the supplied honey presses. The data were analysed by SPSS statistical package using T-test.

Results and Discussion

The two improved models of manual operated honey presses were evaluated with respect to their technical performance and farmers view. The technical performance result obtained from Debre-work *wereda* trials site is shown on Table 1. It is the summary of the mean for crude honey used for experiment (kg), pure honey extracted (kg), time required to extract pure honey (min.), machine efficiency (%) and capacity (kg/h).

The data in Table 1 shows that the average amount of mixed honeycomb used for each trail for both model of honey press were equal. On the average from 10.7kg of crud honey, 8.5 and 7.3 kg of pure honey were obtained by screw and lever type honey presses, respectively.

Table 1. Summary of the average data obtained during honey presses testing

Machine Model	Trail's	Crude Oney (kg)	Pure Honey (kg)	Pressing time, (min.)	Efficiency, (%)	Extracting rate (kg/h)	Honey Losses (kg)
Screw Type Honey Presses	*Test-1*	9	6.5	9.6	95.6	40.6	0.30
	Test -2	11	9.3	6.8	97.9	82.0	0.27
	Test -3	12.2	9.7	14.9	97.0	39.0	0.28
	Average	**10.7**	**8.5**	**10.4**	**96.8**	**53.9**	**0.28**
Lever Type Honey Presses	*Test -1*	9	6.7	13	95.7	30.9	0.30
	Testy-2	11	6.2	7.7	80.5	48.3	0.54
	Test -3	12.2	8.9	17.7	95.7	30.2	0.42
	Average	**10.7**	**7.3**	**12.8**	**90.6**	**36.5**	**0.42**

The average extracting time for pressing of 8.5 kg of pure honey, were 10.4minute for screw type and for pressing 7.3 kg of pure honey were 12.8 minute for lever type honey presser. The average out-put and efficiency for screw type honey press was 53.9 kg/h and 96.8% whereas, for the lever, one was 36.5 kg/h and 90.6 % in that order

The screw type of honey press has the capacity of extracting honey a little more than the lever type. However, there was broken wax seen in the pure honey that increase cleaning time and decrease the quantity of the wax. It saves from 0.25 – 0.5kg honey that can be lost by the lever type, this condition make the screw honey press get preferred by farmer and indicates that the screw one shows less losses of honey. As table 1 shows the average amount of honey loses by the lever one is greater by one and half times than that of the screw one. However, even though the lever type honey press was not able to extract fully as the screw one, it does not break wax. . Since all parameters were equal for both presses i.e. volume of honey pressing chamber, strainer hole diameter, weather condition and type and condition of crude honey, the difference in out-put, loses, and efficiency was due to the variation of driving mechanism. The screw driving mechanism has an advantage on constant pressing and holding ability on crude honey. This action makes the honeycomb under steady and continuous pressure and facilitates to be extracted very fast whereas, for the lever one, it is not easy to maintain fully this condition.

Most of participated farmers during testing and demonstrating time gave there view that the screw one is better than the lever one due to its ability of high extracting rate, less power requirement and honey losses. They also assumed that, the lever one also has the advantage over the screw one by its easy for operation and less damage of wax particles. Among farmers, evaluation parameters given above some of them were supported by figures and found acceptable as indicated on the test results. The other thing observed during testing time was that the perforated basket hole were clogged and it was difficult to extract the honey as to be, so that it requires re-inverting of the crude honey and cleaning of holes once or twice during the processing time. Finally, participants gave their opinion that the machines require improvements. Increasing of holding capacity of the pan and volume of perforated basket, minimizing selling cost, and weight of the machines were some of the comments that need to be addressed.

From participants' comments and observation, we realize that the existence of delaying of pressing time due to waiting of honey until reduced the over flow of honey over the bottom pan and less volume of the basket makes the presses to have reduced performance. Therefore, this condition indicates that, the requirements of upgrading both honey pan and perforated basket holding capacity, thereby, increasing the rate of out-put and decreasing time taken through avoiding idling time

Traditionally when honey exposed to high temperature, honey loses in nutritional value and quality. In addition, the smoky fire employed is full of ashes, charcoal, dust and gravel which contaminate the honey. Such honey tastes bitter and smoky (Adjare, 1990**)**. That is why extracting honey using mechanical honey presses is very advantages since it keeps the honey quality (color, odor, purity and test).

On the other hand, the statistical analysis using t-test shows significant difference at 0.05 level of confidence. As shown in Table 2, the honey losses and machine efficiency between the two models have significant difference where as the amount of extracting of pure honey and extracting rate was found statistically not significant. That means the screw honey press has an advantage over the lever one regarding honey losses and efficiency.

Table 2. Independent Samples Test

Observation		t-test for Equality of Means		
		t	**Sig. (2-tailed)**	**Mean Difference**
Pure honey	Equal variances assumed	1.038	.315	1.2000
	Equal variances not assumed	1.038	.315	1.2000
honey loss	Equal variances assumed	-2.948	.009	-.1378
	Equal variances not assumed	-2.948	.013	-.1378
Machine efficiency	Equal variances assumed	2.818	.012	2.4444
	Equal variances not assumed	2.818	.016	2.4444
Pressing time	Equal variances assumed	-1.108	.284	-2.3778
	Equal variances not assumed	-1.108	.284	-2.3778
extracting rate	Equal variances assumed	1.885	.078	20.0000
	Equal variances not assumed	1.885	.083	20.0000

Conclusion and Recommendation

Screw and lever model honey press were capable of extracting mixed honey. These presses can be manufactured by small workshops with exception to the strainer and threaded lever, which require special machine. The total cost for manufacturing theses presses will be acceptable by farmers particularly for those who engaged partially or fully on honey processing activities. In addition, farmers are benefited by using these presses in two ways, selling pure honey and wax. Therefore, the return of machine cost will be in short time. Moreover, they have very less maintenance cost; they are simple in construction, and operation...

Even though both honey presses were abele to extract pure honey, farmer comments and technical test result shows that the screw honey press has better performance regarding the honey out put, losses, and efficiency. So that, in the Region, development of apiculture technologies is needed to enhance the income generation potential of small holders. Therefore, the screw type honey press can be recommended for farmers' use.

However, it is also necessary to focus on increasing of out put in order to maximize the performance of the machine by further improving driving mechanism attachments, perforated basket, and pane assembly. For proper exploitation of the machine, it is also necessary to consider the following points while extracting honey.

1. The crude honey should not be highly crushed so that it will not be difficult to separate the mix;
2. The pressing process should be carry out immediately after harvesting;
3. During pressing time, the pressed comb should be re-inverted and the container hole cleaned;

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Book

Quinn, G.P., and Keough M.J (2002). Experimental design and data analysis for biologists. Cambridge university press, Cambridge.

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