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Soil and Water management, Forestry, and Agricultural Mechanization

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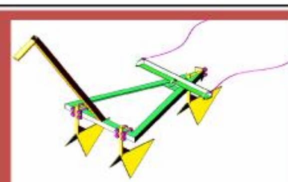

Amhara Region Agricultural Regional Institute (ARARI)

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Proceedings of the 3rd Annual Regional Conference on Completed Research Activities on Soil and Water management, Forestry, and Agricultural Mechanization

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Editors

Birru Yitaferu (PhD)
Teshome Tesema (PhD)
Zewudu Ayalew (MSc)

Amhara Region Agricultural Research Institute
P.o.Box-527
Bahir Dar Ethipia

Tel: +251 058 220 64 00
Fax:+251 058 220 51 74
Website: www.AR-ARI.ORG
E-mail: arari@ethionet.et

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Forward

Amhara Agricultural Research Institute is the first to pioneer annual conference on completed research activities in Ethiopia. It is now three years since we started undertaking the conference. As it helps to critically evaluate and select results which have contribution to the agricultural research development, the conference, is serving as one of the monitoring and evaluation tools of research system. Publication of the research findings in the form of proceedings has helped to improve the archiving and documentation culture of the institute. In addition, it has simplified knowledge and information transfer to those who work on agricultural research and development. Researchers, however, are expected to do more in order to complement this endeavor through other tools of technology and knowledge transfer such as manual, leaf lets, training, provision of starter material technology etc.

In Ethiopia, the scientific community has no adequate print scientific media to publicize research results. This has been discouraging to young and junior researcher involved in the regional research system. ARARI's proceeding of completed research activities have served as medium of communication to its researchers and has helped them improve their skill of scientific writing. Since researchers are partly promoted based on their published results, the proceeding has become a readily available print media to enable researchers timely publish their results and get promoted. Taking in to account the above mentioned benefits, ARARI will do its best to sustain this culture and is determined to provide the resource needed to advance it in the future.

Fentahun Mengistu (PhD)

Director General
Amhara Region Agricultural Research institute
Bahir Dar, Ethiopia

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Printing enough copies of this issue and reaching out our stakeholders would have not been possible without the financial assistance of the International Water Management Institute (IWMI) that is a strong partner of ARARI in its endeavors in the generation of technologies and capacity building.

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I) Agricultural Water Management

Evaluation of the Effects of Alternate Furrow Irrigation on Yield and Water Use Efficiency of Potato

[1]Menelik Getaneh, [2]Mekonen Ayana, [2]Appa Rao
[1]Adet Agricultural Research Center, P.O.Box 8 Bahir-Dar, Ethiopia.
E-mail: menelikgetaneh@yahoo.com
[2]Arba Minch University, P.o.Box 21, Ethiopia.

Abstract

The objective of water management is to provide suitable moisture environment to crop to obtain maximum yield with high water use efficiency. The increasing world wide shortage of water resources requires the optimization of irrigation management in order to improve water use efficiency. This paper evaluates the effect of partial root zone drying (PRD) on potato yield and water use efficiency by method of alternate furrow irrigation. The analyses was based on Agronomic parameters and soil moisture content data collected during two years field work at a place near Adet Agricultural Research Center for two years period (i.e. January -June 2007 and 2008). The analysis was performed using statistical software, MSTATC. Appropriate standard errors of the means (SE) and least significant differences (LSD_s) at $P = 0.05$ were calculated. The response of each agronomic parameter to three water levels and three furrow water application methods, and the relative moisture status under each treatment has been evaluated. Tremendous water saving was made possible in this experiment. Up to 42% water saving was practically achieved with 82% and 45% improvement in WUE in CFI and AFI methods respectively. Water saving to this extent has practically significant meaning on the overall water management system. It was found that as compared to the control (i.e. CFI with 100% IR level which is assumed to represent farmers practice), PRD treated potato under half (50%) IR level resulted only in 15% marketable yield reduction.

Key words: Alternate Furrow, Irrigation, Partial Root Zone Drying, Water `Use Efficiency, Irrigation Requirement

Introduction

The success of irrigation in ensuring food security and rural welfare has been impressive, but past experiences also indicate that inappropriate management of irrigation has contributed to environmental problems including excessive water depletion, water quality reduction, water logging and salinization (Mark et al., 2002).

Many countries depend on surface irrigation to grow crops for food and fiber. Without surface irrigation their agricultural production would be drastically lower and problems of unreliable food supply, insufficient rural income and unemployment would be widespread. Although precise data are lacking, estimation of surface irrigation accounts for some 80 to 90 percent of the total 7260 million hectares of irrigated land worldwide, mainly in developing countries in the tropics and sub-tropics, where hundreds of millions of farmers depend on surface irrigation to grow their crops (Yesuf, 2004).

FAO (1989) indicated the problems irrigated agriculture may have to face in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that about 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff.

Water is one of the largest renewable natural resources but fresh water is expected to emerge as a key constraint to future agricultural growth. Globally, and more particularly in developing countries, changing water availability and quality pose complex problem and management options are not easy. The changing situation comes partly from increasing demands such as population, industry and domestic requirements and partly from consequences of climatic change (Magar, 2006). Therefore, great emphasis is placed in the area of *crop physiology and crop management* with the aim to make plants more efficient in water use under dry condition (Stikic et al., 2003).

Poor management of agricultural water leaves almost all parts of Ethiopia highly susceptible to rainfall variability which depicts itself in terms of prolonged dry spell and drought (Seleshi, 2006). Over 70% of the country is either arid or semi arid, characterized by low and erratic rainfall both in terms of spatial and temporal distribution (Kamara, 2002). This is one of the most challenging problems that limit agricultural production, and makes larger parts of the country vulnerable to recurrent drought.

Therefore, it is necessary to consider the on farm design and management factors that improve the water use efficiency by choosing appropriate method of irrigation water application. The overall objective of this paper is to evaluate the effect of partial root zone drying by a technique of alternate furrow irrigation on yield and water use efficiency of potato.

The concept of partial root zone drying

Partial root zone drying (PRD) is a practice of using irrigation to alternately wet and dry (at least) two spatially prescribed parts of the plant root system to *simultaneously maintain plant water status at maximum water potential* and *control vegetative growth* for prescribed parts of seasonal cycle of plant development. The reason for doing this is to control vegetative growth or improve water use efficiency or both while maintaining reproductive growth & development.

If part of the root system was allowed to dry and the remaining roots were kept well watered, chemical signals produced in the drying roots reduced stomata aperture. At the same time the fully hydrated roots maintain a favorable water status through out the aerial parts of the plant. In addition to reduced stomatal conductance, it was noted that shoot extension was also inhibited as a result of partial root drying. A surprising finding was that the effect was *temporary*, and despite the fact that part of the root system remained dry, stomatal conductance, photosynthesis and growth returned to pre-treatment levels within a few weeks (Kriedemann et al., 2003).

Abscisic acid and cytokinins are plant hormones. Plant hormones can act as chemical signals (Stoll, 2000). ABA is an effective stomatal closing agent and relationship between stomatal conductance and xylem (ABA) generated from data collected in field suggest that ABA can have controlling influence and determine day to day variation in stomatal behavior as soil dries as well as leaf to leaf variation in conductance when different cultural treatments are applied. ABA induced partial stomatal closure and reduced leaf area have been considered to be the main causes for saving water in plants under PRD treatment (Davis et al. 2002).

It was also found that PRD caused a reduction in the levels of other plant hormones called *cytokinins*. The function of these is to stimulate transpiration and to control the development of side shoots in the canopy. The combined effect of these hormonal changes was to reduce water losses and also to reduce the total size of the leaf canopy. Armed with knowledge about the transient nature of the effect and the likely role of the chemical signals it is possible to devise irrigation schedule which keep one part of the root system , or other in a state of drying so as to maximize the production of chemical signals and hence their inhibitory effect on transpiration and growth. (Kriedemann et al., 2003)

Materials and methods

The field experiment was conducted near Adet ($11^0$17'N, $37^0$43'E). It is about 490 km NW of Addis Ababa and 43 km from the capital of the Amhara National Regional State (Bahir Dar). It has an altitude of 2240 m.a.s.l. and represents mid to high altitudes and high potential areas (ANRSBOA, 1999). Mean daily maximum temperature ranges from 22.5 ^{0}C (July and August) to 29.4 ^{0}C (March) and the mean daily minimum temperature ranges from 5.4 ^{0}C (January) to 12.1 ^{0}C in August. Mean annual rain fall in the area is about 1238.7 mm. Soils in the study area are moderately acidic (pH=5.41) and are moderate in its organic matter content (i.e. 2.17%). The relative proportion of sand, silt and clay (15%, 27% and 58% respectively) revealed that the soil of the testing site is clay in its very nature.

In this experiment three furrow irrigation water application methods were tested. These include:

1. Conventional furrow irrigation (CFI), where every furrow is irrigated during each watering.
2. Fixed furrow irrigation (FFI), where irrigation is fixed to one of the two neighboring furrows throughout the growing period and
3. Alternating furrow irrigation (AFI) where one of the two neighboring furrows is alternately irrigated.

Each of them was tested on three separate plots. Each irrigation method was again further divided into three treatments using different levels of irrigation requirements: i.e. full (100%), 75%, and 50% irrigation requirement levels during each watering.

Moreover, each treatment was replicated three times and a total of 27 plots each with an area of 18m^2 (3m x 6m) were used. Four furrows were arranged on each plot. The spacing between two furrows was 75cm. The length of each furrow was limited to 6m. The spacing between plants is 30cm and between rows of plants 75 cm was provided. The spacing between treatments was kept 1m and the spacing between each block was 2m. Totally, the experiment comprises of three blocks. Each block contains nine randomly arranged treatment sets. The total land required for this experiment was about 0.1014 ha (26m x 39m).

The parameter set up and treatment combinations are as follows:

		Factor 1 (Water application methods)		
Factor 2 (Irrigation requirement levels)	100 %	CFI	FFI	AFI
	75%	CFI	FFI	AFI
	50%	CFI	FFI	AFI

Ten years data of on maximum and minimum temperature, relative humidity, wind speed, sunshine hours and rainfall from the nearby station was collected from National Meteorological Authority. The crop water requirement and irrigation requirement of potato was estimated using CropWat 4 Windows Version 4.3 (FAO, 1989). Running this model with the aforementioned and other input data, the crop water requirement and irrigation requirement of potato at the study area was estimated.

Accordingly, the crop water requirement and irrigation requirement of potato at the study area was found to be 522mm and 430mm respectively. As a result, for each watering the full (100%) irrigation requirement level was found to be 22mm. Depending on this value, the 75% irrigation requirement level and 50% level was fixed as 16mm and 11mm respectively.

After the land preparation work, the early maturing potato variety (locally called 'Wochecha') was selected for planting. Potato seeds were allowed to properly sprout and then planting was done. Plant density for each treatment was 80 seeds per $18m^2$ plot. To facilitate proper establishment of the crops, each treatment was supplied with full (100%) irrigation for two consecutive weeks before the actual treatment commenced.

Weeding and other agronomic practices were conducted on time equally for each treatment. Irrigation water was then supplied from the farm channel into the field through siphons for every treatment. Soil samples were taken for analysis of soil texture, bulk density, pH and organic matter content and soil moisture content. The analysis was made using standard procedures. The moisture content is determined using gravimetric method. To determine the agronomic parameters such as plant height, stem diameter, yield, total biomass, root dry weight, shoot dry weight and root to shoot ratio, generally 10 plants were sampled at random and marked from central two rows from each plot.

The data collected for all relevant variables were subject to analysis of variance appropriate to factorial experiment RCBD (Gomez & Gomez, 1984). Appropriate standard errors of the means (SE) and least significant difference (LSD_s) between and / or among treatments at P = 0.01 and P = 0.05 were calculated using the MSTATC computer program.
Results and discussion

Soil moisture analysis

This section presents the results of soil moisture content analysis for soil samples taken from each plot before and after every irrigation, from both wetting and drying sides of the furrows.

Due to the narrow spacing between furrows and the shallow and more specifically wide (onion shape) infiltration characteristic of furrow irrigation under clay soil at the experimental site, it was expected that the non irrigated part of furrows in the AFI treated and FFI treated plots to be influenced by the wetted side. However, the results of soil moisture analysis showed that there exist differences in moisture content between wet and dry sides of the furrows before as well as after irrigation water application (Figures 1-4).

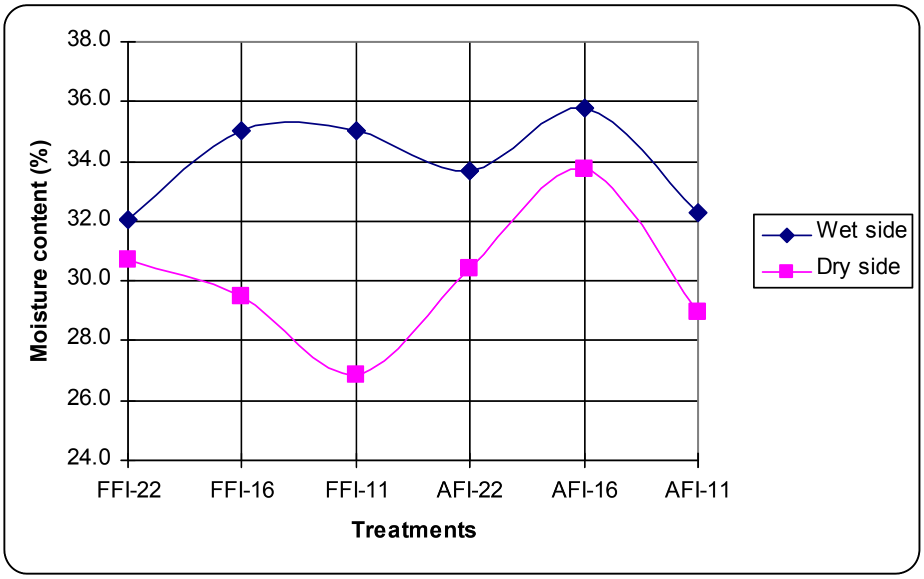

Figure 1. Moisture content at 30 cm depth both at drying and wetting side of the furrow before irrigation. (FFI-22, FFI-16, FFI-11: fixed furrow irrigation at 22mm, 16mm and 11mm water application depths respectively. AFI-22, AFI-16, AFI-11: alternate furrow irrigation at 22 mm, 16mm and 11mm water application depths respectively. 30cm-W: 30cm depth and wetting side, 30cm-D: 30cm drying side).

Moisture content in the wetting side exceeds that of the drying side, both before and after irrigation. This clearly justifies the existence of moisture gradient between the two sides of the furrow and existence of partial root zone drying. Therefore, the crop was exercising PRD throughout its growing season.

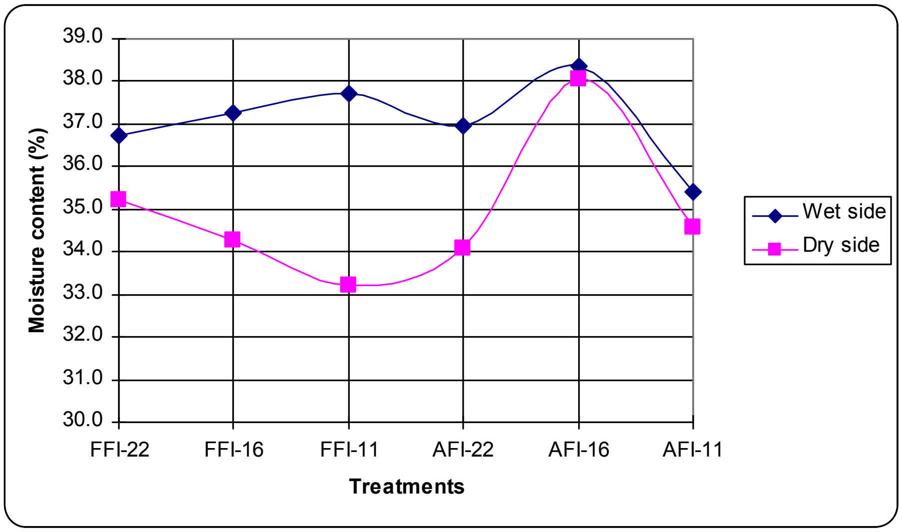

Figure 2 Moisture content at 60 cm depth both at drying and wetting side of the furrow before irrigation

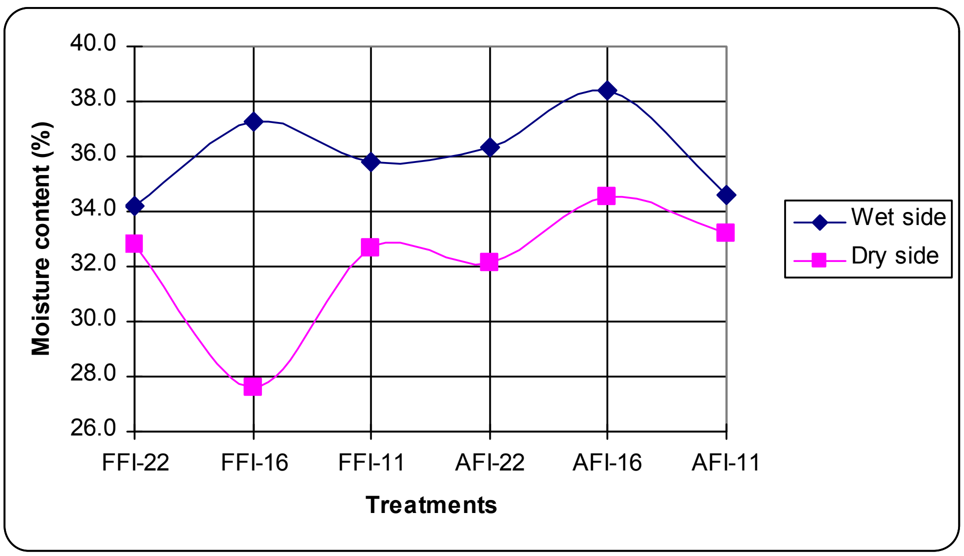

Figure 3 Moisture content at 30 cm depth both at drying and wetting side of the furrow after irrigation

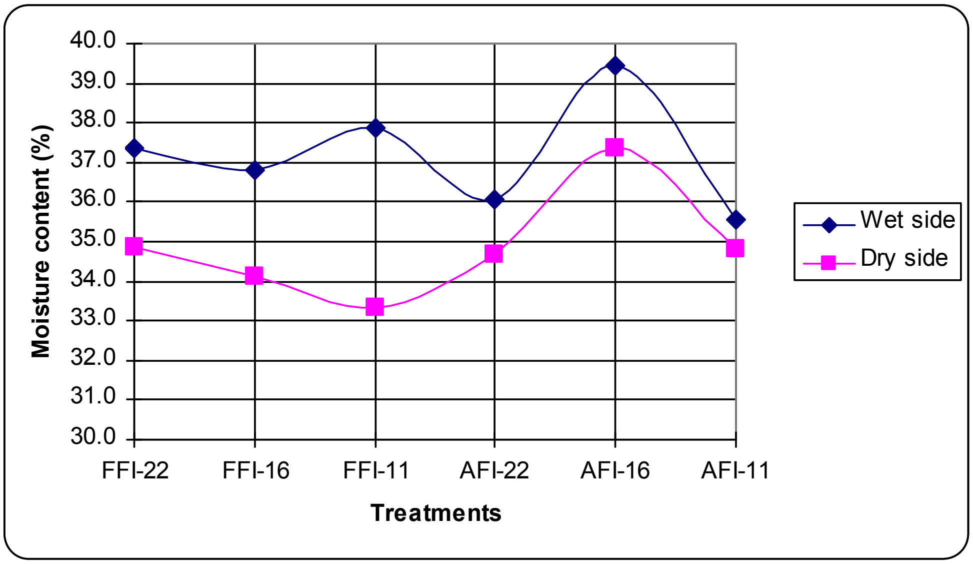

Figure 4 Moisture content at 60 cm depth both at drying and wetting side of the furrow after irrigation

Plant growth and yield parameters

The combined Statistical analysis of most agronomic parameters of the two years (2007 and 2008) data using MSTATC revealed that water application method and / or irrigation water application level resulted into non-significant difference in each treatment. Application of 75% IR level of water under fixed furrow irrigation (FFI-75%) resulted in larger plant height (25.38cm) than the conventional furrow irrigation (23.27cm) under the same water application level (Tab. 1). As the water level declines, the potato crop tends to manage the deficit by controlling its vegetative growth (physiological development) in AFI.

Table1 also shows no statistically significant difference in stem diameter among treatments. This result signifies that there was no injurious water deficit in the shoot at its growing stage when the stem diameter was measured. This also means plant water status was maintained at maximum water potential.

In addition, total biomass was not significantly affected by water application depth and / or IR level (Table 1). This suggests absence of injurious water deficit during the growing period in each treatment. This result goes in line with the fact that AFI tends to manage moisture deficit by controlling vegetative (physiological development) of the crop. Fresh root weight value with AFI at 50% IR level (9.93qt/ha) was higher than CFI values at all IR

Table 1 Comparison of Agronomic Parameters

Treatments	Plant height (cm)	Stem dia. (mm)	No of tubers /plant	Tuber weight (gm)	Total biomass qt/ha	Fresh root weight qt/ha	Dry root weight qt/ha	Fresh shoot weight qt/ha	Dry shoot weight qt/ha	Root /shoot ratio
CFI-100%	23.35	10.02	7.85	71.44	214.43	8.48	2.75	75.12	11.23	0.229
CFI-75%	23.27	9.94	8.57	69.55	239.06	9.71	2.8	89.53	12.43	0.215
CFI-50%	23.62	9.83	8.19	64.65	232.01	8.57	2.67	78.73	10.87	0.222
FFI-100%	24.04	9.96	9.28	66.95	237.07	9.94	2.86	82.83	12.64	0.21
FFI-75%	25.38	10.12	8.47	70.31	251.31	9.15	2.97	87.10	11.85	0.237
FFI-50%	20.98	10.29	6.86	63.88	173.86	5.86	1.99	63.74	9.83	0.208
AFI-100%	24.00	9.79	8.05	64.22	214.68	8.56	2.60	75.00	12.65	0.194
AFI-75%	24.73	10.20	7.47	58.13	174.39	8.28	2.30	71.10	11.00	0.19
AFI-50%	23.73	9.78	7.63	57.27	196.63	9.93	2.88	71.69	10.92	0.234
LCD(0.05)	ns	n	ns	ns	ns	ns	ns	ns	ns	ns
CV(%)	7.84	7.87	16.16	17.94	20.87	22.31	24.45	27.11	19.24	21.05

NS: non-significant difference at 5% probability level, CFI: conventional furrow irrigation, FFI: fixed furrow irrigation, AFI: alternate furrow irrigation, (100%, 75% and 50% are irrigation requirement levels) CV (%): Coefficient of variation in percent, LSD (5%): least square difference at 5%

Table 2 Comparison of yield and biomass performances

Treatments	Total Yield qt/ha	Marketable Yield qt/ha	Non-Marketable Yield qt/ha	Dry Matter Content %
CFI-100%	131.59	118.6	13.05	24.38
CFI-75%	145.05	131.12	14.07	22.92
CFI-50%	140.23	125.87	14.01	24.59
FFI-100%	144.05	128.21	15.72	25.04
FFI-75%	147.41	130.78	16.61	23.76
FFI-50%	100.45	88.5	12.42	24.76
AFI-100%	122.53	115.2	17.46	23.34
AFI-75%	104.21	84.29	19.53	23.61
AFI-50%	114.64	100.37	14.3	27.05
LCD(0.05)	ns	Ns	ns	ns
CV(%)	21.21	19.64	49.78	15.92

NS: non-significant difference at 5% probability level, CFI: conventional furrow irrigation, FFI: fixed furrow irrigation, AFI: alternate furrow irrigation, (100%, 75% and 50% are irrigation requirement levels), CV (%): Coefficient of variation in percent, LSD (5%): least square difference at 5% levels. This indicates better root development in AFI than CFI treated plots. The highest value for dry root weight (2.88qt/ha) is obtained with AFI at 50% IR level, followed by FFI at 100% IR level. The maximum root to shoot ratio (0.237) was obtained from FFI at 75% level followed by (0.234) for AFI at 50% level. This indicates existence of better root development than shoot unlike CFI at the same level. This also means presence of better root density in AFI than CFI at 50% IR level.

AFI at 50% IR level brought the highest dry matter content (27.05%) as compared to the other treatments. This goes in with the fact that PRD maintains quality.The highest total yield (147.41 qt/ha) was obtained with FFI at 75% level followed by (145.05 qt/ha) resulting from CFI same irrigation requirement level. CFI showed an improvement (from 131.59 qt/ha to 140.23 qt/ha) in total yield as the IR level declines from 100% to 50%. Total yield of AFI at 50% level (114.64qt/ha) showed only 13% yield decline when compared with CFI at 100% IR level (131.5 qt/ha). This originates probably from the very nature of AFI in maintaining yield at lower water level. Very interesting result was that better value of marketable yield was obtained at 75% (131.12 qt/ha) and 50% level (125.27 qt/ha) than the 100% IR level in CFI. AFI at 50% IR level brought 100.37 qt/ha marketable yield, which is lower than the value obtained by CFI at 100% IR level by only 18.23 qt/ha (i.e. 15.4%). At 50% IR level, AFI method gave better marketable yield than FFI method. This justifies the fact that alternating irrigation on both sides of the furrow maintains quality of potato than fixing irrigation to one side at lower water level.

Water Use Efficiency

As can be seen from table-3, WUE showed progressive improvement in CFI treated plots as the IR level decreases from 100% to 75% and then to50%. The highest value for WUE (8.13kg/m3) was obtained at 50% IR level for CFI followed by AFI at the same level. When CFI and AFI are compared at the same water level, CFI resulted into a better WUE

Table 3 Comparison of the Water Use Efficiency

	Irrigation requirement level (%)	Marketable yield (qt/ha)	Volume of water applied (m^3/ha)	Water use efficiency (kg/m^3)
CFI	100	118.6	2640	4.49
	75	131.12	2040	6.43
	50	125.87	1540	8.17
FFI	100	128.21	2640	4.86
	75	130.78	2040	6.41
	50	88.5	1540	5.75
AFI	100	115.2	2640	4.36
	75	84.29	2040	4.13
	50	100.37	1540	6.52

than AFI. In general, WUE can be increased by 82% in CFI and by 47% in AFI by reducing the IR from 100% to 50% level. When CFI at 100% IR level (which assumed to be close to the farmers practice) is compared with AFI at 50% IR level, WUE improves from 4.49 kg/ m3 to 6.52 kg/m3 which is about 45% improvement. Here marketable yield declines from 118.6 qt/ha to 100.4 qt/ha which is only 15% reduction. Water consumption by the crop is also reduced to 58% by adopting this method.

Conclusions and Recommendations

Different suggestions by various scholars were cited about the working principles of PRD. The first line of thought has two theoretical back grounds. (i) Fully irrigated plants usually have widely opened stomata. A small narrowing of the stomatal opening may reduce water loss substantially with little effect on photosynthesis. (ii) Part of the root system in drying soil can respond to the drying by sending a root-sourced signal to the shoot where stomata may be inhibited so that water loss is reduced. Here manipulating the soil water conditions using PRD, there by altering chemical signals, is thought to manipulate stomatal conductance (Stoll, 2000).

The other dimension of thinking by the second group of scholars is that stomatal control only constitutes part of the total transpiration resistance. The boundary resistance from the leaf surface to the outside of the canopy may be so substantial that reduction in stomatal conductance is small and may be partially compensated by the increase in leaf temperature(Kang and Zhang,2004).

In addition, PRD can expose part of the root system to soil drying and the roots in the drying zone may produce a signal that restrict stomatal opening. Although this might be expected to increase the WUE as outlined above, the situation is complicated by the fact that, in many crop canopies, the stomatal control over transpiration is only minimal and depends on the degree of environmental or atmospheric coupling (Jarvis, 1981, 1985; Jarvis and Mc Naughton, 1986). Canopy transpiration will largely be determined by huge boundary resistance and the energy input that sets the leaf temperature difference. If the stomata are partially closed, the leaf will be heated up, the vapor gradient will be higher, and the transpiration will eventually reach an equilibrium rate where the energy input matches the energy used by evaporation.

As it was indicated in the previous sections, the response of most agronomic parameters such as plant height, stem diameter, number of tubers per plant, tuber weight, dry matter content, total biomass, total yield, number of plants per plot, root and shoot weight to water application method and/ or IR level was found to be statistically non-significant. This suggests that introducing PRD even at 75% and 50% IR level had no injurious effect on the growth of potato crop. During field observation also it was seen that PRD treated plots showed no vigorous variation with that of the fully irrigated control treatments physiologically. Moreover, there was no major variation in days required to reach maturity.

Tremendous water saving was made possible in this experiment. Up to 42% water saving was practically achieved with 82% and 45% improvement in WUE in CFI and AFI methods respectively. Water saving to this extent has practically significant meaning on the overall water management system. It minimizes the risks associated with water logging, evapotranspiration and deep percolation loss, leaching of minerals and salt buildup in the system which may result due to excess water application. Moreover, the 42% water which is saved could be used for other beneficial purposes: i.e. to extend irrigable area or to irrigate high value crop or provide supplementary irrigation for rain fed crops. Reduction in pumping cost, labor and time are additional benefits.

As compared to the control (i.e. CFI with 100% IR level which is assumed to represent farmers practice), PRD treated potato under half (50%) IR level resulted only in 15% marketable yield reduction. PRD can be seen as a more efficient irrigation strategy where a small amount of water is available particularly as it doesn't result in significant yield penalties (Stoll, 2000). A slight decrease in yield as a response to halving the amount of irrigation water may be acceptable if fruit quality improves. Compared to other deficit irrigation techniques the yield reduction measured under PRD condition relative to control was minor (Stoll, 2000 and Dry, 1997) A consistent feature of these trials was that there was no significant reduction in yield due to PRD treatment, even though the amount of irrigation was halved. Accordingly, in this experiment, the maximum dry matter content (27%) was obtained with 50% (half level) irrigated PRD treated potato crop which is an indicator of better quality. The WUE improved by 45% as compared to the control. Most recently, a study by Saeed et al. (2005) showed also that PRD could also modify shoot growth and increase WUE in potatoes. However, the physiological basis for improving WUE in potatoes under PRD remains unknown. Moreover, AFI has certain advantages over CFI. It requires less labor during water application, less irrigation time and it has lesser chance for evaporation since lesser surface area is exposed to the environment.

The relatively low performance of FFI at lower (50% IR level) could be associated with the prolonged exposure of roots to drying. It is thought that this condition may cause exposure of roots to drying soil and may bring anatomical changes in the roots such as, suberization of the epidermis, collapse of the cortex and loss of succulent secondary roots (North and Noble, 1991). These changes are such that the roots under prolonged soil drying may function simply as transportation 'pipes' with a very low radial permeability of water. Such hydraulically isolated roots in soil would have reduced ability to sense soil drying. On the contrary, alternate watering or re watering, after long period of soil drying, may improve this situation by inducing new secondary roots (Liang et al., 1996b).

Therefore, CFI and AFI at 50% IR level can help efficient utilization of water with insignificant or no yield loss especially in areas where irrigation water is scarce and in water harvesting schemes to make crop production possible with limited water. Moreover, to maximize the utilization of the existing potentials of PRD, further research on broader range and variety of horticultural crops at different location is still required.

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Effect of Alternate Furrow Irrigation and Amount of Water on Water Productivity and Yield of Potato in East Belesa

Yirga Alemu and Hanibal Lemma
Gondar Agricultural Research Center, P.O.Box 1337, Gondar, Ethiopia

ABSTRACT
Three irrigation methods: conventional furrow irrigation (CFI), fixed furrow irrigation (FFI) and alternating furrow irrigation (AFI) were tested on three separate plots. Each irrigation method was further divided into three treatments using different irrigation amount: i.e. 22 mm, 16 mm and 11 mm water for each watering at 7 days interval, were tested for irrigated potato in East Belesa over 2 years (2006–2007). It was found that alternate furrow irrigation gives a significantly higher yield advantage than the conventional and fixed way of furrow irrigation. Alternate furrow irrigation with 22 mm of irrigation water gives the highest total yield (19509 kg/ha) while the conventional and fixed one with the same amount of water gives 13566 and 13663 kg/ha total yield respectively. There is also significant difference among the treatments in water productivity. The comparison of irrigation methods shows that there is significant difference in marketable and total yield between alternate and conventional as well as between alternate and fixed furrow irrigation methods, whereas no significant difference obtained between fixed and conventional furrow irrigation methods. Alternate furrow irrigation method gave significantly high yield and water productivity than the conventional and fixed furrow irrigation methods. Similarly, there is no significant difference among the three irrigation water amounts both in marketable and total yield of potato in East Belesa. However, the combined mean result shows 22 mm of applied water gave the highest marketable and total yield of potato.

Based up on the two years combined result alternate furrow irrigation with 22 mm of applied water at 7 days interval gives the highest yield of potato compared with other treatment combination in East Belesa. Hence, it is advised that farmers in East Belesa should use alternate furrow irrigation for better and efficient production of potato. However, further research required to accurately determine the amount of irrigation water for alternate furrow irrigation method for maximum production of potato in East Belesa.

Key words: *Alternate furrow irrigation, East Belesa, Irrigation amount, Water productivity, Yield of potato*

INTRODUCTION

Amhara region, with a population of about 18 million, faces both chronic and transitory food insecurity due to a combination of factors including erratic and unreliable rainfall, degraded resource base, high population to cultivated land ratios and low productivity related to management practices (BoARD, 2003). As a result of these and other factors, an estimated 18-20% of the population is chronically food insecure. Recognizing this fact, the regional government has prioritized the provision of reliable irrigation water (supplementary and/or full) to reduce the incidence of drought related crop failures as prerequisite for increasing agricultural productivity to reduce the level of household food insecurity (BoWRD, 2005).

Efficient water use has become an important issue in recent years because the lack of available water resources in some areas is increasingly becoming a serious problem. Agronomic measures such as varying tillage practices, mulching and anti-transpirants can reduce the demand for irrigation water and improve irrigation water use efficiency (IWUE). Development of novel water saving irrigation techniques represents another option for increased water use efficiency. During the last two decades, water–saving irrigation techniques such as deficit irrigation (DI) and partial root zone drying (PRD) or alternative irrigation (AI) have been developed and tested for field crops and fruit trees. Most recently, these irrigation techniques are being tested also in vegetable crops such as tomatoes (Zegbe-Domínguez, 2003).

Alternate irrigation is a new irrigation technique which requires that approximately half of the root system is always exposed to drying soil while the remaining half is irrigated as in full irrigation. The wetted and dried sides of the root system are alternated in a frequency according to crops, growing stages and soil water balance. This technique has the potential to reduce crop water use significantly, increase canopy vigor, and maintain yields when compared with normal irrigation methods. This technique has two theoretical assumptions. (i) Fully irrigated plants usually have widely opened stomata. A small narrowing of the stomata opening may reduce water loss substantially with little effect on photosynthesis (Jones, 1992). (ii) Part of the root system in drying soil can respond to drying by sending a root-sourced signal to the shoots where stomata may be closed to reduce water loss (Davies and Zhang, 1991).

Ideally, WUE should be improved by reduced leaf transpiration. Stomata control the door of plant gas exchange and transpiration water loss. Recent investigations have shown that stomata may directly respond to the availability of water in the soil such that they may reduce their opening according to the amount of water available in the soil. The advantage of such regulation is that plant may delay the onset of an injurious leaf water deficit and enhance its chance of survival under unpredictable rainfall conditions. More recent evidence has shown that such a feed forward stomatal regulation process works through a chemical signal. The increased concentration of abscicie acid (ABA), in the xylem flow soil can produce large amount of ABA while the rest of the root system in wet soil may function normally to keep the plant hydrated (zhang and devise 1987). The result of such a response is that the plant may have a reduced stomatal opening in the absence of a visible leaf water deficit.

Fischbach and mulliner (1972) reported that alternate furrow irrigation in cash crops offer the opportunity for reduced water use and increased WUE. Alternate furrow irrigation was practiced for a number of crops such as potato, tomato, soybean and corn to conserve water. In a study on tomato on Orissa (India), alternate furrow irrigation gave the highest WUE (5,140 Kg ha^{-1} mm^{-1}) among several furrow treatments (Sahoo et. 1998)

The hypothesis behind irrigating alternate furrows is that:

1. In alternate furrow irrigation less surface water is wetted and less evaporation from the surface occurs.
2. More lateral roots are stimulated and a chemical signal is produced in drying roots to reduce the shoot water loss.
3. Amount of water needed (i.e. irrigation water use), time and labor requirement for irrigation is decreased.
4. Water use efficiency (WUE) will be nearly doubled by using this method.

In Ethiopia there were no research works on alternate furrow irrigation and water resources are used inefficiently even in water deficient areas. But there are not any researches in our country regarding alternate furrow irrigation for better yield of potato while utilizing water resources efficiently. Thus, this study was initiated to evaluate efficiency of alternate furrow irrigation and amount of water on water productivity and yield of potato.

MATERIALS AND METHODS

Description of Study Area

The study was conducted for two consecutive years from 2006 to 2007 in Dengora about 7km from Gohala, woreda capital of East Belesa. East Belesa is one of the woredas in North Gondar Administrative Zone of Amhara Region. It is bordered with Janamora and Wogera in the North, Ebinat in the South, West Belesa in the West and Wagehamera zone in the East. Geographically the woredas lies between 35^0 52' to 38^0 39'E and 11^0 38' to 13^0 32' N. The woreda has a total area of 1,563 Km^2. The woreda capital Gohala is located 160 Km from Bahir Dar town.

Agro climatically the woreda is located in dry sub humid area. In the Woreda there is no meteorological station. Data from nearby station, Addis Zemen, was used for the designing of irrigation infrastructures. The maximum ET_0 in the area is 5.8 mm/day in March. The mean annual temperature ranges from 22^0C to 25^0C. The woreda receives annual average rainfall of 600-800mm. Most of the rain is received from the fourth week of June to the end of August. The coincidence of late onset, early cessation and uneven distribution of rainfall with short effective season has resulted terminal dry spells, recurrent drought and unreliable rainfed cropping in the area.

The woreda is endowed with 15 perennial rivers and a number of small springs and streams. The rivers and springs are used for water supply and irrigation. Besides, there exist developed water points and household water harvesting structures. Currently there are 8 traditional and 3 modern irrigation schemes, which can have a capacity to irrigate around 310ha of land, operating in the woreda. In most of the irrigation schemes, whether traditional or modern, the irrigation water management practices followed by farmers are traditional and poor water management. The soil in the experimental site is Cambsols, texturally clay loam. The effective soil depth in the experimental site is moderately deep (150 cm) with moderate fertility.

Methodology

In the field three different methods of furrow irrigation were tested for irrigated potato in East Belesa over 2 years (2006–2007). Irrigation water was applied through furrows in three ways: alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI). AFI means that one of the two neighboring furrows was alternately irrigated during consecutive watering. FFI means that irrigation was fixed to one of the two neighboring furrows. CFI was the conventional way where every furrow was irrigated during each watering. Each irrigation method was further divided into three treatments with different irrigation amounts, i.e. 11, 16, and 22 mm water for each watering.

The test plant was potato (*Solanum Tuberosum*) of variety *'Gera*'. The plot size was 3m x 6m. The spacing between plants was 30cm and between rows 75 cm. The spacing between treatments was 1m and the spacing between each block was 2m. Potato was planted on January 13 and harvested on May 02 with the length of growing period around 125 days. The frequency of irrigation was fixed as 7 days interval, hence all plots was irrigated 18 times throughout the growing season. The design of the experiment was RCBD with three replications. Prior to planting all plots was irrigated with equal amount of water up to the field capacity to initiate germination. There is no rainfall throughout the growing season. Finally, prior to harvest, 10 plants were sampled at random from central three rows of each plot for determination of agronomic parameters. Data collected include total, marketable, and unmarketable (decay, split, and under weight) yield, tuber diameter, number of tubers, and tuber weight.

RESULTS AND DISCUSSION

Analysis of variance was conducted by combining two years of irrigation season data using SAS statistical software. The combined result shows that there is significant difference for total and marketable yield of potato among treatments (see Table 1). However, in the first year, there is no statistically significance difference in the total and marketable yield of potato. The mean total and marketable yield of potato of alternate furrow irrigation with 22 mm of applied water is significantly different from the conventional and fixed way of furrow irrigation. It is obvious that conventional furrow irrigation is labour intensive and time consuming, each furrow is irrigated at each frequency of irrigation, however, alternate irrigation consumes half of the labour and time required to irrigate. In addition to this advantage in this experimental result alternate furrow irrigation with 22 mm of irrigation water saves the highest total yield (19509 kg/ha) while the conventional and fixed ones with the same amount of water gives 13566 and 13663 kg/ha total yield respectively.

Stem diameter, number of tubesr, and tuber weights did not significant difference among treatment, as it is shown on Table 2. Average number of tubers and diameter of tuber is also highest in alternate furrow irrigation than the other two. It is only with fixed furrow irrigation with 11 mm of irrigation water that the highest tuber weight (80.24 gm) was recorded.

Table 1 Mean Marketable and Total Yield of Potato for the Whole Experimental Season in East Belesa

	Year 1/2006		Year 2/2007		Combined	
Treatment	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)
22mm & CF	13309	12983	14830BA	14148BA	14069B	13566B
16mm & CF	14035	13487	13156B	12133B	13595B	12810B
11mm & CF	15418	14736	15855BA	15262BA	15636BA	14999BA
22mm & FF	15752	15026	12759B	12300B	14256B	13663B
16mm & FF	13823	13096	14863BA	14063BA	14343B	13579B
11mm & FF	13816	12942	15870BA	14685BA	14843B	13814B
22mm & AF	**18485**	**17907**	**20533A**	**19822A**	**19509A**	**18864A**
16mm & AF	16173	15729	17393BA	16756BA	16783BA	16383BA
11mm & AF	15196	14574	17437BA	17037BA	16317BA	15665BA
C.V (%)	20.12	21.39	26.91	26.96	22.29	22.73
Fisher's LSD (0.05)	ns	ns	7319	6999	4018	3916

- ns = non significant difference at 5% significant level
- Means with the same letter are not significant different

Table 3 shows values of water productivity, quantifies changes in crop yield per m^3 irrigation water supplied. There is significant difference among the treatments in water productivity. Alternate furrow irrigation with 11 mm of applied water gives the highest water productivity; in fact the conventional furrow irrigation with 11 mm of irrigation water also shows almost equal water productivity as that of the alternate furrow irrigation. Therefore, in areas with insufficient water resource for irrigation in East Belesa or agro climatically similar areas can use 11 mm (110 m^3/ha) of water at 7 days interval, or 1980 m^3/ha of water through out the growing season, for optimum total yield production of irrigated potato. However, to get maximum total yield of potato in East Belesa farmers are advised to use at least 22 mm (220 m^3/ha) of water at 7 days interval, or 3960 m^3/ha of water through out the growing season.

Table 2 Average Number of Tubers, Tuber Weight and Diameter of Tuber of Potato for the Whole Experimental Season in East Belesa

	Year 1/2006			Year 2/2007			Combined		
Treatment	Av. No. tubers	Av. Tuber Weight (gm)	Av. Diameter of tuber (cm)	Av. No. tubers	Av. Tuber Weight (gm)	Av. Diameter of tuber (cm)	Av. No. tubers	Av.Tuber Weight (gm)	Av. Diameter of tuber (cm)
22mm & CF	3.87	67.13	34.40	5.07	66.57	33.53	4.47	66.9	33.97
16mm & CF	4.53	73.47	32.40	6.87	44.24	33.07	5.7	58.85	32.73
11mm & CF	4.47	82.10	33.80	6.20	58.60	34.00	5.33	70.35	33.90
22mm & FF	3.87	102.20	33.33	6.13	47.53	33.67	5.00	74.87	33.50
16mm & FF	3.33	72.73	31.07	6.27	56.06	31.60	4.80	64.40	31.33
11mm & FF	3.87	**109.47**	32.40	7.53	51.01	31.13	5.70	**80.24**	31.77
22mm & AF	4.33	70.40	32.80	**8.40**	56.78	32.80	6.37	63.59	32.80
16mm & AF	5.00	87.73	32.00	5.60	**71.58**	31.40	5.30	79.66	31.70
11mm & AF	**5.07**	62.60	**35.33**	7.40	56.60	**34.07**	**6.23**	59.60	**34.70**
C.V (%)	28.33	39.49	9.62	33.35	24.84	5.43	39.00	40.45	7.11
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns

- ns = non significant difference at 5% significant level

By separating the combined effect of irrigation method and amount of irrigation the data was analyzed separately for irrigation method as it is shown in Table 4. In 2006 irrigation season even if statistically there is no significant difference among irrigation methods both for marketable and total yield of potato, the mean marketable and total yield obtained with alternate furrow irrigation is higher than the fixed and conventional furrow irrigation methods. There is significant difference in marketable and total yield between alternate and conventional as well as between alternate and fixed furrow irrigation methods in 2007 experimental year and the two years (2006 and 2007) combined result. However, there is no significant difference between fixed and conventional furrow irrigation methods. Alternate furrow irrigation method gives significantly high yield and water productivity than the conventional and fixed furrow irrigation methods.

Table 3 Effect of Applied Water and Furrow Irrigation Method on Water Productivity of Potato in East Belesa

Treatment	Number of irrigation	Irrigated water (m^3/ha)	Total Yield (kg/ha)	Water Productivity (kg/m^3)
22mm & CFI	18	3960	14069B	3.55C
16mm & CFI	18	2880	13595B	4.72CB
11mm & CFI	18	1980	15636BA	7.90A
22mm & FFI	18	3960	14256B	3.60C
16mm & FFI	18	2880	14343B	4.98CB
11mm & FFI	18	1980	14843B	7.50A
22mm & AFI	18	3960	**19509A**	4.93CB
16mm & AFI	18	2880	16783BA	5.83B
11mm & AFI	18	1980	16317BA	**8.24A**
C.V (%)	-	-	22.29	**23.21**
Fisher's LSD (0.05)	-	-	4018	**1.53**

Table 4 Effect of Irrigation Methods on Marketable and Total Yield of Potato in East Belesa

Irrigation Method	Year 1/2006		Year 2/2007		Combined		
	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marke-table Yield (kg/ha)	Total Yield (kg/ha)	Water Productivity (kg/m^3)
Alternate Furrow Irrigation (AFI)	160.70	166.18	17872A	18454A	16971A	17536 A	6.33
Conventional Furrow Irrigation (CFI)	137.35	142.54	13848B	14613B	13792B	14434 B	5.39
Fixed Furrow Irrigation (FFI)	136.88	144.64	13683B	14498B	13685B	14481 B	5.36
Coefficient of Variation (CV %)	20.08	19.00	24.91	24.87	22.35	21.91	36.59
Fisher's LSD (0.05)	ns	ns	3668	3837	2216	2270	ns

- Means with the same letter are not significant different
- ns = non significant difference at 5% significant level

Fixed furrow irrigation gives low total and marketable yield as compared to alternate furrow irrigation. This is because it is only one side of potato root system that is wetted for the whole irrigation season, the roots in the dried soil encountered shortage of moisture; hence, nutrient uptake from the soil is reduced, which affect the physiology of the crop and as a result the plant did not maintain the yield. However, in the alternate furrow irrigation each of the furrow gets water at 14 days interval. Even if there was a moisture stress on one side of the plant after 7 days from the previous irrigation, this stress was overcome by stomata closure to reduce water loss and a chemical signal is produced in drying roots to reduce the shoot water loss.

Conventional furrow irrigation saves similarly low yield as that of fixed furrow irrigation as compared to alternate furrow irrigation. The reason is that in conventional furrow irrigation more soil surface area is wetted almost as double as that of alternate furrow irrigation, this leads to high evaporation loss in conventional furrow irrigation. This loss affects the yield significantly, as Belesa is a dry area.

Table 5 Effect of Applied Irrigation Water on Marketable and Total Yield of Potato for the Whole Experimental Season in East Belesa

Irrigation Amount (mm)	Year 1/2006		Year 2/2007		Combined		
	Marketable Yield (kg/ha)	Total Yield (kg /ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Water Productivity (kg/m^3)
11	14084	14810	15568	16387	148.26	155.99	7.88A
16	14104	14677	14411	15137	142.58	149.07	5.18B
22	15305	15848	15423	16041	153.64	159.45	4.03C
CV %	21.25	20.09	28.14	27.52	24.53	23.76	23.54
Fisher's LSD (0.05)	ns	ns	ns	ns	ns	ns	0.89

- ns = non significant difference at 5% significant level
- Means with the same letter are not significant different

In the two consecutive years of irrigation, statistically there was no significant difference among the three irrigation amounts both in marketable and total yield of potato in East Belesa as it is shown in Table 5. However, in 2006 22 mm of water saves the highest yield compared to 11 and 16 mm of applied irrigation water and in 2007 11mm applied irrigation water saves the highest yield compared to the other two. The combined result however shows 22 mm of applied water gives the highest marketable and total yield of potato in East Belesa. There is significant difference among irrigation amounts in water productivity. 11 mm of applied water gives significantly high (7.88 kg/m^3) water productivity than 16 and 22 mm of irrigation amount.

CONCLUSIONS AND RECOMMENDATIONS

Results showed that there is significant difference for total and marketable yield of potato among treatments. However, stem diameter, number of tuber, and tuber weights are not significant difference for furrow irrigation methods and amount of irrigation water. Alternate furrow irrigation with 22 mm of applied water at 7 days interval saves significantly higher total yield (19509 kg/ha) while the conventional and fixed one with the same amount of water saves 13566 and 13663 kg/ha total yield respectively. Generally Fixed and conventional furrow irrigation saves the lowest total and marketable yield compared to alternate furrow irrigation. Average number of tubers and diameter of tuber was also highest in alternate furrow irrigation than the other two.

Among the treatments alternate furrow irrigation with 11 mm of applied water saves significantly highest water productivity. Therefore, in areas with scarce water resource for irrigation in East Belesa or agro climatically similar areas can use 11 mm (110 m^3/ha) of water at 7 days interval, or 1980 m^3/ha of water through out the growing season, for optimum production of irrigated Potato. However, to get maximum total yield of potato in East Belesa farmers are advised to use at least 22 mm (220 m^3/ha) of water at 7 days interval, or 3960 m^3/ha of water through out the growing season.

By separating the combined effect of irrigation method and amount of irrigation the data was analyzed separately for irrigation method. The result shows that there is significant difference in marketable and total yield among irrigation methods in the two year experimental season. Therefore, the two years combined result shows that alternate furrow irrigation method gives significantly higher yield than the other two irrigation methods at 5% significance level. Similarly, in the two consecutive years of irrigation, statistically there is no significant difference among the three irrigation amounts both in marketable and total yield of potato in East Belesa. However, the combined mean result shows 22 mm of applied water gives the highest marketable and total yield of potato in East Belesa.

Based up on the two years combined result, alternate furrow irrigation with 22 mm of applied water at 7 days interval gives significantly highest total and marketable yield of potato compared with other treatment combination in East Belesa. Hence, it is advised that farmers in East Belesa area use alternate furrow irrigation for better and efficient production of potato. However, the irrigation amount treatments are few in number to show precisely water yield production function, hence, further research is required to accurately determine the amount of irrigation water for alternate furrow irrigation method for maximum production of potato in East Belesa.

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Water Harvesting: Improving Tree Seedling survival & Biomass production at *Kalu Woreda*, South *Wolo*, Ethiopia

Sisay Demeku1, Berhan Tegegn1, Tewodros Assefa1, Belete Berhanu and Gete Zeleke[2]

Abstract

An experiment was conducted to compare and evaluate three different micro-basin structures (eyebrow, half-moon and trench) and the normal seedling plantation practice by farmers (normal pit). Trench and eyebrow structures showed better performance in improving tree growth parameters as compared to the normal pit: a 65%, 90% and 50% increase in root collar diameter (RCD), diameter at breast height (DBH) and height of the tree seedling was recorded respectively. The trench technique increased grass production in the plantation area by 41 %. Eyebrow is recommended on hillsides where stone is available and trench can be used where stone is scarce.

The results indicate that micro-basin structures can mitigate both flood and dry spell shocks with low investment and skilled manpower costs. It increases livestock water productivity as more feed can be produced with the existing variable rainfall.

Key words: In situ water harvesting, micro-basins, water productivity, hillsides.

Introduction

Although Ethiopia is known as the “Water Tower of East Africa” with 12 major river and lake basins and high rainfall amounts, recurrent drought, erosion, flooding and drying of streams, springs and lakes hit the country several times. The country’s annual rainfall is estimated at about 1090 mm, while the total annual runoff is estimated at 110 Billion cubic meters or 98 mm. Only 5% of this runoff is used in the country and the rest is lost (Getachew, **A.,** 1999. Rainwater Harvesting in Ethiopia: An Overview, pp.387-390. In: 25th WEDC Conference on Integrated Development for Water Supply and Sanitation, Addis Ababa, Ethiopia. (Retrieved February 16, 2005, from http://www.lboro.ac.uk/wedc/papers/25/387.pdfPoverty, undulating and steep topography, and mismanagement of water and land resources together result in the low productivity of this runoff. Climatic change and mismanagement of water and land cause erosion, low production, and famine and food insecurity.

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[1] Sirinka Agricultural Research Center, P.O.Box 74, Woldia, Ethiopia. (Email: sdemeku@yahoo.com); [1] Global Mountain Program (GMP), C/O ILRI, P.O.Box 5689, Addis Ababa, Ethiopia. (Email: g.zeleke@cgiar.org)

The dry land areas of North-Eastern *Amhara* around the eastern escarpment are characterized by undulating topography in which hillslopes alternate with bottom farmlands. The high population growth has forced people to clear off trees from the hills and plow very steep slopes and marginal lands. This disturbs the natural hydrological cycle by reducing the water holding capacity of the soil and infiltration and percolation to the ground water table. It is familiar to observe formation and expansion of gullies on productive grazing and farmlands that are caused by seasonal runoff. Although annual cumulative rainfall is relatively high, it´s distribution is erratic with many dry weeks even within the main rainy season from July to September. Occasionally, high-intensity rain produces high runoff with low soil water storage.

In order to increase the forest coverage and biomass production and to improve the environmental conditions of the area, millions of tree seedlings were repeatedly planted by different afforestation programs, but almost none survived. In addition to browsing and loose follow-up, water stress is the major limiting factor, which reduces the survival rate and productivity of tree seedlings in the semi-arid areas in the region.

One of the recent approaches to overcome such problems of low water availability in semi-arid areas is the use of different in situ water harvesting structures that fits with the existing social, technical and economical conditions of the society. Water can be harvested above the ground as above ground tankers, on the ground as large dams and small micro-basins and with in the soil profile as a soil moisture conservation. Different kinds of structures and techniques exist, differing from each other with respect to catchment area and storage type, like roof top, runoff, flood, above-ground tank, excavated cisterns, small dams and soil moisture (or in situ) water harvesting (Mitiku, H., Sorsa, N., 2002. The experience of water harvesting in the drylands of Ethiopia. Workshop proceeding. Deutschen Cichliden Gesellschaft (DCG) report 19. Bonn, Germany. To favor the growth of tree seedlings, excess runoff can be temporarily stored in artificial water harvesting structures around the seedlings. Multi-purpose trees are very advantageous as they can be used as forage, increase soil fertility and minimize soil erosion by their canopy and rooting system. Methods able to increase water availability for plants include rainfall multiplier systems (that are methods of harvesting rain water from one surface and used to an other area) and micro runoff storage mechanisms directed at storing water in the root zone for growing (Mitiku, H., Sorsa, N., 2002. The experience of water harvesting in the drylands of Ethiopia. Workshop proceeding. Deutschen Cichliden Gesellschaft (DCG) report 19. Bonn, Germany. In situ water harvesting structures retain excess rainfall during rain events around the seedlings. Ponding increases the time for infiltration so that chances for root absorption and groundwater recharge can be improved. In addition, in situ water harvesting eases the technological and health complications by directly supplying water to the root zone and reducing sediment load and erosion in downstream sites. Simple structures that can be dug by farmers have the chance to be replicated easily once their importance is understood. The monetary and skill investment is relatively low. Their importance is not only to increase the seedling survive rate with resulting increased feed and wood production, but also to prevent huge dams from siltation. The research results in other areas show that v-shape structures are effective in Kenya (Mugwe J., Mick O., Samual G., Jonathan M., Jack M., 2001. Participatory Evaluation of Water Harvesting Techniques for Establishing Improved Mango Varieties in Smallholder Farms of Mbeere District, Kenya. Pages 1152-1157. In: D.E. Stott, R.H. Mohtar and G.C. Steinhartt (Eds.). Sustaining the Global Farm, 10th International Soil conservation Organization Meeting, Perdu, May 24-29, 1999. Perdu University, USA.Experimental results on in situ water harvesting in eastern Ethiopia show that micro-catchments of $100m^2$ result in a 7.8% seedling survival increment for Acacia *saligna* compared to $50m^2$ area at Dire Dawa (Abdelkdair A., Richard, C.S., 2005. Water harvesting in a 'runoff–catchment' agroforestry system in the dry lands of Ethiopia. *Agroforestry Forum.* 63: 291–298

Awareness campaigns were held and huge investments were made to promote harvesting and use of the runoff water at household level using concrete structures. Approximately, 70,000 ponds and tanks were constructed during 2002 (UN OCHA, 2003). However, the structures need more skilled manpower, follow-up and investment than the households are capable of. According to the assessment report of UN OCHA (2003), cracking and leakage problems of constructed tankers, safety and mosquito hazards, siltation, and irrigation technology needs were the challenges faced when implementing rainwater harvesting technology.

The general aim of the study was to contribute to alleviating water stress and improve biomass productivity in water stressed areas of north eastern Amhara region in Ethiopia. The specific objectives of this study were:

- To evaluate the effect of different micro-basin water harvesting techniques (eyebrow, half moon and trench) on survival rates and growth of trees and grasses in moisture stressed areas of north eastern *Amhara*, Ethiopia.
- To formulate recommendations towards development planners and experts, farmers and catchment treatment programmers on the use of micro-basin water harvesting structures.

Materials and methods

Description of the study site

The field experiment was conducted at *Kalu* district about 350km north of the capital city of Ethiopia, Addis Ababa, at a geographical location of 10°56'25"N and 39°46'57"E on the way to Desie. The area has more than 1000mm average annual rainfall with the average monthly distribution shown in *Figure 1:* Average monthly rainfall, mean daily temperature and number of years that had less than 14.7mm monthly rainfall out of 16 years of data from *Combolcha* meteorological station *(*1985-2000). From near by meteorological station, Combolcha. About half of the year is dry with 50% probability to get a monthly rainfall of less than 14.7 mm, which is the threshold rainfall to fill interception losses before deep infiltration and runoff. On the other hand, the main rainy season goes to a climax abruptly in July, when surface vegetation cover is low due to the dry spell in June. This is an indication of severe erodibility unless mitigated by appropriate soil surface management. November, December and January are the driest months of the year that need moisture management to increase seedlings survival rates and to increase the water productivity of rain events in August and September.

Area closure is advised and it is practicing in the area to rehabilitate hillsides and protect hill bottom farmlands from gully erosion. Farmers are using cut and carry system to feed their livestock from the closed area. The regional government is trying to distribute and certify hillsides for individual farmers.

Table 1 Base line information on soil, and slope of the experimental plots.

Plot No. (*)	P^H	N (%)	P (ppm)	OC (%)	Texture			Texture class	Slope (%)	Soil depth (cm)
					Clay (%)	Silt (%)	Sand (%)			
R_1T_1	6.2	0.186	16.8	1.998	32.25	30.0	37.75	Clay Loam	17.4	60
R_1T_2	6.4	0.189	16.4	2.014	49.75	27.5	22.75	Clay	18.8	70
R_1T_3	6.5	0.203	5.6	1.497	42.25	30.0	27.75	Clay	13.9	60
R_1T_4	6.6	0.169	7.2	2.016	37.25	30.0	32.75	Clay Loam	18.2	70
R_2T_1	6.4	0.214	15.2	2.590	54.75	27.5	17.75	Clay	20.7	40
R_2T_2	7.0	0.253	8.4	2.253	49.75	35.0	15.25	Clay	43.3	70
R_2T_3	6.5	0.234	12.8	2.687	47.25	35.0	17.75	Clay	28.8	90
R_2T_4	6.7	0.211	8.4	2.464	54.75	30.0	15.25	Clay	36.6	80
R_3T_1	7.0	0.245	10.8	1.713	22.25	32.5	45.25	Loam	26.0	60
R_3T_2	6.9	0.291	6.4	2.853	42.25	37.5	20.25	Clay	81.5	35
R_3T_3	6.7	0.221	16.0	1.702	37.25	37.5	25.25	Clay Loam	61.1	45
R_3T_4	7.0	0.151	12.0	1.626	34.75	30.0	35.25	Clay Loam	41.4	55

(*) KEY: R=Replication T_1=Half-moon T_2=Eyebrow T_3=Trench T_4=Normal pit

Experimental set up

The experiment was designed as randomized complete block with four water harvesting structures and three replications established in a 50m by 25m treatment plot area with 2m spacing between the treatments. Base line data was collected at the beginning of the experiment from each experimental plot (*Table 4* Base line information on soil, and slope of the experimental plots).

The structures were half-moon, eyebrow basin, water collection trench, and normal pit as control. Normal pit is a small cylindrical hole normally dug by farmers. The construction techniques described in (Carucci, V., 2000. Guidelines on water harvesting and soil conservations for moisture deficit areas in Ethiopia: The productive use of water and soil. Manual for trainers. World Food Programme, Addis Ababa, **Ethiopia.** were employed for the study, taking into account to have an equal number of seedlings in each experimental plot.

The dimension of the normal pit was 30cm diameter and 50cm depth. Acacia *saligna*, an adaptable and multi-purpose tree species for the area, was selected as a test plant. Experimental data was collected every three months for 2 years starting from plantation. These data include survival rate, root collar diameter (RCD, i.e. diameter of the seedling at the ground surface), diameter at breast height (DBH, i.e. at 1.3m above the ground surface), height of the tree and annual grass biomass production. RCD, DBH and height were taken from all the seedlings surviving, except from the borderlines of the plots. Survival rate was calculated as the percentage of seedling surviving at data collection time to the total number planted in the treatment. The diameters were taken using precise caliper. Three 3m by 3m sample areas per treatment were harvested to determine sun dried grass biomass.

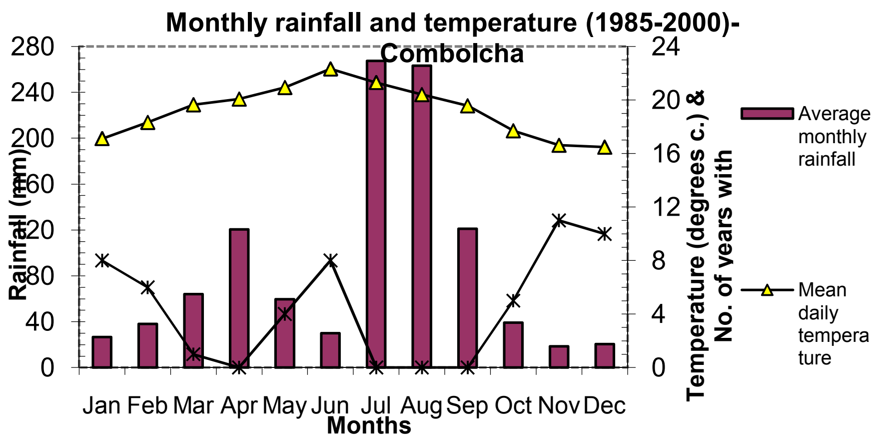

Figure 1: Average monthly rainfall, mean daily temperature and number of years that had less than 14.7mm monthly rainfall out of 16 years of data from *Combolcha* meteorological station *(*1985-2000).

Statistical analysis

Analysis of variance was used to identify significant differences among treatment means of the variables considered in the experiment. When analysis of variance showed significant differences at α=0.1, α = 0.05 and α =0.01, further mean separations were made using Fisher's LSD mean separation test. Time series graphs were drawn for growth variables to indicate treatment effect and seedling response along the age of the seedling.

Results and discussion

The time series graphs (see Figure 2) of growth variables show that, after high moisture stress during the winter dry spells (at 6th and 18th months age) and the autumn dry spells (at 12th and 24th months age), increment rates are minimal. During the first 15 months, seedlings need careful management for survival and fast growth. Trench and eyebrow show efficiency to promote seedling survival and growth. The dimension and shape of eyebrow and half-moon are similar, but they differ with respect to growth and seedling survival efficiency. The reason might be the location of the water collection pit. It is located above the plantation pit for the eyebrow structure and around the plantation pit for the half-moon structure. In the latter case, there is a chance to lose some water as subsurface flow away from the root zone due to the hydrostatic (gravitational) head of the harvested water. For the eyebrow on the other hand, the water flow is towards the root zone since the water collection pit is located upstream from the plantation pit. This assumption can be verified by determining the moisture profile over time of each structure around the water collection pit.

All three micro-basins have better results for all measured variables as compared to the normal pit (Table 2. Mean values of root collar diameter-RCD (cm), diameter at breast height-DBH (cm), height (cm), survival rate (%) and grass biomass (kg/ha) of each treatment at the 15th month.. At the age of 15 months (i.e. when corresponding grass biomass data are available), treatments are highly significantly different at $\alpha = 0.01$ for survival rate. For RCD and grass biomass differences are significant at $\alpha = 0.05$ and for DBH & height at $\alpha = 0.1$. Therefore, 32.2-45% for survival rate, 54.8-70.4% for RCD, -5.5-41.1% for grass biomass, 69.5-97.8% for DBH and 35.5-52.6% for height increments are shown as compared to the normal pit by eye-brow, trench and half-moon, respectively (see *Table* 3 **Increments/decrements as compared to the normal pit.** The disturbance of the surface area due to the construction of the structures influences grass production. The effect of the treatments on grass biomass production may therefore be seen clearly only in the next years.

Table 2. Mean values of root collar diameter-RCD (cm), diameter at breast height-DBH (cm), height (cm), survival rate (%) and grass biomass (kg/ha) of each treatment at the 15th month.

Treatments	RCD (cm.)	DBH (cm)	Height (cm.)	Survival rate (%).	Grass Biomass (kg/ha)
Half-moon	2.26A	0.78AB	173.19AB	50.55A	6656.4A
Eye-brow	2.49A	0.91A	195.13A	63.65A	4808.0B
Trench	2.40A	0.88A	193.25A	61.95A	7181.0A
Normal pit	1.46B **	0.46B *	127.85B *	18.33B ***	5087.4B **
CV	13.46	26.13	16.56	15.77	12.74
LSD	0.539	0.355	51.31	13.77	1359.0

Note:* significant at 10% ** Significant at 5% *** Significant at 1%

NB: Numbers indicated with the same alphabets are not statistically significant at a given significant level.

Table 3 Increments/decrements as compared to the normal pit.

No.	Treatments	RCD		DBH		Height		Survival rate (%)	Grass biomass (%)
		%	cm	%	cm	%	cm		
1	Half-moon	54.8	1.08	69.5	0.32	35.5	45.3	32.2	30.8
2	Eye-brow	70.4	1.03	97.8	0.45	52.6	67.3	45.3	-5.5
3	Trench	64.9	0.94	91.3	0.42	51.1	65.4	43.6	41.1

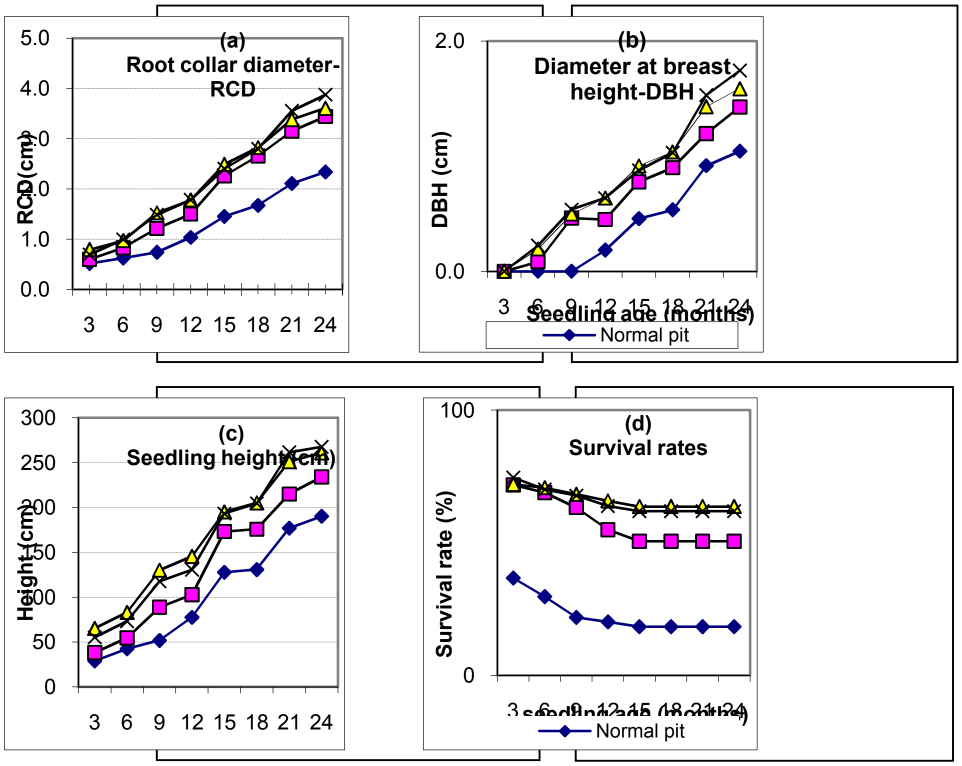

Figure 2: Time series of growth variables: (a) Root collar diameter (RCD), (b) diameter at breast height (DBH) in cm, (c) seedling height in cm and (d) survival rate in %.

Table 4 shows the overall combined time series statistical analysis of the eight observations which were conducted with 3 months time interval. All three structures show statistically significant differences from the normal pit in all variables and especially with respect to the survival rate of tree seedlings. There is an almost insignificant difference between trench and eyebrow, except for height and survival rate. Eyebrow shows a significantly higher survival rate at $\alpha=0.1$ in the second year.

Conclusion and recommendations

Generally, it can be concluded from the data of this study that the three micro-basins improve the biomass production and land cover as compared to the normal practice with in the existing erratic rainfall. It is possible to interpret the additional biomass production to livestock water productivity for the area. For example, using 12kg/day dry forage biomass need for one animal unit-AU (equivalent to 454kg heavy cow), 1569.0 – 2093.6 kg/ha additional grass biomass produced by the micro-basins can feed for 131-175 days for one AU. Safe and sustainable production at down stream farmlands, additional biomass production during small rainy season and biomass from survived seedlings increases the productivity of rainwater. Small harvesting capacity to water for long dry spell season and frequent maintenance were observed as short comings of the micro-basins. The following points are derived from the data listed and the observation during experimentation period as recommendations.

1. Trenches are a very important water harvesting technique for hillsides with relatively gentle slope, less stony and deep soils and for areas where the availability of stones is insufficient to construct eyebrows. Eyebrows are effective on steep slopes with shallow soils and on stone available areas for construction.
2. The water productivity of the afforested hillslopes could be increased more if high value multi-purpose fruit trees, forages and grasses would be used. This would not only increase rainwater productivity but also minimize hillside plowing for short-term benefits and create ownership feeling. This will fill the gaps of the existing hillside land distribution policy of the region.
3. The studied in situ structures have few complications for the farmers. Risk of malaria, sedimentation, cost recovery and the need for additional technology to use the stored water for irrigation is almost none.
4. Some rain events at the beginning of the main rainy season are beyond the capacity of the in situ water harvesting structures. The excess water needs to be removed safely through cut-off drains and waterways to the main drainage system. Big reservoirs are important at the downstream side to store this excess runoff after treating the hillsides with in situ water harvesting structures.

Acknowledgement

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Appendices

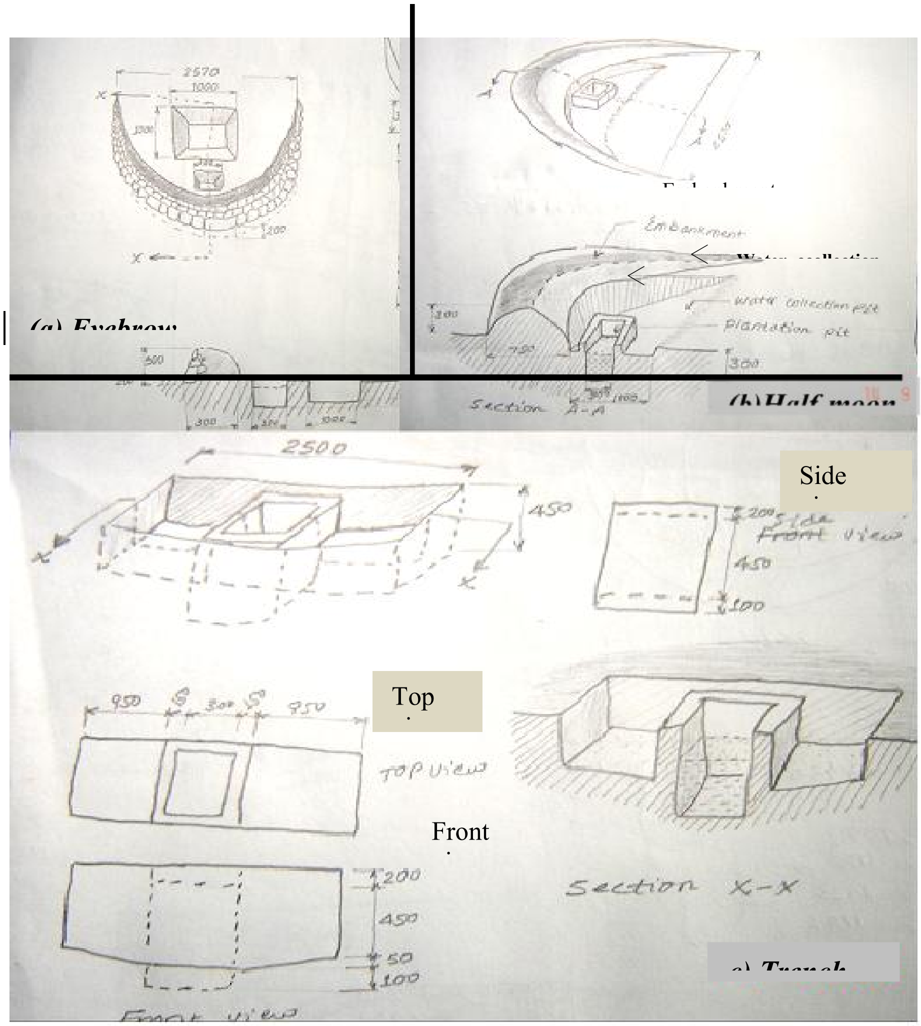

Figure 3 Dimensions of the water harvesting strictures (All numbers are in mm): (a) Eyebrow, (b) Half-moon and (c) Trench.

Table 4: Average growth variables (Combined analysis of root collar diameter (RCD), diameter at breast height (DBH), height) and survival rate for different treatments and seedling age

Age (months)	Treatment	RCD (cm)	DBH (cm)	Height (cm)	Survival rate (%)
3	Normal pit	0.52C	0	29.02B	36.67B
	Half-moon	0.60BC	0	38.31B	71.77A
	Eye brow	0.79A	0	65.37A	72.06A
	Trench	0.69AB	0	55.23AB	74.60A
	CV	**15.67**	**-**	**21.83**	**16.38**
6	Normal pit	0.63A	0	42.61C	29.67B
	Half-moon	0.83A	0.08AB	54.75BC	68.92A
	Eye brow	0.97A	0.19A	83.08A	70.76A
	Trench	1.00A	0.22A	73.17AB	70.13A
	CV	**30.37**	**89.11**	**25.91**	**16.58**
9	Normal pit	0.74B	0	52.00C	21.83B
	Half-moon	1.21A	0.46A	88.81B	63.30A
	Eye brow	1.52A	0.50A	130.21A	68.25A
	Trench	1.49A	0.54A	117.88AB	67.78A
	CV	**20.11**	**48.3**	**23.21**	**14.23**
12	Normal pit	1.04B	0.18B	77.71C	20.17B
	Half-moon	1.50A	0.45A	102.8BC	54.88A
	Eye brow	1.78A	0.64A	145.70A	65.75A
	Trench	1.78A	0.64A	130.57AB	63.85A
	CV	**16.03**	**31.07**	**16.05**	**18.11**
15	Normal pit	1.45B	0.46B	127.85B	18.33C
	Half-moon	2.26A	0.78A	173.19A	50.55B
	Eye brow	2.48A	0.91A	195.13A	63.65A
	Trench	2.40A	0.88A	193.25A	61.95AB
	CV	**13.46**	**26.13**	**16.56**	**15.77**
18	Normal pit	1.67B	0.55B	130.82B	18.33C
	Half-moon	2.65A	0.90AB	175.79AB	50.55B
	Eye brow	2.82A	1.04A	205.27A	63.65A
	Trench	2.79A	1.03A	204.60A	61.95AB
	CV	**18.91**	**25.39**	**16.2**	**15.77**
21	Normal pit	2.11B	0.92B	176.94C	18.33C
	Half-moon	3.15A	1.20AB	214.98B	50.55B
	Eye brow	3.38A	1.43A	251.08AB	63.65A
	Trench	3.55A	1.53A	261.63A	61.95AB
	CV	**19.06**	**22.28**	**10.37**	**15.77**
24	Normal pit	2.34B	1.04B	190.26B	18.33C
	Half-moon	3.44A	1.43AB	233.99AB	50.55B
	Eye brow	3.61A	1.59A	261.00A	63.65A
	Trench	3.87A	1.74A	267.66A	61.95AB
	CV	**18.63**	**20.22**	**12.43**	**15.77**

A, at α=0.05 and AB at α=0.1, CV is coefficient of variation.

Analytical documentation of successful traditional practices and farmers Innovations in agricultural water management in the Amhara Region[3]

Melisew Misker, Hanibal Lemma, and Abebech Abera

Abstract

Amhara region is one of the regions in the country with vast potential for irrigation development. In the region more than 86% of the irrigated land is served by traditional schemes. The traditional irrigation belong those schemes that are designed, developed and operated by farmers themselves. Generations of farmer have developed different water management technologies applying their indigenous knowledge of crop characteristics, soil condition, topography, climate, hydrology and social values that allowed them to live under harsh conditions.

The paper encompasses diverse farmer's innovation in traditional irrigation schemes. With the help of Woreda agricultural office experts and development agents' successful traditional schemes were selected and beneficiaries and water committees of the schemes were discussed using informal tools and semi-structured interviewing. The paper also discusses opportunities to promote farmers' innovations by linking innovative farmers with each other and with formal research and extension.

Key words: *Traditional irrigation, innovation, farmers practice, water management*

Introduction

Amhara region is one of the regions in the country with vast potential for irrigation development. The region is endowed with four river basins having a total potential area of more than 0.57 million ha, however, till recently, only less than 2% (73, 035 ha) has been developed both by modern and traditional irrigation. In the region more than 86% of the irrigated land is served by traditional schemes. The traditional irrigation belong those schemes, which are designed, developed and operated by farmers themselves.

Currently small-scale irrigation is highly favored by Government as a means of bringing about household food security, reduced dependence on food aid and economic growth. Hence, the traditional schemes both at communal and household level are now in a better position from the point of land coverage. The practice includes diverting small streams and springs, constructing ponds and shallow wells (Muluken, 2005). In addition, the over all land coverage of modern irrigation schemes indicated they were working below 50% of their planned capacity. Traditional irrigation schemes are started long years ago due to multifarious reasons and farmers have developed their own indigenous knowledge and

[3] Authors have equal right on the value of the paper

skills range from designing, operation, maintenance and equitable distribution of water resources to maximize benefits from both rain fed and irrigation farm activities.

Population pressure on a limited natural resource base appears to be an important incentive for innovating and investing in agricultural diversification, where farmers have their "backs against the wall" and few options left, experimentation and innovation find fertile ground. Farmer innovators frequently recount that they were driven by the need to feed their families. Farmers are keen to experiment with technologies that promise to create substantially increasing production and at the same time, maintaining or improving the environment. Higher yields are important not because they improve food security at household level, but also because more agricultural products can be sold to generate cash for other expenditures (Hassane et.al. 2000).

In the region as well as in the country traditional irrigation schemes take the lion share of irrigation practices. So it is important to document and understand their knowledge of irrigation water management and the practice they use successful practices and be used in improving efficiency of modern irrigation schemes, which are currently operating below 50% of efficiency (irrigation Inventory, 2005). Such research undertakings are more important in areas like in Amhara region where agricultural water management technologies are scare or entirely absent.

For centuries, farmers have developed technological innovations, to produce improved crops, livestock, tools and machinery and manage their resources in a sustainable manner. Yet in many countries, this kind of intuitive experimentation remained untapped, and farmers receive scant credit for their contributions.

Objectives

- To describe the traditional practices and farmer innovations in agricultural water management in detail, context of their development, benefits from such practices and their strengths and weaknesses
- To analyze the underlying principles of the innovations used by the farmers and factors that sustain these practices and their successful adoption so that those principles and factors could be used in improving the quality and relevance of formal research
- To assess potential to extrapolate such practices and innovations in similar agro-ecological environments and socio-economic conditions
- To assess potential to improve the performance of such practices through formal on-farm and/or on-station research

Methods of Data Collection and Analysis

The study was carried out in different parts of the Amhara Region: eastern, northern and western parts of the Region. In the eastern part of the Region (north and south Wello): Gurd shola and Sanka traditional irrigation schemes were selected for the case study. Gurde shola traditional irrigation scheme is found in Girana kebele of Harbu district located 15km from the high way of Woldia to Dessie with an altitude of 1473 masl longitude $11^0$33'44.6" N and Latitude $39^0$41'57.1" E while Sanka traditional irrigation scheme is situated in the main road from Woldia to Woreta at a distance of 35km from Woldia with a geographical location of 2100 masl altitude, $11^0$53'43.2" N longitude and $39^0$27'7.0" E latitude.

In the northern part of the Region (North Gonder): the two irrigation schemes used for this case study were Beles and Zarima Traditional Irrigation Schemes. The former scheme is found in Amba-chira *Kebele* of Gondar-zuriya district and the later in Zarima *Kebele* of Adi-arkay District. Both districts are found in North Gondar Administrative Zone of Amhara region, Ethiopia. Geographically, Beles irrigation scheme is located at 2529 m.a.s.l on 12^o23'52.5'' Northing and 37^o41'32.9'' Easting about 60 km SSW from Gondar town while Zarima Traditional Irrigation Scheme is situated at 1213 m.a.s.l on 13^o20'44.76" Northing and 37^o52'9.13" Easting and 140 km NN from Gondar town. Agro-ecologically, Zarima is *kola* and Beles is *dega* with mean annual rainfall 1170mm and 740mm, respectively.

The third study locations were selected from the western Amhara region ((Agewawi, east and west Gojam, and souoth Gonder); these include**:** Banja Shukudad (Ascuna Abo kebele), Ankesha (Shumata & Bekafta kebeles) Jahbi Tahnan (Mankusa Abdokoma kebele), Deby tilat Gin (Wodebe Yesus & Debre Yesus kebeles) and Fogera (Bebeks Kebele) woredas

Primary data were collected by surveying the schemes with interdisciplinary team using semi-structured questioner. Water users and leaders of the schemes were discussed using informal tools and semi structured interviewing. Development agents and district agricultural experts were also participating in the interview process. Transect walks and other rapid appraisal techniques have been employed to get an overview of the whole scheme. Group of farmers who are assumed to be front liners in brining new or innovative ideas and practices in designing, operation and maintenance of irrigation schemes including water fathers or Yewuha committees are interviewed. In addition, secondary data were collected from different sources about the scheme. More over, photos have been taken showing general overview of the schemes and particular innovations with in each scheme. Collected data have been analyzed using descriptive statistics.

Result and discussion

I. The case of Eastern Amhara (north and south Wello)

Gurdshola traditional irrigation scheme is literally started in 1971 by elder fathers of the present water users. In the beginning water is diverted from the other side of the river with a flume made traditionally from corrugated iron and wooden pillar 1km down from the current point of diversion. But farmers found up stream see their neighbors benefited from irrigation, and then they think over to use the river together with the downstream beneficiaries by searching a new point of diversion which covers the majority of the land.

As a result farmers found the current point of diversion 1km upstream from the earlier point of diversion, which helps the farmers to irrigate additional land. Since then experienced farmers choose the diversion point every year by looking the river trend and slope of the land. The headwork structure is constructed traditionally every year with mud and stone and it takes about three months to lead in to the farm. The canals are aligned unexpectedly in a very steep slope with minimum slope difference with out any external technical assistance and engineering equipment. They divert the water in 12m deep gorge. They dig the canal on hill sides in a trapezoidal shape to protect the canal from land slide. Secondary and tertiary canals are seen aligned depending on the topography of the land. Seepage losses are controlled by lining the canal with crop remains and mud. In the previous years gullies are crossed using corrugated iron and wooden flumes but now it is replaced by a permanent structure made from metal and this helped them to irrigate additional two hectares of land. Gullies and canals are stabilized by planting bamboos, grass and shrubs on the border of the canal and gullies. Water is distributed to the farm rotationally according to the order. Each team leader of the block distributed to each plot sequentially with specific time allocation, but farmers that grow crops that demand high water will be given a priority through negotiation. During water shortage farmers practice deficit irrigation and reduce land size. In addition, they use mulch and cultivation. Farmers claims that these practices conserve moisture, close soil pore spaces and reduce evaporation. In dry seasons, irrigation of the crop starts at the commencement of the command in order to reduce conveyance and other losses. However, in good season, when the flow of the river is high, it is given with agreement those who need more water.

Sugarcane, onion, mango, maize, avocado, tomato and papaya are the major crops grown in the scheme. Crops were selected mainly by their high-income return (sugar cane & onion), the time it takes to harvesting, farmers choose early maturing crops (onion), and resistant to crop pests. The interest of farmers to plant pepper drops due to disease problem. The cropping intensity is 200% and some times it exceeds from this by choosing early maturing crops. For example, during irrigation from January to April they plant onion then with supplementary irrigation they grow tomato from April to July finally they grow tef from August to October. Except tomato and onion, farmers usually plant local crop varieties. Synthetic fertilizers are not dominantly used in Gurdshola traditional irrigation scheme; rather they largely apply compost and farm yard manure. Farmers rotate crops considering their nutrient demand, for example, onion sown under irrigation is given high organic and inorganic fertilizer as a result farmers believes high soil nutrient is accumulated in the soil. Then during the wet season they saw crops that demand high nutrient. Hence farmers are utilizing the carry-over-effects of both irrigated and rainfed systems.

In Gurdshola traditional scheme the majority of crops are irrigated by flooding while onion and tomato are irrigated by furrow or with in the ridge and basin irrigation for fruit crops. Depending on the availability of water the irrigation interval varies from 10-30 days for sugar cane, 5-10 days for onion, 10-15 days for tomato, and 20-30 days for maize. The amount of irrigation to each crop is determined when the infiltration of water into the soil is ceased and water logging started to occur.

Table1. Irrigation frequency, method of irrigation of crops grown in Gurdshola traditional irrigation scheme

Crop	Irrigation frequency		Method of irrigation
	Good flow	Scarce	
Sugar cane	10-15 days	30 days	Flooding
Onion	5-7 days	10 days	Furrow/between the ridge
Tomato	10 days	15 days	Furrow/between the ridge
Maize	20 days	30 days	Flooding

Farmers themselves determine the frequency of irrigation by looking the soil moisture and physiology of the crop based on their century old experience. Water is mainly allocated on the type of crop planted i.e., crops that demand more water will be given frequently. A number of wooden culverts are constructed at footpaths and animal crossings to protect canal damage.

There are water management committees (*Yewuha* committees) comprising of three members elected by the beneficiaries to manage the overall irrigation system. Under Yewuha committees there are 'Yewuha abats' (father of the water management) in each block principally working on managing of secondary and tertiary canals. There is no defined time for reelection of the committees but it is according to his/her managerial efficiency. They have unwritten traditional bylaws fully respected by all the beneficiaries. Some of the bylaws are:

- A person who is absent during water abstraction and canal clearing will penalized by giving a labour work service to the members;
- A person who divert water illegally will penalized 50 birr;
- Conflicts among water users will be resolved by the decision of Yewuha committees.

However, all the beneficiaries are respecting the bylaws and accept the decision of Yewuha committees and also they compromise with their local justice. As a result, no person is getting the highest penalties yet.

The main market place for Gurdshola traditional irrigation is Girana, which is in the midst of the scheme. Most of the farmers in the scheme have sugar cane plantation. Therefore, to get better price farmers remain harvesting until the price of sugarcane escalates. To get better price, one farmer is planting onion early in the irrigation season alone, and what he believes is that it will help to escape from mass production of all the farmers at the same time, which results low market price of the product. But farmers are getting problem due to the brokers. The brokers fix their sugar cane product on the farm at low price and went to the merchant and deal with another high price and get higher amount of money without any contribution on the farm. So, farmer's service cooperatives are essential to assist for maintaining better market opportunities and to timely harnessing other input delivery and credit services.

The other case study is Sanka kebele traditional irrigation schemes where tremendous traditional irrigational activities are undertaken ranging from water abstraction to wonderful land husbandry system. In the kebele there is one big river called Gimbora and other small streams and springs which covers a total irrigable land of 142.71ha and 691 beneficiary households. Farmers of this area utilize these water sources more proficiently by diverting on very steep slopes crossing big gullies, high ways and undulating topographies starting long years ago. *Bariyaayemotem* is one of the streams in Sanka which farmers' of Geshober and Debot kebeles used for traditional irrigation. Water abstraction is done with simple stone bund and straw. Farmers put big stones before summer season starts at the point of diversion to protect the area from high flood erosion, as a result it would be easy for next irrigation season water abstraction. Farmer's of Geshober kebele and Debot divide the water at the point of diversion equally by floating method. i.e. at the upper area from the point of diversion they drop a leaf and allow it to float down to the two kebeles dividing point, then when the leaf move to one side of the canal, they realized that the canal carries high volume of water, then reconstruct the diversion point until the leaf remains the head point of the two diversions which they thought equal amount of water is flowing in the two diversions. The canal is aligned in a very steep slope ranging up to 80% with minimum slope difference and without any external technical assistance. Secondary and tertiary canals are aligned based on the topography of the land by minimizing the flow of water to reduce erosion. To stabilize the canal they grow eucalyptus trees and fruit trees like coffee, and banana. More over, at hillsides they support with stone bund. They cross gullies using a flume made from stone and mud. One famous work of the farmers is that, due to the construction of the road from Woldia to Woreta their traditional canal crossing the road was destroyed, at this time the farmers realigned their canal in another way to pass through the old road culvert used for flood drainage with out any reduced irrigated land. Seepage loss is minimized using clay and grass and if the loss is very high they used to redesign the canal in another place. Repeatedly looking the size of the land and the time it takes to irrigate it, they decide the amount of water to irrigate a given land.

The major crops grown are sugar cane, maize, shallot, potato, tef and coffee. Farmers usually rotate maize with tef, tef with fababean, potato with tef and tef with wheat. They are growing crops two times a year. The majority of the farmers in most of the crops used local varieties. However, improved varieties of wheat, maize and tef were used in the previous years. But currently, due to lack of an organization which delivers inputs, they are forced to use their local varieties. For maize, tef, wheat and potato they use inorganic fertilizer, however compost and farm yard manure were prominently used for all crops.

Table 2. Irrigation frequency, method of irrigation and of crops grown in Bariya ayemotem traditional irrigation scheme

Crop	Frequency of irrigation	Method of irrigation
Maize	15-21 days	Flooding
Potato	10-12 days	Furrow/flooding
Sugar cane	10-20 days	Flooding
Shallot	5-8 days	Furrow/flooding
tef	15-20 days	flooding

Water is distributed to each farm rotationally with specified time. During water shortage they cover with leaves after irrigation to reduce evaporation loss and cultivate it to increase percolation. For easiness of work and to use the time allocated for irrigation effectively the majority of the farmers practice flood irrigation. However, vegetable crops like onion and potato are irrigated by furrow, but this also becomes flood irrigation after two or three irrigation due to sandy nature of the soil and the furrow will be mixed up. The depth of application is determined until the soil is saturated.

The scheme is mainly administered by 'yewuha abates' or water fathers who are elected by the beneficiaries. They have traditional bylaws worked for as the age of the scheme. The bylaws are more or less similar to Gurdshola traditional scheme like a person who divert water illegally will pay the estimated price of the crop failed due to lack of water during his illegal diversion; and a person who is absent during development work will be penalized his water schedule. However, with their social interaction and living together for so many years, they compromise each other and resolve with their local justice.

The market place for the produce is Sanka and Woldia towns. Farmers are staring to legalize water users associations which they believe that it creates an opportunity for better marketing of their product and service deliveries.

II. The case of norfthern Amhara (North Gonder)

1. Zarima irrigation scheme

Traditional irrigation practice in Zarima is started during the *Derg* regime (1986) and widely practiced since 1994 when the government provides water pump to deliver water from Zarima River to the schemes so as to secure food production to the local community. Due to improper operation and lack of maintenance, the generator is failed to work a year later. Since then, the farmers traditionally divert water from the river to their fields.

In terms of water source and coverage, the only water source in Zarima traditional irrigation scheme is Zarima River. Zarima River is a perennial river flowing year round. From the 50 total irrigators, 18.5% used pump to deliver water from the river and 81.5 % use gravitational flow in canal. Water from the river is diverted to a big primary canal and directed to secondary and tertiary canals during the dry season through temporarily constructed diversions to irrigate 42ha of land while during wet seasons it flows its natural way. To satisfy the needs of irrigating additional land, Organization for Rehabilitation and Development in Amhara (ORDA) has been upgrading the canals by cement and concrete.

The temporary diversion structure is just like a canal which has wider inlet and receiving water from some part of the river as shown in the Figure 1 below. The canals are constructed by stone, lined with plastic sheet, and supported by sand/soil sacks. The diversion structure is laid down inside the river bed/side and goes down up to 2km.

Primary and secondary canals are constructed by stones and lined with plastic sheet, and has 1.20-2m wide and 20-30cm depth. Its shape is Trapezoidal. Making most canals wider and shallow in depth for sufficient water flow is unavoidable means to overcome the difficulty of excavating the stony and outcropped rocky area of the river bed.
Why plastic sheet? Farmers are using plastic sheet as lining material because of

- Most soil in the area is sandy for lining purpose
- It is relatively lower expense than constructing by cement and concrete
- Its easiness to construct, replace, maintenance, etc

Figure 5. Diversion structure and primary canal at Zarima

Usually farmers in Zarima used furrow irrigation for tomato, maize, pepper and cabbage; controlled flooding for shallot and banana; and pit for perennial crops like papaya, coffee, guava, and avocado. Farmers have skill about the relationships between soil texture and furrow width. Width of furrows depends up on the soil texture, that is sandy the texture the wider and deeper the furrow is and vice versa to deliver sufficient stream size to the downstream. Field observation shows that

- Wider (40-75cm width) furrow for sandy soil to get sufficient stream size
- Narrow (≤40cm width) furrow soil for clay soil
- Pit for tree

In rugged topography, sending water across gullies and river is costly and sometimes not possible at all. According to farmers, gully and river crossing structures are different depending on the depth and width of the gully/river bank i.e. the depth and width of gully/river governs the type of crossing structure and the material used for construction. Field observations are summarized in the Table 3 below.

Table 3. Summary of gully crossing structures

Depth	**Width**	**Material used**	**Action taken**
≤1m	≤12	Soil, Stone , plastic sheet	• Restructuring or reshaping by earth moving • Filling the gully by stone and lining by plastic sheet
1-2m	≤5m	Stone, plastic sheet	• Construction stone to bridge the gap and lining by plastic sheet
≥2m	≥ 4m	Wooden pole, metal pole, plastic sheet	• Suspending wooden/metal poles on the embankment and lined by plastic sheet

Figure 2. Different types of gully/river/ hilly area crossing structures

Not only gully/river crossing is problems for the area but also hilly and rock-out-crop areas are hindering water flow (Figure 2). In this case, deep digging is the means to maintain the

water flow gradient. Since most canals are constructed by stone alone, collapse of canal structures and canal seepage are common problems of the area.
To mitigate such problems:

Canals are stabilized by
- Where the area is stony, the canals are supported with sacks containing sand/soil
- Where soil is available, compacting the stony canals by soil-crop residue mixture
- Keeping ungrazed the plants on the canals

Seepage minimizing by
- Lining the canals by plastic sheet
- Compacting the stony canals by mixture of soil-crop residue

Crops and cropping pattern

Tomato, pepper and onion are produced mainly for market purpose but also for household consumption. Pepper, tomato, maize and onion are also grown as pure stand or intercropped with each other. Banana, mango, guava and avocado are planted on farm borders for land demarcation as well as for market purpose. Most farmers in Zarima prefer to produce pepper because of its profit margin.

Table 4 shows the types of crops grown in irrigation, yield and irrigation frequency practiced in Zarima area. The frequently practiced crop rotation system is that pepper and tomato is planted at the end of rainy season (when the depth of Zarima River is lowered) in October. After its harvest in January/February; maize, onion or potato as pure stand or intercropped is followed at the end of February. Potato and onion is harvested in June/July while maize stayed until the end of August. Tomato and pepper are followed after land preparation in October. Maize and potato as pure stand or intercropped is irrigated at the beginning of until the rain begins in June/July. So farmers are utilizing the synergetic effects of both irrigated and rainfed systems.

Table 4. Irrigation frequency and estimated average yield of crops grown in Zarima Traditional Irrigation Scheme

Types of crops	Yield (t/ha)	Irrigation frequency
Tomato	6.7	3-5 days
Pepper	1.7	3-5 days
Cabbage	31.3	3-5 days
Potato	13.3	4-7 days
Onion	15	3-5 days
Potato intercropped with maize		
Potato	13.3	3-5 days
Maize	1.2	3-5 days

Access to input and market

By its nature irrigation agriculture requires skill, intensive labor and capital investment. Irrigation is related with the access for irrigable water and demands higher marginal amount of labor as compared to rain fed agriculture.

Many farmers need to borrow to purchase farm implements (especially water pump) and micro financial institutions like Amhara Credit and Saving Institute (ACSI) are there to deliver the service. The institution gives credit service to the farming community with group guarantee method. 60% of the farmers included in the interview replied that they are users of credit from ACSI and all of them are using the credit for the whole production activities not for a specific enterprise.

Farmers in the study area are not using inorganic fertilizers and improved seeds in their irrigated farms rather they apply farm yard manures and pant their own local varieties. Even if farmers have shown interest to use improved seeds, there is no seed and inorganic fertilizer supply during the irrigation season.

Farmers accessed seeds/seedling from

- Farmers to farmers seed exchange mechanisms
- Raising the seedling in their garden (especially pepper, onion and tomato) and
- From extension agents (perennial crops like avocado, mango etc.)

In the farming community, irrigable land is more valuable as compared with rain fed farm. About 60% of the household in Zarima cultivate their irrigable land where as 40% of irrigators rented the land from farmers that are involved in non-farm income generating activities, aged, disabled or female headed households. Female headed households rent out their land to other because they cannot afford labor to irrigate especially in night. Male headed households who involve in non-farm income generating activities also rent out the land. The productivity of the farm is deteriorating due to lack of farm input supply and decline in soil fertility. In addition, lack of efficient market sink lower the potential production.

Like any other agricultural output market, the vegetable market in Ethiopia failed to benefit small scale producers by receiving the minimum share from sales and there has been seen long chain in the marketing system of horticultural products. Potential market places are Debark, Gondar and Shire towns which are 40, 140 and 140km far from the scheme respectively. Since tomato and shallot are perishable and farmers have not any storage facilities, selling prices during harvesting time are low. Limited access of vehicles also aggravates the problem. The average farm gate price per kilogram for onion is 1.75 Birr and for tomato is 0.50Birr. However, the retail price per kilogram for these commodities is Birr 4.50 and 2.00 in Gondar respectively. This shows that whole sellers and retailers take the largest margin of the sales price. Therefore, farmers are establishing cooperative to buy their own vehicle to looking for better market opportunities.

Their living condition is much better than those practicing only rain fed agriculture. Farmers have expressed that sending of children to school, having of houses with corrugated iron roof and some savings would have been unthinkable without the existence of the scheme.

Water allocation and controlling systems

Everyone who possesses irrigable land has got equal access to water regardless of the size of the farm and the type of commodity the farmer cultivates. Water is allocated in rotation and all farmers use their turn until they satisfy the farm water demand. The water in the whole irrigation scheme is administered by one "Yewuha komitie" (water committee). The water committee has five members that are elected by water users democratically every year. If water users agree, they can be elected again and again. Members of the committee are serving the community with out any kind of incentives. The farmers in Zarima traditional irrigation scheme has unwritten and traditional bylaws, which are respected by all water users.

Among the bylaws the following are the main ones:

- Users who are absent during diversion construction will pay 500 Birr, the money is used for daily laborer wage
- Watering on others' turn may penalize 10 Birr for the first time and then 50 Birr for the second mistake. If it happened for the third time, the man will be in prison for a month.
- Conflicts among water users will be resolved by the decision of the *water committee*.

Therefore, everybody is respecting the decision of *water committee* and informants even do not remember any water user who has been experienced such highest level of penalty. *Water committee* controls especially the water sharing of users from the main canal. Those farmers having land to be irrigated from a given secondary canal are organized in a group so that partitioning of water among them is again controlled by the group leader. Any maintenance and controlling at secondary canal in a given day is carried out by the individuals that irrigates on that specific day. Any problem raised in a given group which is beyond the capacity of its leader, will be resolved by the decision *water committee* and then by Kebele officials.

Keeping the farm from animals grazing, rodents and thieves are the main challenge. In Zarima, farmers have constructed a guarding house and staying there throughout the night. In addition, dogs are serving as farm guard.

Gender in irrigation scheme

Farmers irrigate their farm in days and nights according to their shift. Female headed households are obliged to rent out their irrigable land since they didn't afford labor in nights. However, females equally contribute in other farm activities like planting, weeding, transplanting and harvesting. Women are also responsible to sell the farm produce.

Farmers' innovation in Zarima traditional scheme

Canal shape

The farmers make the canal trapezoidal shape (1.2-2m wide) while canal depth is 20-30cm. Farmers develop the experience of making the canal wider for sufficient water flow rather than excavating and out cropped rock. Moreover, farmers are keeping un-grazed the plant around the edge of the canal embankment so as to protect the flowing water in the wider canals from sunlight so as to minimize evaporation as well as for canal stabilizing.

Crop selection

In 2007/08, market oriented crops like tomato, pepper, mango, avocado, banana and papaya cover 75% of irrigated area because of its higher market price and the remaining is composed of potato, shallot, and maize for household consumption.

Table 5. Trends of crop selection from 1993 to 2008/09

Year	1993-1998	1999-2003	2004-2007/08
Produced crops	Chick pea	Cabbage, shallot, perennial crops	Pepper, tomato, potato, maize, perennial crops
Purpose	Local consumption	Local consumption as well as for market purpose	Focused for market purpose

Table 5 shows that the farmers produce for local/household consumption at the earlier stage of the scheme and now it is focused on market oriented crops like pepper and tomato.

Crossing the structure

In rugged topography, sending water across gullies and river is costly and sometimes not possible at all. Farmers in the study are used locally available materials such as wooden poles, metal poles and plastic sheets to construct crossing flumes across big gullies and rivers.

2. The Beles traditional irrigation schemes

The second case study is Bales traditional irrigation scheme. Traditional irrigation in Beles started during the Italian invasion to cultivate *Rhamnus (Gesho)* for processing and making *Tela* (local beer). Then after, farmers in the area produce cereals like barley, wheat, Fenugreek, Coffee, and now Garlic contributes 60% of the irrigable area and fenugreek, shallot and potato, barley, cover the remaining portion.

In terms of Water sources and coverage, the sources of water in Beles traditional irrigation scheme is ground water as well as Beles River. The ground water discharged from bed and side of Beles River covers 65% and the remaining 35% from Beles River. All of 252 irrigators (11.1% female headed households, 88.5% male headed households and 0.4% local institution) use gravitational flow as means of delivering the water in canal. Ground water and Water from the river is diverted to a big primary canal and directed to secondary and tertiary canals during the dry season through temporarily constructed diversions to irrigate 61.4ha of land while during wet seasons it flows its natural way. To satisfy the need of irrigating additional land, farmers have diverted the water by constructing five temporary earth and stone diversion dams.

Figure 3. Diversion structure in Beles Traditional irrigation scheme

Diversion structure and shape

The dominant source of water is from the near ground water discharged from the sides and beds of Beles River (Figure 3). Making embankments across the river bank is the means of harvesting (collecting) the ground water. The embankment is constructed from stone and *lata* (part the soil that grass roots are more concentrated). To prevent water flow through the pores of stone mound, *lata* is highly compacted using wooden mortar. The primary canal is laid on extreme of the embankment.

Canal structure and shape

Both primary and secondary canal constructed by excavating/digging the earth in rectangular shape. The width of the primary canal is wider (2m) at the inlet and narrower (about 40cm) at secondary canal, and the depth of the canal is 40-75cm. Making the canal deep and narrow minimize surface area of water exposed to seepage and that in turn minimize loss of water through deep percolation as farmers explained. Farmers also compact the side and beds of the canal with *lata* to reduce seepage loss. Moreover, leaving un-grazed the grass/plant on the canal embankment is means of reducing evaporation from the water surface in the canal.

Methods of irrigation, Furrow types and spacing

Farmers in Beles traditional irrigation scheme are used furrow irrigation for garlic, onion and maize where as controlled flooding for potato, fenugreek and barley; and using bucket for seedling preparation (Figure 4).

Spacing of furrows is depending up on the crop type. For instance

- Broad bed (60-100cm) and furrow (20-40cm) for garlic and shallot
- 30-40cm spacing furrow for maize.

Since the normal plant spacing is narrow for shallot and garlic, farmers used broad bed and furrow to minimize the area lost by furrow.

Crossing structure

Depending on the gully/river width and depth, Farmers around Beles traditional irrigation scheme are used wooden flume when it is wide and deep, restructuring the gully using stone and earth to restore the ground surface when the gully/river is narrow and shallow, or reshape the hilly areas by digging deep to send water across the gullies, rivers or hilly area (Table 6). The flume indicated at Figure 5 is put off during the wet season to protect from carrying away by flood.

Figure 4. Methods of irrigation at Beles traditional irrigation scheme

Table 6. Summary of gully/river crossing structure based on their depth and width

Depth	width	Material used	Action taken
≤2m	≤5m	Stone and *lata*	Refill the soil by lata by constructing the stone and compacted by lata as cement
>2m	>5m	Wooden pole (Eucalyptus)	Making wood flume and suspended on the bank of gully/river

Figure 5. Wooden flumes

Canal stabilizing and minimizing seepage

Canal stabilizing materials

- Keeping the growing grass on canal embankment.
- Compacting with lata (the grass root provides compacted soil).

Minimizing seepage

- Compacting the canal seepage area with *lata*
- Using wooden flume.

Crops and cropping pattern

Base on crop coverage, 63.6 % of irrigated land is covered by garlic because of its storage ability and profit margin, and the remaining is composed of fenugreek, potato, shallot and maize in 2008 (Table 7). Garlic and fenugreek are produced mainly for market purpose. But potato, barley and shallot are produced for consumption as well as for market purpose. The crop rotation system in Beles traditional irrigation scheme is that garlic, barley and fenugreek are planted in September/October. After their harvest in March; maize, potato and barley as pure stand is followed in April. Potato is harvested in July while maize stayed until the end of August. After land preparation either garlic, barely and fenugreek is followed in September/October. It is interesting to mention here that garlic or barely sown at the end of September make use of the soil moisture or late rain showers to germinate and grow. Depending on the duration of the rainfall, irrigation of crops is followed beginning in November /December. On the contrary, maize and potato as pure stand is irrigated at the beginning until the rain begins in May. So farmers are utilizing the synergetic effects of both irrigated and rain fed systems.

The irrigation interval is different for different crops as shown in the table above. It is depending on the soil texture and type of crop grown. Farmers irrigate in 7-14 days interval for fenugreek, maize and barley, and 4-14 days interval for garlic and shallot. More frequent for sandy soil and less frequent for vertic soil.

Table 7. Estimated average yield and irrigation frequency in Beles Traditional Irrigation Scheme

Types of crops	Yield (t/ha)	Irrigation frequency
Garlic	3.2	4-14 days
Fenugreek	0.45	7-14 days
Barley	1.2	7-21 days
Potato	4.1	5-14 days
Shallot	3.6	4-14 days
Maize	1.2	7-21 days

Access to input and market

Credit opportunity doesn't exist for the communities in the scheme which might have hindered farmers from using inputs. Like in Zarima, Farmers in the Beles traditional irrigation scheme area are not using inorganic fertilizers and improved seeds in their irrigated farms rather they apply farm yard manures and plant their own local varieties. Even if farmers have shown interest to use improved seeds, there is no seed and inorganic fertilizer supply during the irrigation season. Farmers accessed seeds/seedling mostly by raising the vegetable seedling in their garden and from local market.

The proportions of farmers in Beles that irrigate their own land are 86% where as 14% of them rent the land from aged, disabled farmers or female headed households. Female headed households rent out their land to other because they cannot afford labor to irrigate.

Everyone who possesses land has got access to water depending on size of the farm and the type of commodity the farmer cultivates. Farmer that grows garlic and shallot has got maximum time to irrigate where as minimum time for potato. Because farmers believed that water requirement of potato is lower than that of garlic or shallot. All of farmers understand that the water is limiting due to the increase in the number of beneficiaries. The productivity of the farm is deteriorating due to lack of efficient water and decline in soil fertility.

The potential market places are Maksegnit and Gondar towns which are 20 and 60 km far from the scheme respectively. The average farm gate price per kilogram for garlic is 6 Birr, for fenugreek is 6 Birr, for shallot is 0.75 Birr and for potato is 1.50 Birr. However, the retail price per kilogram for these commodities is Birr 12, 15, 4.50 and 4.0 in Gondar respectively. This tells us that whole sellers and retailers take the largest margin of the sales price. Transportation and lack of cooperatives are the main problem here. Here in Beles, Their living condition of farmers is also much better than those practicing only rain fed agriculture. Farmers have expressed that sending of children to school; additional employment and having of houses with corrugated iron roof are the main benefits of irrigation agriculture.

Water allocation and controlling systems
Water is allocated in rotation and all farmers use their turn until they satisfy the farm water demand. The water in the whole irrigation scheme is administered by one "Yewuha komitie" (water committee). The water committee has 25 members (group of five for each diversion) that are elected by water users democratically every year. If water users agree, they can be elected again and again. Members of the committee are serving the community without any kind of incentives. The farmers in Beles traditional irrigation scheme has written traditional bylaws, which are produced and respected by all water users.

Among the bylaws the following are the main ones:
- Users who are distract any structure will pay 50 Birr and will stay in prison for a month
- Watering on others' turn may penalize 50 Birr
- Any farmer keep watering on his turn only
- Any user who will not respect the decision of water committee will pay 40 birr and will stay in prison for a week

Conflicts among water users will be resolved by the decision of the *water committee*.
Water committee controls especially the water sharing of users from the main canal. Those farmers having land to be irrigated from a given diversion are organized in a group so that partitioning of water among them is again controlled by the group leader. Any maintenance and controlling activity at secondary canal in a given day is carried out by the individual that irrigates on that specific day. Any problem raised in a given group which is beyond the capacity of its leader, will be resolved by the decision *water committee* and then Kebele officials. To protect the farm and their product farm from animals grazing and rodents, each farmer has fenced the farm plot with shrubs and human like doll has also put to protect the farm from animal grazing. Dogs are serving as farm guard as well.

Gender in irrigation scheme
Female headed households are obliged to rent out their irrigable land since they didn't afford labor to irrigate at nights. However, females equally contribute in other farm activities like weeding, transplanting and harvesting. Women are responsible to sell the farm produce especially when the amount of sale is small in amount.

Farmers' innovation in AWM in Beles Irrigation scheme

1. Social institutions
Farmers in Beles establish functional water users association (water committee) with written bylaw stating the role and responsibility of each member and the penalty paid for abuse. According to the respondents, these social institutions have been seen efficient in resolving disputes. All of the respondents support the presence of written bylaws. 45% of them replied that it is the responsibility of the committee which to look after defaulters and to accuse them.

2. Canal shape

The farmers make the canal rectangular where the canal deeper and narrow in width (Figure 6). The main reason is to minimize the surface area of seepage of flowing water. Moreover, farmers keep the grass on the canal embankment to protect the canal water from direct sunlight to minimize evaporation loss.

Figure 6. Canal shape

3. Determining when to irrigation and water management in extreme cases

In addition to their turn, farmers in Beles traditional irrigation scheme have experience of determining when to irrigate the crops. Such as

- By judging root zone soil moisture content by feel and appearance method. According to the informants, the soil is moist when on squeezing wet outlines is left on hands and the soil is water stressed when it appears to dry.
- When the soil surface shows cracking
- When the plant starts to wilt

In addition farmers have experience of Managing of excess or deficit water conditions such as in water logged situation

- Spreading wood ash
- Extending the irrigation interval and Draining excess water

Water stress situation

- Mulching
- Planting crops that have lower water requirement (Example: planting potato than garlic or shallot)

4. Mulching

Mulching is one of the simplest and most beneficial practices one can use in the garden. Mulch is simply a protective layer of a material that is spread on top of the soil (Figure 7). Using crop residue as mulching is widely practiced for the following purpose in order of the farmers' preference

1. to improve the water holding capacity of the soil since mulching improves porosity by reducing soil compaction
2. conserves moisture, reducing the need for frequent watering
3. reduce water runoff and soil erosion
4. reduce evaporation
5. For its residual effect as organic fertilizer

Figure 7.6 The use of mulching in conserving soil moisture

5. Spreading HH wood ash

Farmers in Beles spread wood-ash on their farm land so as to drain the excess water on the field. Farmers have the experience of spreading wood ash primarily to improve water logging situation especially on potato field (Figure 8). Their principle is that wood ash is the capacity to absorb excess water.

Figure 8. Spreading wood-ash on excess water condition

6. Crossing the structure

In rugged topography, sending water across gullies and river is costly and sometimes not possible at all. Farmers in the study are used locally available materials such as wooden flumes, are the main structure to cross water on wider (>5m) gullies and rivers (Figure 9).

Figure 9. Wooden flume

7. Crop selection

In 2000, garlic covers 63.6% of cropped area because of its higher market price and the remaining is composed of fenugreek, potato, shallot and barley respectively. The trend of crop production since 1938 is summarized in Table 8.

Table 8. Trends of crop selection in Beles Traditional Irrigation Scheme

Year	1938	1965-1975	1975-1994	1995-2007/08
Produced crops	Rhamnus	seedlings	Barley, Wheat, Potato	Garlic, Fenugreek, Potato
Purpose	Local consumption	Local consumption	Local consumption as well as for market purpose	Focused for market purpose due to their marginal profit and storage ability

Table 8 shows that the farmers produce for local/household consumption at the earlier stage of the scheme and now it is focused on market oriented crops like garlic and Fenugreek.

8. Minimizing seepage and canal stabilizing

Farmers use *Lata* to prevent seepage loss through the diversion structure as well as through canals. *Lata* also used for stabilizing the diversion and canals. Farmers also keep grasses ungrazed on canals' embankment to stabilize the canal.

III The case of western Amhara (Gojam and Awi Zones)

All irrigation schemes visited in this survey were traditional and even some have about centuries of experience.

Important Innovations and Traditional Practices

Farmers, through experience, know very well about where and how to divert the water (Figure 10). They also know how to convey & distribute water to the farm. The following pictures are some of the examples of innovative practices observed in the field.

Figure 10. How farmers traditionally divert river water

Figure 11. Use of 'GENDA'

Very important innovation is the use of "GENDA" (which is a traditional wooden or iron sheet gutter like conveyance system to pass obstacles like gullies, roads, etc…) (Figure 11).

Strengths of some of the traditional practices

Farmers use rectangular canals that can minimize evaporation due to minimum surface area. The canals covered with grass reduce evaporation but vegetation might cause competition for water (Figure 12).

Figure 12. Stable and semi covered canal

Another important practice is to convey water in a difficult topography. They follow exactly the contour without using any instrument.

In water administration & equitable use, almost all farmers know the idea of resource allocation. From the survey result farmers use the following criteria in water allocation.

1. Land size based
2. Crop type based
3. Time base

According to the farmers the last method is the best for equitable allocation of irrigation water.

- Farmers use cash crops like onion (shallot), vegetables, coffee, pepper, mango, sugarcane, etc, than cereals to maximize profit.

Shortcomings of some practices

The problem in the use of 'GENDA'

There is leakage problem due to technical limitation and the quality of the material used for construction (Figure).

Figure 13. Leakage loss due the poor use of 'GENDA'

Figure 14. Unstable ditches

The problem in shape and depth of channels
Rectangular ditches are susceptible to side sliding because of straight edges of the wall (Figure 14).

Labor demand for frequent maintenance of structures
Annual maintenance of structures is a serious problem farmers faced in these areas for maintaining collapsing ditches (Figure 14).

Having all these, farmers have the following questions and problems.

- In all schemes farmers need help from government (any other concerned body) to construct permanent weir (structure). This will help them to reduce their labour cost that would otherwise be wasted for frequent maintenance of structures, promote early sowing (so as to increase cropping intensity) and stabilize the market price of farm products.
- Water shortage during peak time. This could be due to similar sowing & harvesting date

- Since most farmers grow same crop at the same time, price fall is a common problem.

However, our observation in the field, the problems can be summarized into the following three points:

- The Most serious problem, but that farmers did not worry about, is water wastage at conveyance and distribution system.
- Most farmers use irregular shaped and rectangular channels. This will have its own problem on sustainability of the channel bank. Both types of ditches have no fixed depth. This leads to unequal water allocation among the beneficiaries.
- Most farmers do not have practices on water harvesting technologies. They simply depend on River diversion. There are only few farmers who use this technology.

Conclusion and Recommendation

These case studies have shown that farmers have plenty of indigenous knowledge in developing irrigation schemes and water management abilities. The study presented here tries to see farmer's indigenous knowledge of water abstraction, conveyance and distribution; crops and cropping systems; water use (methods and frequency of application), management of the scheme and marketing of products.

It was found that farmers in the studied traditional irrigation schemes were highly innovative in searching the diversion point in which it is difficult to determine the exact point where the river is flowing in deep gorges and undulating topography. Canals were constructed in a very steep slope which seems unthinkable without any engineering knowledge and equipment. Farmers cross gullies using a flume made of corrugated iron, wood and stone bund & mud. A number of wooden culverts were made at footpaths and animal crossings. Gullies and canals were stabilized by planting trees, shrubs and grass.
The method of irrigation, frequency and depth of application for irrigated crops is developed and practiced by farmers accordingly. It is also interesting to note that the scheme management of the farmers is another good example of farmers' innovation. The schemes are administered by water or *yewuha* committee which is elected by water users. They have bylaws set by all the beneficiaries, resolve conflict according to the bylaw and distribute water evenly to each farmer. As a result the schemes were managed without any big conflict for centuries. Despite all these, traditional irrigation schemes were encountered problems i.e. in all the schemes diversions and other structures were constructed by local temporary materials, consequently farmers are forced to construct each irrigation season which takes their time, labor and money every year; no input and credit service; poor extension service and scant irrigation technologies complementing them. Therefore, replacing temporary structures with permanent structure has a paramount importance in using traditional irrigation schemes more effectively.

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II) Soil fertility

Response of Maize, Malt Barley and Tomato to Potassium

Tadele Amare, Tesfaye Feyisa and Yihenew G.Selasie

ABSTRACT

This paper presents about the status of soil potassium and the response of tomato, maize, and malt barley for the applied potassium. Three potassium rates (0 kg K_2O/ha, 50 kg K_2O/ha and 100 kg K_2O/ha) were compared for all testing crops for all locations with uniform recommended nitrogen and phosphorus. Under all locations and testing crops there was a good response for the applied potassium though insignificant statistically. The minimum cumulative tomato yield (26913 and 20773 kg/ha for first and second year respectively) was recorded from control (0 K_2O/ha) while the maximum (29333 and 23580 kg/ha for first and second year respectively) was recorded from maximum potassium rate (100 kg K_2O/ha). Minimum (4687 kg/ha) and maximum (4905 kg/ha) maize yield at Dangla (second year) were obtained from control and 100 kg K_2O/ha treatments respectively. At Mota the minimum (2950.8 kg/ha) and maximum (3929.4 kg/ha) yield of maize in the first year were recorded from control and 100 kg K_2O/ha respectively. At Lay Gaint the highest malt barley yield (3127.3 kg/ha) was obtained from the highest level of potassium while the lowest (2742.7 kg/ha) from control for first year and similar trend of response was observed for the second year too. As yield increased to addition of potassium fertilizer brought insignificant result over control, application of potassium fertilizer is not, worthy but needs regular follow-ups.

INTRODUCTION

The productivity of the land is the function of ray of factors which can be grouped in to two main categories: uncontrollable (sun shine, rainfall etc) and controllable soil fertility etc). Ethiopian agriculture depends on the rainfall conditions and the fertility status of the soil. A slight variation in amount and distribution of rainfall has a very high and significant influence on the agricultural sector. Effective utilization of the rain water resource with various soil fertility management options is one of the strategies to enhance the productivity of the land resources (soil). The rate of chemical fertilizers added per unit area is very small to build the fertility of soil and boost production sustainable, because of various reasons including economy. There is a negative input-output balances of nutrients under Ethiopian farming resulted from low chemical fertilizer use, lose of nutrients by erosion, leaching, gaseous lose and mining (Smaling, 1993) and Smaling et al, (1993) leading to a non sustainable and subsistence agriculture.

Detailed studies for the potential supplies of nitrogen and phosphorus across different soils and different agro-ecology was assessed. Crops' response ranged from medium (pulse crops) to very high (cereal crops) for nitrogen and phosphorus and blanket fertilizer recommendation exists. Awareness about the relevance of nitrogen and phosphorus nutrients is very high everywhere across the country and demand is steadily increased every year. However information is scarce about other plant nutrients including potassium in the country.

Potassium is the 3rd major nutrient next to nitrogen and phosphorus needed by plants to accomplish biological process. It is important for the synthesis and translocation of carbohydrates, encouraging cell wall thickness and stalks strength, influence uptake of other nutrients, respiration, transpiration etc. Fertilizer containing potassium nutrient is a less priority in East Africa in general and Ethiopia in particular as soils parent materials of East Africa are assumed to be rich with clay minerals such as feldspars and micas that have high potassium. Upon weathering these minerals give free potassium ion (K^+) available to plants. However, Smaling (1993) clustered Ethiopia to countries where high rate of potassium depletion (40 kg k_2O/ha/year) occurs. According to Smaling et al (1993), the input-output balance of potassium is negative under Ethiopian farming system. According to Sahlemedihin Sertsu and Pedro A. Sanchez (1978), the level of k was not reach to critical level of 0.2 meq K/100 ml even by burning of the vertisols of Sheno. According to the reports of Atlas of common beans production in Africa (www.ciat.cgia.africa/pdf/atlas_bean_africa), potassium is less important at Awasa, hararge highlands and rift valley.

Abayneh, Demeke and Ashenafi (2006) reported low relative proportions of K^+ for the soil of Adet, Finote Selam and Dibretabor research stations. Regional studies for demands of potassium by faba bean showed no response while Yihenew et al (2007) reported that potato responded at Injibara, where the exchangeable K is below 0.3 centi-mol/kg of soil, while other sites did not show any significant response. Intensive research work on major nutrients (N, P, K) and other macro and micro nutrients under different agro-ecologies is still untouched. Thus this research was initiated for the objective designed below. The objectives of this study is to investigate whether potassium is a yield limiting nutrient or not for the production of maize, malt barley and tomato.

MATERIALS AND METHODS

Three testing crops (tomato, malt barley and maize) were used. Tomato was studied under irrigation system. A processing type of tomato (var. Melkasa) was used. Seedlings were raised at the nursery and transplanted to the farm. , when reached at physiological stage. Three potassium levels (0 kg K_2O/ha, 50 kg K_2O/ha and 100 kg K_2O/ha) with uniform 105 Kg N/ha and 92 kg P_2O_5 were used. All phosphorus and potassium were applied at planting, while half rates of nitrogen at planting and the other half at flower initiation stage. All yields from a plot were collected whenever it reached to maturity (every week on average). Yields at each harvesting date was compared and analysed independently to see change of response overtime. Cumulative yield is used for each harvesting date except for the first harvesting with the formula $Y_{2T} = Y_1 + Y_{2t}$, $Y_{3T} = Y_{2T} + Y_{3t}$, $Y_{4T} = Y_{3T} + Y_{4t}$

etc… Where Y_{2T} is the total yield at second harvest, Y_1 total yield at first harvest, Y_{2t} amount yield collected from the field at second harvest etc.

Malt barley was studied during the rainy season at three locations (Lay gaint, Erob Gebeya/Gozamin and Injibara) and three sites per location using variety Beka. Three potassium levels (0 kg K_2O/ha, 50 kg K_2O/ha and 100 kg K_2O/ha) with uniform 60 kg N/ha and 60 kg P_2O_5/ha were evaluatedin the study. All phosphorus and potassium were also applied at planting, while half nitrogen at planting and the other half nitrogen at tillering. All crop managements were done accordingly to the procedure.

Maize was also studied during the rainy season at two locations (Dangla and Mota) and at three sites for each location with variety BH 540. Three potassium levels (0 kg K_2O/ha, 50 kg K_2O/ha and 100 kg K_2O/ha) with uniform of 60 kg N/ha and 60 kg P_2O_5 /ha at Dangla and 120 kg N /ha and 46 kg P_2O_5/ha at Mota were used for comparison. All phosphorus and potassium were applied at planting while half nitrogen at planting and half nitrogen at knee height. All crop management practices were done accordingly.

Soil sampling and analysis

Soil samples were taken at a depth of 0 - 40 cm with augur and analysed for the following parameters with specific procedures.The pH of the soil with soil water ratio of 1:2.5 (in volumetric base), organic matter with wet digestion (walkley) procedure and available P- with Olsen procedure were determined. By percolating one mole of NH_4-acetate, exchangeable potassium was analysed and it was computed by the formula

$$K_{exchangeable} = 1.279(a-b)/m \times (100+W)/100,$$

Where, K exchangeable is exchangeable potassium in c mole/kg of soil,

a = concentration of K in the percolates mg/l,

b = concentration of K in the blanks mg/l,

m = mass of air dried soil sample in gm and

w = the water content in percentage.

All biological data was summarised and subjected to statistical analysis with SAS program.

RESULTS AND DISCUSSION

Soil analysis

The pH of the soil was range from 4 - 6 which is acidic in general classification. The result laid within the range of most agricultural soils of the north western Amhara and in accordance to other reports. Exchangeable potassium was ranged from 0.29-0.43 cent-mole /kg of soil. It was not in the range of higher category (3 cent-moles/kg). This low level of exchangeable potassium might be resulted due to erosion, leaching, mining and crop residue removal from the field. The organic matter content was below 2% which lies in a range of low category. The available Phosphorus (P-Olsen) was also in the range of lower class (2-4 mg/kg of soil).

The result of soil analysis indicated that there is an urgent need of integrated soil management intervention to improve the quality of the soil and enhance productivity of the soil for longer time.

Biological yield responses

Effect of potassium on tomato fruit weight

The yield of tomato was increased uniformly starting from 5th harvest as shown on Table 1 for year 1 and for all harvesting dates in year 2 by increasing potassium rate. The maximum (29333 kg/ha) and minimum (26913 kg/ha) yield of tomato recorded from highest potassium rate application (100 kg K_2O/ha) and control (without K), respectively for year 1. In year 2 the response of tomato was stronger than year 1 as shown on Table 1 and Table 2. The highest (23580 kg/ha) and the lowest (20773 kg/ha) yield at final harvest (harvest 12) were from 100 kg K_2O/ha and control, respectively.

Table 1. Tomato yields (kg /ha) at different harvesting dates (Year 1)

	Treatments				
Harvesting dates	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
1st	1233	1147	700	NS	-
2nd	4127	3613	2867	NS	-
3rd	6867	5947	4780	NS	-
4th	11000	8713	9820	NS	-
5th	14993	16533	18420	NS	-
6th	23540	24953	25973	NS	-
7th	26913	29193	29333	NS	23.2

Table 2. Tomato yields (kg/ha) at different harvesting dates (Year 2)

	Treatments				
Harvesting dates	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
1st	493	527	1033	NS	-
2nd	4387	3680	4920	NS	-
3rd	6027	6520	8460	NS	-
4th	8333	8813	11273	NS	-
5th	9910	10310	12820	NS	-
6th	11793	12460	14633	NS	-
7th	14273	14820	16887	NS	-
8th	15760	16500	18733	NS	-
9th	17173	18000	20267	NS	-
10th	18860	19933	22040	NS	-
11th	20160	21227	23147	NS	-
12th	20773	21553	23580	NS	23.3

Table 3. Tomato yield (kg /ha) for combined years

Harvesting dates	Treatments				
	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
End of harvesting	24233	24980	26460	NS	23.4

The combined year result (Table 3) showed similar trends to the 1st and 2nd year.

Effect of potassium on number of fruits

For both year 1 and year 2 the effect of potassium on tomato fruit number production was not inconsistence as shown on Table 4, Table 5 and Table 6.

Table 4. Number of tomato fruits /plot (15 $m^{2)}$ at different harvesting dates (Year 1)

Harvesting dates	Treatments				
	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
1st	115	106	81	NS	-
2nd	318	299	271	NS	-
3rd	512	455	414	NS	-
4th	885	782	753	NS	-
5th	1400	1194	1224	NS	-
6th	1769	1729	1895	NS	-
7th	2116	1943	2017	NS	26.3

From Table 1, 2 and 3, the effect of potassium especially for the last harvests were increased proportionally to the rate of potassium applied. However the effect on the number of fruits was not inline with weights, implying potassium did not play a role to increase the number of fruits. There were conditions that lower number of fruits from high rates of potassium. Indicating individual fruits gave higher weights and contribute for the higher total yields as the rate of potassium increased.

Table 5. Number of tomato fruits /plot $^{(}$15 $m^{2)}$ at different harvesting dates (Year 2)

Harvesting dates	Treatments				
	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
1st	70	60	168	NS	-
2nd	507	405	552	NS	-
3rd	868	711	863	NS	-
4th	1115	913	1096	NS	-
5th	1260	1039	1227	NS	-
6th	1425	1202	1371	NS	-
7th	1668	1416	1551	NS	-
8th	1851	1574	1709	NS	-
9th	2053	1712	1848	NS	-
10th	2317	1927	2021	NS	-
11th	2607	2180	2204	NS	-
12th	2682	2254	2285	NS	27.5

Table 6. Number of tomato fruits /plot (15 m^2) for the combined year

Harvesting dates	Treatments				
	Control	50 kg K_2O/ha	100 kg K_2O/ha	LSD $_{0.05\%}$	c.v. %
End of harvesting	2399	2099	2151	NS	22.5

In general, application of potassium increased the yield (weight), which is not significant but does not have an effect on the number of fruits.

Maize

For both locations (Dangla and Mota) and seasons, there was an increase in grain and biomass yield for increased potassium rates. At Dangla the highest (19716.7 kg/ha) and the lowest (18202 kg/ ha) biomass was from 100kg k_2O/ha and control treatment respectively for the year 1. The second year data also showed similar response to applied potassium (Table 7).

Table 7. Effect of potassium on maize yields at Dangla

Treatments	Year 1			Year 2		
	Height (cm)	Grain (Kg/ha)	Biomass (Kg/ha)	Height (cm)	Grain (Kg/ha)	Biomass (Kg/ha)
Control	220.6	4473.2	18202.6	163.5	4687	9101.9
50 kg K_2O/ha	230.3	4121.3	18395	165.2	4729	9343.9
100 kg K_2O/ha	224.1	4403.3	19716.7	162.2	4905	9615.1
LSD 0.05%	NS	NS	NS	NS	NS	NS
c.v. %	6.4	14.9	16.5	6.7	17.4	17.3

The highest (4905 kg/ha) and the lowest (4687 kg/ha) grain yields were recorded from 100kg K_2O/ha and control treatment respectively in year 2 (Table 7)

Table 8. Effect of potassium on maize yields at Mota

Treatments	Year 1			Year 2		
	Height (cm)	Grain (Kg/ha)	Biomass (Kg/ha)	Height (cm)	Grain (Kg/ha)	Biomass (Kg/ha)
Control	242.0	2950.8	18976.0	159.7	2530.42	9949.2
50 kg K_2O/ha	249.0	3428.0	21648.5	157.2	2467.07	10246.9
100 kg K_2O/ha	241.6	3929.4	22692.4	154.3	2614.55	10188.8
LSD $_{0.05\%}$	NS	NS	NS	NS	NS	NS
c.v. %	4.5	35.7	17.4	5.6	20.5	11.4

At Mota the maximum grain yield was obtained in both years from treatments with higher rates of potassium fertilizer, while the minimum was obtained from control (Table 8). Similar trends response was recorded for biomass production. In general, yield of maize at both locations responded insignificantly to the applied potassium rates.

Malt Barley

The effect of potassium on the yield and other agronomic parameters of malt barley were found insignificantly increased. At Injibara (Table 9) grain yield was increased from 1539.2 kg/ha to 2275.6 kg/ha for year 1 from without potassium and highest rate of potassium (100 kg/ha), respectively. However, while at Gozamin yield response to potassium was inconsistent (Table 10). In Lay Gaint malt barley responded to applied potassium insignificantly to for most parameters (Table 11).

Table 9: Effect of potassium on yield and yield components of malt barley at Injibara

Year	Treatments	Height (cm)	Spike numbers /m2	Grain Kg/ha	No. tillers /m2	Spike length (cm)
I	Control	88.2	618.0	1539.2	319	7.9
	50 kg K_2O/ha	92.5	638.0	2142.6	306	7.9
	100 kg K_2O/ha	90.3	808.0	2275.6	431	7.8
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	5.9	15.8	23.9	22.8	7.0
II	Control	93.55	319.2	1323.2	323.22	7.8
	50 kg K_2O/ha	97.6	297.1	1360.7	325.22	7.9
	100 kg K_2O/ha	98.2	319.2	1536.2	346.33	7.8
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	9.1	37	7.1	34.7	16.2

Table 10: Effect of potassium on malt barley at Erob Gebeya (Gozamin)

Year	Treatments	Height (cm)	Fertile spike /m2	Grain Kg/ha	No. tillers /m2	Spike length (cm)
I	Control	87.0	524	1441.8	280	6.82
	50 kg K_2O/ha	91.0	600	1998.7	321	7.12
	100 kg K_2O/ha	93.7	661	1661.0	326	6.98
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	5.4	12.2	26.3	12.8	3.7
II	Control	69.	217.3	740.8	310.33	7.1
	50 kg K_2O/ha	67.0	297.3	606.4	423.	7.0
	100 kg K_2O/ha	67.8	263.0	646.7	367.3	6.8
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	9.7	17.8	39.7	32.5	14.2

Yield was increased from 2742.7 to 3127.3 kg/ha respectively, for the application of 0 kg K_2O/ha (control) and 100 kg K_2O/ha for year 1. For year 2, the highest (1495.1 kg/ha) and the lowest (1867.5 kg/ha) malt barley yields were recorded from application of 0 kg K_2O/ha (control) and 100 kg K_2O /ha respectively. In general biological yields of malt barley were slightly increased with the application of different rates of potassium. However, the increase with potassium application was insignificant.

Table 11. Effect of potassium on malt barley at Lay Gaint

Year	Treatments	Height (cm)	Fertile spike /m2	Grain Kg/ha	No. tillers /m2	Spike length (cm)
I	Control	123.0	572	2742.7	471	8.8
	50 kg K_2O/ha	123.7	601	2884.2	491	8.8
	100 kg K_2O/ha	122.6	611	3127.3	512	8.3
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	5.2	17.2	13.9	18.9	6.4
II	Control	97.5	220.3	1495.1	225	6.4
	50 kg K_2O/ha	99.3	194.0	1753.9	201	7.7
	100 kg K_2O/ha	103.7	243.3	1867.5	246.	7.2
	LSD $_{0.05\%}$	NS	NS	NS	NS	NS
	c.v. %	7.1	14.3	28.4	13.5	5.3

CONCLUSION

Soil status of exchangeable potassium was not as high as expected. For all testing crops (tomato, maize and malt barley) yields were yield is increased by increasing the potassium rates. However, for all crops under all locations, the yield increase was statistically insignificant to incorporate potassium as a package for the test crops.

RECOMMENDATION

For all testing crops at all locations, there was insignificant yield advantage by potassium application. However, there was a positive response by potassium application and the level of exchangeable potassium for all the study sites is not in a range of high level indicating future strategies must be designed for the management of potassium and enhance yield production sustainable. According to the current data potassium is not a yield limiting nutrient for tomato, maize and barley for the sites addressed by the study. Hence there is no need to add potassium fertilizer at these sites. But the response and change of soil potassium must be regularly monitored.

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Effect of *Bradyrhizobium Japonicum* (TAL 379) on nodulation and grain yield of Soybean

Tesfaye Feyisa1, Tadele Amare1 and Yihenew G.Silassie[2]
1, Adet Agricultural Research Center, P.O.Box, 08 Bahir Dar. E-mail: tesfaberhan98@yahoo.com
2, Amhara Regional Agricultural Research Institute (ARARI), P.O.Box 527

Abstract
The experiment was conducted at Finoteselam sub center on station during 2006 and 2007 on red soil in a randomized complete block design with three replications to study the effect of Bradyrhizobium japonicum (TAL 379) on nodulation and yield of soybean. Seeds of soybean var. cherry was sprinkled by lukewarm water to adhere the inocula on its surface and inoculated with the strain (TAL 379) at a rate of 10 gm per kg of seed and immediately sown in rows. Significant difference ($P<0.05$) was recorded for plant height, grain yield, nodule number and nodule volume. There was no nodule in the un inoculated plots implying that the strain is exotic and not found in the soil of Finoteselam. Maximum grain yield was recorded by 23 kg N + TAL 379 (2.17 t ha^{-1}) and TAL 379 alone (2.15 t ha^{-1}). The strain alone has significantly increased the grain yield by 19.3% (347 kg) over the control combined over years. The maximum nodule number per plant was recorded by 46 kg N + 46 kg P_2O_5 + TAL 379 (71.5) and by TAL 379 alone (69). However, effective nodules were observed in the plots inoculated only by the strain in the absence of N fertilizers. The over all result indicates that the strain (TAL 379) has good effect on nodulation and grain yield of soybean. Therefore, for soybean to nodulate and fix atmospheric nitrogen and produce high grain yield, the seed should be inoculated with the Bradyrhizobium japonicum (TAL 379). Facilities to maintain and multiply the strain should be in place to help soybean growing commercial farmers and to initiate other farmer to produce the crop for commercial use with reasonable cost.

Key words: *Bradyrhizobium japonicum*, grain yield, inoculation, nodule, soybean,

Introduction

Fertilization of intensively managed crop systems is essential in maintaining or increasing world food production which is heavily dependant on nitrogen input to maximize yield potential. Nitrogen is the most limiting nutrient for plant growth. Approximately 85 million metric tones of nitrogenous fertilizers are added to soil worldwide annually up from 1.3 million tones in 1930s. (Frink *et al*., 1999). For productivity to be simply sustained at current levels, let alone improved in the future, the N removed in agricultural produce or lost from the system must be replaced by N derived either from nitrogenous fertilizer or biological nitrogen fixation (Peoples *et al*., 1995).

Nitrogen is one of the key elements required for growth and productivity of crops. It is abundant in atmosphere (80%), but can't be utilized by plants as such. It has to be converted to nitrate or ammonium form either by chemical or biological process to be used by plants.

Chemical synthesis of N-fertilizer by industry means is energy intensive and costly (Singh, 1998). However, the same process is also carried out enzymatically by cyanobacteria (blue green-algae) and certain species of bacteria (Singh, 1998).

The contribution of biological nitrogen fixation (BNF) to the N cycle on the other hand can be controlled by manipulating various physical, environmental & biological factors (Hansen, 1994) and may therefore be more open to managing than applying fertilizer N. There is growing international concern about issues of global warming, environmental degradation and loss of natural resources.

Soybean is a grain legume cultivated in many areas in the world from tropics to temperate regions with a seed yield of 1.4 -2 t ha^{-1}. The seed (bean) contains about 18% oil and 38% protein and the extraction residue represents more than 40% of the utilization value of the plant (Asiedu, 1989). Soybean fixes up to 200 kg N ha^{-1} $year^{-1}$ when in symbiotic association with *B. japonicum* (Zhange et al., 2002) reducing the need for expressive and potentially environmental damaging N fertilizer (Asiedu, 1989).

Soybean is a recently introduced crop to Ethiopia. According to CSA (2001/02), the area covered by soybean in the country was 1,769 ha of which 251 ha was in the Amhara region with a total yield of 1621 t and 207 t respectively. The average yield per hectare is by far below the world's average. To give high yield and use its potential the crop needs association with *Bradyrhizobium japonicum* (the only rhizobial symbiont) to fix atmospheric nitrogen. There is no information in the region regarding the symbiotic effect of soybean and *Bradyrhizobium japonicum*. Therefore, the present work was initiated to study the effect of *Bradyrhizobium japonicum* (TAL 379) on nodulation and yield of soybean.

Materials and methods

The experiment was conducted at Finoteselam on station on a randomized complete block design with three replications. *Bradyrhizobium japonicum* (TAL 379) strain was received from National Soil Research Center Microbiology section (Addis Ababa) whereas soybean seed (Cherry) was received from pulse crops breeding program of the Center. The seeds were measured for each plot and sprinkled by lukewarm water to moisten the seed and adhere the strains on its surface. Immediately, the seeds for inoculation were inoculated with the strain at the rate of 10 g per kg under shade and sown to their respective plots at 40 cm distance between rows and 10 cm distance between plants on 2x4 m^2 plot size.

Treatment combination

Treatment no	Nitrogen (kg ha^{1})	P_2O_5 (kg ha^{1})	Strain (TAL 379)
1	0	0	0
2	0	46	0
3	0	0	TAL
4	0	46	TAL
5	23	0	0
6	23	46	0
7	23	0	TAL
8	23	46	TAL
9	46	0	0
10	46	46	0
11	46	0	TAL
12	46	46	TAL
13	69	0	0
14	69	46	0
15	69	0	TAL
16	69	46	TAL

Data collection

At 50 % flowering three plants were randomly dug out from boarder rows of each plot and nodule number was counted and nodule volume was measured (Fig.1a&b). At maturity five plants were randomly selected from each plot and number of pods per plant was counted. Similarly, five pods per plant were randomly selected from each plot and number of seeds per

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Figure 1. Soybean counted nodules (a) nodule volume (b)

plant was counted. Five representative plants were randomly selected from each plot and plant height was measured using a meter scale. Among 5 rows of soybean per plot, 3 central rows were harvested from each plot and grains and straws were separated and straw and grain yield per plot were measured. For all parameters the mean was recorded

Result and Discussion

Significant differences ($P<0.05$) were observed for plant height, nodule number, nodule volume and grain yield in each year and combined over years. the highest plant height was recorded by 23 kg N + 46 kg P_2O_5 ha^{-1} followed by 46 kg N + 46 kg P_2O_5 ha^{-1} + TAL 379 and 69 kg N + 46 kg P_2O_5 ha^{-1} + TAL 379. The effect of the strain on plant height over the control and other treatment was non significant i.e. the presence or absence of the strain has no effect on plant height but the significant difference among treatments in plant height was due to the applied NP fertilizers (Table 1).

Table1. Effect of *Bradyrhizobium japonicum* on the plant height of soybean

Treatment	*Mean plant height (cm)*		
	2006	2007	Combined
1	50.20	43.60	46.90
2	55.67	45.67	50.67
3	57.53	48.13	52.83
4	53.07	53.40	53.23
5	49.20	48.47	48.83
6	61.27	51.07	56.17
7	60.20	49.60	54.90
8	52.53	53.13	52.83
9	48.93	47.13	48.03
10	58.07	53.27	55.67
11	47.27	53.73	50.50
12	55.13	56.13	55.63
13	48.00	46.60	47.30
14	53.53	52.07	52.80
15	51.67	49.40	50.53
16	54.67	56.07	55.37
LSD (0.05)	8.094	6.417	7.154
C.V (%)	9.06	7.62	8.42

Maximum grain yield was recorded by 23 kg N + TAL 379 and TAL 379 alone followed by 46 kg P_2O_5 + TAL 379. The strain alone has increased grain yield over all treatments equally with 23 kg N ha^{-1}(Table 2). This indicates that, there is no need to apply N to increase grain yield of soybean in inoculated fields. The reason for the reduction of the grain yield and yield components during the second year was terminal moisture stress.

In Jimma and Awassa areas investors who grow soybean have used the strain for better yield advantage. EIAR has found good response of the strain to grain yield and went for scaling up at Jimma during 2006 (masmedia). Therefore, the result is in agreement with those activities.

Table2. Effect of *Bradyrhizobium japonicum* on the grain yield of soybean

Treatment	*Mean grain yield kg ha^{-1}*		
	2006	2007	Combined
1	2054	1550	1802
2	2533	1575	2054
3	2661	1638	2149
4	2364	1714	2039
5	2030	1582	1806
6	2399	1638	2018
7	2665	1665	2165
8	2330	1638	1984
9	2146	1580	1863
10	2431	1616	2024
11	1946	1628	1787
12	2381	1643	2012
13	1834	1566	1700
14	2122	1630	1876
15	2085	1629	1857
16	2191	1716	1953
LSD (0.05)	484.2	58.22	337.8
C.V (%)	12.85	2.15	10.64

Nodule was formed in all inoculated plots (fertilized and unfertilized).The maximum nodule number was recorded by 46 kg N + 46 kg P_2O_5 + TAL 379 (71.5) and TAL 379 alone (69) followed by 23 kg N + 46 kg P_2O_5 + TAL 379(67.5) and 23 kg N ha^{-1} + TAL 379 (66.83) (Table 3). However, effective nodules were observed in the plots inoculated by the strain alone (without N fertilizer) and the strain with P fertilizer alone (Fig. 2). The nodules in plots with N fertilizer were light green to light pink in color. The size of the nodules from the plots inoculated with the strain alone was as large as the well matured field pea seed and pinkish in color when dissected whereas the size of most nodules of the other plots with N fertilizer are small and green to light pink in color. The less effectiveness of the nodules in inoculated plots with N fertilizer may be due to the preference of the crop to the applied N fertilizer than soothing the strain for symbiotic association to fix atmospheric N.

Figure 2. Effective nodules

Table3. Effect of *Bradyrhizobium japonicum* on the nodule number of soybean

Treatment	*Mean nodule number per plant*		
	2006	2007	Combined
1	0	0	0
2	0	0	0
3	106	32	69
4	67	58	63
5	0	0	0
6	0	0	0
7	91	42	67
8	98	37	68
9	0	0	0
10	0	0	0
11	62	46	54
12	99	44	72
13	0	0	0
14	0	0	0
15	70	33	52
16	87	43	65
LSD (0.05)	39.96	18.33	30.45
C.V (%)	13.98	16.05	14.93

Similarly, Table 4 showed that there was significant difference in nodule volume among the treatments. The maximum nodule volume was recorded by 46 kg N + 46 kg P_2O_5 + TAL 379 (3.592 ml) and TAL 379 alone (3.412 ml). Both nodule number and volume were high during 2006 than during 2007 (Table 3 and 4).

Table4. Effect of *Bradyrhizobium japonicum* on the nodule volume of soybean

Treatment	*Mean nodule volume in ml*		
	2006	2007	Combined
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	4.56	2.27	3.41
4	2.73	3.60	3.16
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	3.45	2.56	3.00
8	4.00	2.11	3.06
9	0.00	0.00	0.00
10	0.00	0.00	0.00
11	2.67	2.86	2.76
12	4.55	2.63	3.59
13	0.00	0.00	0.00
14	0.00	0.00	0.00
15	3.22	2.26	2.74
16	3.33	2.77	3.05
LSD (0.05)	1.46	0.8632	1.172
C.V (%)	40.75	39.33	40.05

Conclusion

In general, the over all result indicates that the strain (*B. japonicum* TAL 379) has good effect on nodulation and grain yield of soybean. Soybean needs *Bradyrhizobium japonicum* for nodulation and fixing atmospheric nitrogen and thereby increase yield and yield components. No *B. japonicum* was observed in the soil of the trial site in the non inoculated plots whereas good number of nodule was counted in all inoculated plots implying that the strain is exotic and should be introduced to the system with the crop to increase its yield. In addition, the strain was performed well and adapted to Finoteselam and similar agroecological zone and resulted in a significant crop yield increment. The grain yield of soybean was increased by the strain alone over the control by 19.3% (347 kg) ha^{-1}.

Therefore, for soybean to nodulate and fix atmospheric nitrogen and produce high grain yield, the seed should be inoculated with the *Bradyrhizobium japonicum* (TAL 379) and facilities to maintain and multiply the strain should be in place to help soybean growing farmers and to initiate other farmer to produce the crop for commercial use with reasonable cost.

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Effect of Green and Dry Azolla on wheat yield and yield components

Tesfaye Feyisa1, Tadele Amare1 and Yihenew G.Selassie[2]
1, Adet Agricultural Research Center, P.O.Box, 08 Bahir Dar. Tel: 0583380234.
E-mail tesfaberhan98@yahoo.com
2, Amhara Regional Agricultural Research Institute (ARARI), P.O.Box 527 Tel: 0582206400

Abstract

The experiment was conducted at Adet on station during 2006 and 2007 on red soil in a randomized complete block design with three replications with the objective of studying the effect of green and dry Azolla on yield and yield components of wheat and generate information on use of green and dry azolla as N source for crops other than rice. Azolla multiplied in two concrete tanks of a size 10 x 5 m^2 was harvested, dried and stored during the off season (winter). Green azolla at a rate of 10 t ha^{-1} and dry azolla at a rate of 2.5 t ha^{-1} were incorporated to the respective plots ten days before sowing. Significant differences ($P<0.05$) were recorded for plant height, grain yield and straw yield. green azolla + 92 kg N ha^{-1} recorded maximum grain yield (4.6 t ha^{-1}) followed by 92 kg N ha^{-1} alone (4.3 t ha^{-1}) and dry azolla + 92 kg N ha^{-1}(4 t ha^{-1}). Green azolla and dry azolla alone increased grain yield by 25% (385 kg) and 31% (478 kg) respectively over the control equivalently with 23 kg N ha^{-1} (30.7%(470 kg)). Hence, Azolla can be used as N source for wheat. However, since wheat is produced on larger plot of land and need large amount of N, it may not be possible to satisfy its N requirement from green azolla and dry azolla for large amount of green and dry azolla is needed per hectare. Therefore, green and dry azolla can be used for high value crops (vegetables and fruit) that can be grown on small plots of land.

Keywords: Green Azolla, dry azolla, inoculation, N source

Introduction

Nitrogen fertilizers supplement the natural soil nutrient supply to satisfy the demand of the crops to compensate for N lost by removal of plant products, N leaching and gaseous N loss and maintain productive soil conditions for agriculture (Tabachow *et al*., 2001). Chemical synthesis of N-fertilizer by industry means is energy intensive and costly (Singh, 1998). However, the same process is also carried out enzymatically by cyanobacteria (blue green-algae) and certain species of bacteria (Singh, 1998). Most of the cyanobacteria exist under free living conditions but some of them are found in symbiotic association with lower plants like water fern azolla (Giller, 2001, Suba Rao, 1999).

The aquatic fern azolla together with blue green algae (*anabaena azollae*) provides a symbiotic association that can fix agrnomically significant amounts of nitrogen (Giller, 2001). With repeated harvesting, annual N production rate by azolla can be as high as 500 kg-1200 kg N ha^{-1} with daily production rate of 0.4-3.6 kg N ha^{-1} per day (average 2 kg N ha^{-1} per day) (Kikuchi *et al*., 1982). It can be grown as green manure and incorporated into the soil during land preparation or as green manure and transported to the field where crop (usually rice) is produced or as intercrop with the crop (rice) (Singh, 1998).

Azolla provides N to the crop after its decomposition. Unincorporated azolla decomposed slowly as compared to incorporated azolla which took 8-10 days to decompose and release 67 % of its N within 35 days (Singh *et al*., 1991). The N from azolla is released slowly in comparison to fertilizer N and its availability to the first rice crop is about 70 % of ammonium sulphate N (Saha *et al*., 1982).

Azolla makes the soil fertile by increasing the contents of organic carbon, N, P, and K (Singh and Singh, 1987). It also increases availability of micronutrients like Fe, and Mn in soil as a result of its incorporation. In addition, azolla reduces bulk density and soil resistance and increases aggregate stability and available moisture content (improve soil physical and chemical property).

Azolla is converted into compost to be used as fertilizer for dry land crops and vegetables (Singh, 1998). Experimental results have shown that 10 tones of azolla green manure can increase a rice yield by 470 kg ha^{-1} (Rains and Talley 1978) in FAO 1982). Tesfaye *et al*., 2007 also reported that azolla incorporated once to a soil can increase rice by 15-19% (721 kg – 911 kg ha^{-1}).

Loss of azolla N according to Watanabe *et al*. (1989), was found to be small (0-11%) in comparison with the loss from an equivalent amount of urea fertilizer (30%) which was probably due to direct volatilization of ammonia to the atmosphere. When azolla was incorporated into the soil, the overall fertilizer loss was reduced by 35-55% (Kumarasinghe and Eskew, 1993).

Soils of Ethiopian highlands are inherently poor in available plant nutrients and organic matter (Tekalign *et al*., 1988). Murphy (1963) reported that the major part of Ethiopian soils is deficient in nitrogen and phosphorus. However, the use of fertilizer N in different agricultural systems by Ethiopian farmers is limited by low percapita income, poor credit facilities, poor current commodity value, and absence of effective infrastructures for fertilizer production and distribution. In addition, the cereal dominated cropping systems, aimed at meeting the farmers' subsistence requirements, coupled with low usage of chemical fertilizers have led to the widespread depletion of soil nitrogen in the cereal crops growing areas of Ethiopia. Moreover, the heavy rains during the early part of the main cropping season (June-August) cause substantial soil nutrient losses due to intensive leaching and erosion (Amsal and Tanner, 2001).

Therefore, since azolla is easy to manage, cheap nitrogen source and its mat is harvested every 2-3 weeks, composted and stored during the dry season, it is high time to evaluate and generate information on its effect on crop yield other than rice and its N contribution efficiency. Therefore, the present work was proposed to study the effect of azolla green manure and dry compost on yield and yield components of wheat and to generate information on use of azolla as green manure and dry compost for wheat.

Materials and Methods

The experiment was conducted at Adet Agricultural Research Center on station on Nitosol in a Completely Randomized Block Design (RCBD) with three replications. Two ponds of 10 m x 5 m size were constructed with concrete tank in the center, filled with loam soil (forest soil) at the rate of 5 kg per m^2 (250 kg loam soil per pond) and filled with tape water at a depth of 10 cm and left over night to let the suspended materials settle. Next day, the suspended materials were removed and fresh *Azolla filiculoides* was inoculated to the tanks at a rate of 3 kg per tank (Fig. 1a). The water level was maintained to a depth of $\geq$ 5cm every day. 725 gm TSP (333.5 gm P_2O_5) was applied to each tank initially and when deficiency symptom was observed. The azolla mat was harvested every two weeks, weighed, dried and stored to be used for the experiment during the dry season (Fig. 1c). Ten days before sowing 3 kg (2.5 t ha^{-1}) of dry azolla and 12 kg (10 t ha^{-1}) of green azolla (Fig.1b) was weighed and applied to the respective plots (12 m^2) and incorporated to the soil. After 10 days of incorporation wheat was sown at a seed rate of 150 kg per ha^{-1} with a spacing of 20 cm between rows and 1 m space between plots and blocks with the following treatment arrangement. Phosphorus was applied at a rate of 46 kg P_2O_5 ha^{-1} to each plot uniformly during planting. Similarly, half of the N was applied during planting and half at tillering.

Figure 1. Azolla pond (a), harvested green azolla (b), and dry azolla (c)

Treatments

1. Control
2. 23 kg N ha^{-1}
3. 46 kg N ha^{-1}
4. 69 kg N ha^{-1}

5. 92 kg N ha^{-1})
6. Dry azolla
7. Dry azolla + 23 kg N ha^{-1}
8. Dry azolla + 46 kg N ha^{-1}
9. Dry azolla + 69 kg N ha^{-1}
10. Dry azolla + 92 kg N ha^{-1}
11. Green azolla
12. Green azolla + 23 kg N ha^{-1}
13. Green azolla + 46 kg N ha^{-1}
14. Green azolla + 69 kg N ha^{-1}
15. Green azolla + 92 kg N ha^{-1}

Data collection

Five representative plants were randomly selected from each plot and plant height was measured using a meter scale and the average was recorded. Among 15 rows of wheat per plot, 13 central rows were harvested from each plot and grains and straws were separated and straw and grain yield per plot were measured. 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 ha^{-1}.

Data Analysis

The data collected for all relevant characters were subjected to analysis of variance appropriate to factorial experiment CRBD (Gomez and Gomez, 1984). Significant differences between and/or among treatments were calculated using the Least Significant Difference (LSD) MSTATC Computer software.

Result and Discussion

Significant difference in mean plant height was observed among treatments combined over years (Table 1). The maximum mean plant height was recorded due to 92 kg N ha^{-1} + dry azolla followed by 92 kg N ha^{-1} alone, green azolla + 92 kg N ha^{-1}. During 2006, there was no significant difference in plant height due to dry or green azolla alone compared to the control whereas significant difference in plant height was recorded due to green azolla alone over the control during 2007. Green azolla alone increased plant height equally with 69 kg N ha^{-1} alone in both years whereas dry azolla increased plant height equally with 46 kg N ha^{-1}alone during 2006 and with 23 kg N ha^{-1} alone during 2007. In general, combined over years there was no difference in plant height due to green or dry azolla alone, the difference was due to the N fertilizer applied from urea (Table 1).

Table 2 showed that there was significant difference ($P<0.05$) in grain yield among the treatments. The combined analysis showed that green azolla + 92 kg N ha^{-1} gave the maximum grain yield (4.6 t ha^{-1}) followed by 92 kg N ha^{-1} alone (4.3 t ha^{-1}) and dry azolla

+ 92 kg N ha^{-1}(4 t ha^{-1}). Dry and green azolla equivalently increased grain yield with 23 kg N ha^{-1}. Dry and green azolla with 46 kg N ha^{-1} increased grain yield equally with 69 kg N ha^{-1} alone. Dry azolla and green azolla alone increased grain yield by 31% (478 kg) and 25% (385 kg) over the control respectively.

Table1. Effect of Azolla dry compost and green manure on plant height of wheat during 2006 and 2007

Treatment	*Mean plant height (cm)*		
	2006	2007	Combined
Control	67.67	61.00	64.33
23 kg N ha^{-1}	72.53	69.13	70.83
46 kg N ha^{-1}	73.20	75.87	74.53
69 kg N ha^{-1}	79.07	78.87	78.97
92 kg N ha^{-1}	80.20	83.20	81.70
Dry azolla	71.33	68.80	70.07
Dry azolla + 23 kg N ha^{-1}	75.07	78.13	76.60
Dry azolla + 46 kg N ha^{-1}	78.73	80.93	79.83
Dry azolla + 69 kg N ha^{-1}	81.60	78.27	79.93
Dry azolla + 92 kg N ha^{-1}	81.40	85.87	83.63
Green azolla	72.00	71.67	71.83
Green azolla + 23 kg N ha^{-1}	74.00	73.53	73.77
Green azolla + 46 kg N ha^{-1}	76.07	74.60	75.33
Green azolla + 69 kg N ha^{-1}	77.60	81.67	79.63
Green azolla + 92 kg N ha^{-1}	79.47	82.73	81.10
LSD (0.05)	7.703	7.899	7.630
C.V (%)	6.06	6.19	6.19

Table2. Effect of Azolla dry compost and green manure on grain yield of wheat during 2006 and 2007

Treatment	*Mean grain yield kg ha^{-1}*		
	2006	2007	Combined
Control	1645	1420	1533
23 kg N ha^{-1}	2251	1555	1903
46 kg N ha^{-1}	3193	2425	2809
69 kg N ha^{-1}	3675	3123	3399
92 kg N ha^{-1}	4699	3813	4256
Dry azolla	1884	2138	2011
Dry azolla + 23 kg N ha^{-1}	2330	2504	2417
Dry azolla + 46 kg N ha^{-1}	3335	3377	3356
Dry azolla + 69 kg N ha^{-1}	3759	3726	3743
Dry azolla + 92 kg N ha^{-1}	3944	4074	4009
Green azolla	1803	2034	1918
Green azolla + 23 kg N ha^{-1}	2421	2318	2370
Green azolla + 46 kg N ha^{-1}	3768	3354	3561
Green azolla + 69 kg N ha^{-1}	4245	3577	3911
Green azolla + 92 kg N ha^{-1}	4825	4345	4585
LSD (0.05)	134.9	280.3	215.1
C.V (%)	2.53	5.74	4.31

Table3. Effect of Azolla dry compost and green manure on straw yield of wheat during 2006 and 2007

Treatment	*Mean straw yield kg ha^{-1}*		
	2006	2007	Combined
Control	2553	2006	2280
23 kg N ha^{-1}	3153	2241	2697
46 kg N ha^{-1}	4251	3126	3688
69 kg N ha^{-1}	4651	3719	4185
92 kg N ha^{-1}	5709	4426	5068
Dry azolla	2879	2686	2783
Dry azolla + 23 kg N ha^{-1}	3440	3238	3339
Dry azolla + 46 kg N ha^{-1}	4485	3974	4229
Dry azolla + 69 kg N ha^{-1}	4880	4413	4647
Dry azolla + 92 kg N ha^{-1}	5025	4890	4957
Green azolla	2692	2422	2557
Green azolla + 23 kg N ha^{-1}	3388	2847	3118
Green azolla + 46 kg N ha^{-1}	4309	3876	4093
Green azolla + 69 kg N ha^{-1}	5231	3997	4614
Green azolla + 92 kg N ha^{-1}	5805	5052	5428
LSD (0.05)	359.9	394.0	369.0
C.V (%)	5.17	6.68	5.87

Table4. Effect of Azolla dry compost and green manure on dry biomass yield of wheat during 2006 and 2007

Treatment	*Mean dry biomass kg ha^{-1}*		
	2006	2007	Combined
Control	4208	3426	3817
23 kg N ha^{-1}	5403	3796	4599
46 kg N ha^{-1}	7445	5550	6497
69 kg N ha^{-1}	8325	6842	7583
92 kg N ha^{-1}	10410	8240	9324
A. f. dry compost	4792	4824	4808
A. f. dry compost + 23 kg N ha^{-1}	5770	5742	5756
A. f. dry compost + 46 kg N ha^{-1}	7849	7351	7600
A. f. dry compost + 69 kg N ha^{-1}	8639	7856	8247
A. f. dry compost + 92 kg N ha^{-1}	8969	8964	8967
Green azolla	4505	4455	4480
Green azolla + 23 kg N ha^{-1}	5810	5870	5840
Green azolla + 46 kg N ha^{-1}	8078	7230	7654
Green azolla + 69 kg N ha^{-1}	9476	7574	8525
Green azolla + 92 kg N ha^{-1}	10630	9432	10030
LSD (0.05)	411.6	1002.0	749.0
C.V (%)	3.35	9.25	6.62

There was significant difference ($P<0.05$) among most treatments in straw yield. Maximum straw yield was recorded by green azolla + 92 kg N ha^{-1} (5.43 t) followed by 92 kg N ha^{-1} alone (5.07 t) and dry azolla + 92 kg N ha^{-1} (4.96 t) (Table 3). The straw yield recorded by dry azolla and green azolla alone was comparably equal with the straw yield recorded by 23 kg N ha^{-1}. However, there was no significant difference ($P<0.05$) in straw yield between green azolla and the control. Dry azolla and green azolla with different N rates increased straw yield significantly.

There is significant difference ($P<0.05$) among most treatments in dry biomass yield. Maximum dry biomass yield was recorded by green azolla + 92 kg N ha^{-1} (10.03 t) followed by 92 kg N ha^{-1} alone (9.32 t) and dry azolla + 92 kg N ha^{-1} (8.97 t) (Table 4). The dry biomass yield recorded by dry azolla and green azolla alone was comparably equal with the dry biomass yield recorded by 23 kg N ha^{-1}. However, there was no significant difference ($P<0.05$) in dry biomass yield between green azolla and the control. Dry azolla and green azolla with different N rates increased dry biomass yield significantly over the control and 23 kg N ha^{-1}.

In general, results due to inoculation of dry and green azolla to wheat showed significant difference for most parameters over the control. Green azolla and dry azolla alone have equivalently affected most parameters with 23 kg N ha^{-1} 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 also a recycling source of P, S and other nutrients and hence increases grain yield and other yield parameters (Main, 1991; Singh and Singh, 1987 and Singh et al;. 1981). Talley *et al*;. 1977 also reported that rice yield was increased by 112% (1470) kg over the control by incorporating *A. filiculoides* once and by 216% (2700 kg ha^{-1}) by incorporating once and then growing Azolla as a dual crop with rice. In addition, Lumpkin and Plunknet, 1980, reported that rice yield was increased by 18.6% due to azolla. Tesfaye *et al,*. 2006 also reported that incorporation of azolla alone once to a rice field has increased rice yield by 15% -19% at Fogera plain. Therefore, the yield increment for wheat due to dry azolla and green azolla alone (31% & 25% respectively) is in line with the above findings.

Conclusion and Recommendation

From the results it could be concluded that green and dry azolla can be used as N source for wheat. Dry azolla and green azolla alone at a rate of 2.5 t ha^{-1} and 10 t ha^{-1} respectively increased grain yield and other yield components of wheat equivalently with 23 kg N ha^{-1}. However, wheat is produced on a large plot of land and requires large amount of N fertilizer and the amount of azolla needed to provide the required amount of N would be very high and needs large amount of green and dry azolla. Hence, larger ponds, sufficient irrigation water and high labor are needed to produce the required amount of green and dry azolla. The land to be allotted to larger pond construction could also compete for land. Therefore, azolla should be used as a biofertilizer for high valued crops (such as vegetables and fruit trees) that can be grown on small plots of land.

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Decomposition Dynamics and Inorganic Fertilizer Equivalency Values of Compost Prepared from Different Plant Residues

Yihenew G.Selassie[1], Tadele Amare[2] and Tesfaye Feyissa[2]
[1]Amhara Regional Agricultural Research Institute, P.O.Box 527, Bahir Dar
[2]Adet Agricultural Research Center, P.O.Box 8, Bahir Dar

Abstract

A study was conducted for two years (2005-2006) at Adet to estimate the inorganic fertilizer equivalency values of compost prepared from different plant materials; recommend the appropriate plant materials composition in compost; and measure the optimal duration required for compost formation. The experiment was sub divided into pit and pot sub experiments. The pit experiment included of 5 treatments that included different proportions of composting materials (100% dry cereals stubble, 75% dry cereals stubble + 25% of dry legumes stubble, 50% dry cereals stubble + 50% dry legumes stubble, 25% dry cereals stubble + 75% dry legumes stubble and 100% dry legumes stubble). The pot experiment included growing of tef in pots that contained all treatments in the pit experiment and one control treatment. Similarly a pot experiment on mineral N was conducted side by side with the compost experiment to compare the effects of mineral N fertilizer and compost. All the experiments were arranged in randomized complete block design with three replications. Results of the experiment revealed that the organic carbon content did not have a wide difference among composting plant materials. Nevertheless, all the cereal residues contained lower total N content than the legume residues. During the 8 months of the composting period, organic carbon content showed a reduction trend while total N and inorganic N contents showed increasing trend. Increasing legume contents in composting materials increased yield and yield components of tef. A ratio of 75% legume and 25% cereal was found to be optimal one. Composting upto 7.5 months generally improved inorganic N release and yield and yield components of the test crop. From the experiment it was possible to recommend that since huge amount of compost is required to satisfy the nutrient demand of crops, compost should be applied in combination with mineral fertilizers for commercial purposes. However, for small plot agriculture of Ethiopian farmers, compost remains to be very useful low cost organic fertilizer.

Key Words: C/N ratio, inorganic N, organic carbon, total N, yield and yield components

Introduction

Composting is the practice of creating humus like organic materials outside the soil by mixing, piling, or otherwise organic materials under conditions conducive to aerobic decomposition and nutrient conservation (Brady and Weil, 2002). During the composting process, the C/N ratio of organic materials in the pile decreases until a fairly stable ratio in the range of 14:1 to 20:1 is achieved. Achieving this ratio is possible by selecting appropriate combinations of cereal and legume plant materials, adjusting the composting time and selecting appropriate composting period.

The finished product, compost, is popular as a mulching material, as an ingredient for potting mixes, as an organic soil conditioner, and as slow-release fertilizer. Compost as a fertilizer has a lot of potentials in boosting land productivity. It is less costly, can be prepared from locally available materials and significantly improves soil physical as well as chemical properties. The Amhara Regional State extension endeavors are now pushing compost application for crop production. Therefore, composting has become an urgent priority.

It is apparent that the rates of compost applications are not known. Unlike chemical fertilizers, determination of nutrient rate of application from compost is quite difficult. This is mainly related to the unavailability of information on the inorganic fertilizer equivalency values of compost prepared from different plant materials. Once these values are known, it will be possible to estimate fertilizer rate recommendations using compost as a source of nutrients. The objectives of the study were to determine the inorganic fertilizer equivalency values of compost prepared from different plant materials; identify the appropriate plant materials composition in compost; and estimate the optimal duration for compost formation.

Materials and Methods

Location and Climatic conditions

The experiment was conducted at Adet Agricultural Research Center, located at an altitude of 2240.0 meters above sea level and geographic position of 11^{o}17.2'N latitude and 37^{o}28.9' longitude. The mean monthly temperature and total monthly and annual rainfall data of the experimental site during the experimental period are presented on Table 1.

Table 1. Mean monthly temperature and monthly and annual total rainfall of Adet (2005-06)

	Mean Temperature				Total rainfall	
	2005		2006			
Month	Max	Min	Max	Min	2005	2006
January	26.4	6.1	27.53	6.82	1.7	0
February	29.9	8.8	29.37	8.94	0	0.8
March	29.7	10.8	29.67	10.63	27.9	4.3
April	29.8	13.2	29.78	12.11	40.4	19
May	29.0	11.6	27.5	12.19	30.2	116.4
June	27.2	11.3	24.89	18.41	104.9	175
July	22.4	11.7	23.33	12.46	330.8	429.3
August	23.3	12.3	20.86	10.62	213.6	407.7
September	24.2	12	23.75	11.63	192.6	236.5
October	23.3	11.2	25.96	11.74	152.7	126.8
November	25.3	7.7	25.31	9.15	27.4	17.5
December	26.0	4.7	25.7	7.7	0	27.5
Total					1122.2	1560.8

Experimental design and field layout

Composting experiment
The composting experiment had five treatments that were

1) 100% dry cereals stubble
2) 75% dry cereals stubble + 25% of dry legumes stubble
3) 50% dry cereals stubble + 50% dry legumes stubble
4) 25% dry cereals stubble + 75% dry legumes stubble
5) 100% dry legumes stubble

For composting, proportional equal (by weight) amounts of residues of different plant materials were used. The plant materials included were cereal straws of tef (*Eragrostis tef*), finger millet (*Eleusine coracana*), wheat (*Triticum aestivum* L.), and legume stubbles of faba bean (*Vicia faba*), field pea (*Pisum sativum*) and *Sesbania sesban*.

The treatments were arranged in randomized complete block design with three replications. For composting, small pits with a volume of $1m^3$ were dug. Garden soil (3kg) was mixed to all treatments for microbial inoculation. The pits were filled with the treatments and composting proceeded. The pits were watered regularly so that enough moisture was available for ambient microbial growth. The materials in the pits were overturned regularly to allow air circulation. To minimize moisture and nutrient loss the composting pits were covered with thatched grass.

Composting proceeded for about 8.5 months (from 28 April 2005 to 03 January 2006). Samples from composting materials were collected every month starting from the 3.5 months of composting. The collected samples were analyzed for total N, organic matter and inorganic N contents. These values were used to calculate the mineral fertilizer equivalency values of compost.

Pot experiment
Compost samples were collected from the composting pit in five different times. Composting was started on 28/04/05 and samples were collected in five time intervals on 08/08/05 (Time 1), 07/09/05 (Time 2), 08/10/05 (Time 3), 08/11/05 (Time 4) and 03/01/06 (Time 5). The collected compost samples from the five composting treatments were filled in 5 pots to obtain five treatments. One control treatment containing soil only (collected from the field were the pits were dug) was included making the number of treatments to be six. The amount of compost added to each pot was equivalent to 10 tones of compost per hectare.

The six treatments were arranged in randomized complete block design with three replications. The same arrangement was used for all sampling periods. Tef was used as a test crop and plant height, fresh biomass yield, dry biomass yield and grain yield data were collected from the pot experiment.

Similarly a pot experiment on mineral N was conducted side by side to compare the effects of mineral N fertilizer and compost on grain yield, fresh biomass yield, dry biomass yield and plant height of tef. The treatments for the mineral fertilizer rate experiment included 0, 30, 60, 90, 150, 210 and 270 kg N ha^{-1}.

Results and Discussion

Composting

Chemical composition of the compost materials

The chemical analysis of the plant materials revealed that the organic carbon content did not have a wide difference among them (Table 2). It ranged from 43.1% in *S. Sesban* to 49.3% in wheat. Nevertheless, the cereal plant materials contained relatively higher organic carbon content than the legume plant materials. Regarding total N, all the cereal residues contained total N content of less than 1% (0.71-0.75%). However, the legumes had total N content of above 1.9% (1.9-3.31%). Eventually, the C/N ratio was higher for cereals than the legumes. This parameter was affected more by total N content of the materials than their organic carbon content.

Table 2. Chemical composition of the plant residues used for composting

Plant residues used for composting	Organic carbon content (%)	Total N (%)	C/N ratio
Tef	46.6	0.74	63.0
Finger millet	47.2	0.71	66.5
Wheat	49.3	0.75	65.7
Faba bean	44.2	1.90	23.3
Field pea	43.2	1.97	21.9
Sesbania sesban	43.1	3.31	13.0

Dynamics of organic carbon, total N and inorganic N contents in the compost during composting period

Organic Carbon

Results of the composting experiment which was conducted for 8.5 months (Table 3) revealed that the organic carbon content in the initial composting material ranged from 44% (100% legume) to 47.2% (100% cereal). It was apparent that as the legume content in the composting material increased, the organic carbon content relatively decreased. Nevertheless, there was no wide difference among treatments in their organic carbon content.

As the composting time increased, the organic matter content in all treatments decreased. The loss of organic carbon could be attributed to the mineralization process which causes loss of CO_2. The loss of carbon during the composting time was the highest for the 100%

legume compost and was the lowest for the 100% cereal compost. This indicates that the former was much easier for the microorganisms to decompose it than the later.

Total N

The initial total nitrogen content in the composting material ranged from 0.71% (100% cereal) to 2.03% (100% legume). The total nitrogen content in the compost generally increased as the legume content increased (Table 3). In the course of composting time, the total nitrogen content generally increased. The increase in total N content could be due to the decrease in OC content of the biomass which eventually increased the concentration of nitrogen in the compost.

Carbon-to-nitrogen ration (C/N ratio)

The C/N ratio in the initial composting material ranged from 66.5 (100% cereal) to 21.7 (100% legume). Generally, as legume content in the composting material increased, the C/N ratio linearly decreased (Table 3). With regard to the dynamics of C/N ratio with increase in time of composting, the C/N ratio generally decreased as the composting time increased. However, the C/N ratio in the cereal compost did not decrease too much during the composting period to obtain matured compost. The 100% cereal compost after 8.5 months of decomposition had a C/N ratio of 37.9 which is not still too suitable for application to the soil. The same phenomenon was observed for the treatment with 75% cereal + 25% legume compost.

As the proportion of legume was raised to 50% and the proportion of cereal straw was lowered to 50%, the C/N ratio also dropped below 20 after 7.5 months of composting. As the proportion of legume was further raised to 75%, the C/N ratio dropped below 20 just after 4.5 months of composting. After 8.5 months, the C/N ratio of this treatment was only 12.8. Composting of 100 % legume stover alone gave the lowest levels of C/N ratio at all composting periods and the desirable level of C/N ratio for application to the soil (below 20) was obtained after 3.5 months of composting.

The C/N ratio determines how long decomposition will take. For rapid composting, the initial C/N ratio of composting material should be in the range of 25 to 30. If the C/N ratio is above 35, the process will be considerably slower and if the C/N ratio is less than 20, nitrogen tends to be released than tied up (Biochemical and Microbiological Aspects of Composting, 1974). Compost that is immature or not well decomposed should be used primarily as mulch. Incorporation of immature compost into the soil may result in nitrogen deficiency and poor plant growth (Schumacher et al., 1987).

Inorganic N release

The inorganic N release was the lowest for 100% cereal compost and was the highest for 25% cereal + 75% legume compost. The N release from 100% legume compost was second next to the above treatment but was much better than other treatments which have higher cereal plant material composition. Inorganic nitrogen release increased as the time of composting increased up to the 7.5 months time. After this time all treatments showed a down turn in mineralization of nitrogen. The mean inorganic N release after 8.5 months of composting was 4.0, 6.0, 9.1, 10.1 and 9.7% of the total N for treatments 1, 2, 3, 4 and 5, respectively (Table 3).

Table 3. Dynamics of OC, total N and inorganic N contents in the compost during 8.5 months of composting

Treatment	Compost composition	Parameters	Composting time (months)					
			Initial	3.5	4.5	6.5	7.5	8.5
1	100% cereal	OC (%)	47.2	46.2	45.5	43.1	39.5	37.9
		Total N (%)	0.71	0.79	0.94	1.24	1.53	1.52
		C/N	66.5	58.5	48.4	34.8	25.8	24.9
		Inorg. N (mg/kg)	-	316	353	496	614	603
2	75% cereal + 25% legume	OC (%)	46.5	44.6	42.5	41.1	38.5	36.3
		Total N (%)	1.05	1.06	1.09	1.32	1.60	1.58
		C/N	44.3	42.1	42.5	31.1	24.1	23.0
		Inorg. N (mg/kg)	-	636	653	793	960	943
3	50% cereal + 50% legume	OC (%)	45.7	44.9	41.5	38.7	36.5	35.8
		Total N (%)	1.33	1.45	1.51	1.57	1.83	1.91
		C/N	34.4	31.0	27.5	24.6	19.9	18.7
		Inorg. N (mg/kg)	-	1454	1498	1544	1682	1497
4	25% cereal + 75% legume	OC (%)	45.0	43.3	40.4	38.2	36.5	34.2
		Total N (%)	1.89	2.01	2.39	2.59	2.67	2.68
		C/N	23.8	21.5	16.9	14.7	13.7	12.8
		Inorg. N (mg/kg)	-	2030	2587	2672	2760	2717
5	100% legume	OC (%)	44.0	42.6	39.4	37.8	34.5	31.6
		Total N (%)	2.03	2.37	2.59	2.67	2.76	2.77
		C/N	21.7	18.0	15.2	14.2	12.5	11.4
		Inorg. N (mg/kg)	-	1949	2582	2617	2757	2683

Pot experiment

The effect of compost composition and composting time on different biological parameters of tef

Fresh biomass yield

Compost composition exhibited a significant effect ($p<0.05$) on fresh biomass yield of tef. As indicated in Figure 1a, the control treatments of samples collected at Time 1 and Time 2 gave significantly higher ($p<0.05$) fresh biomass yield than the cereal straw compost. The fresh biomass yield of the control plot from the other sampling periods was still higher than the same yield obtained from the pot filled with cereal compost. This indicates that application of cereal compost composted for 4.5 months is not at all better than not applying compost. The poor growth of tef in the pot with cereal compost should be attributed to higher C:N ratio which caused nitrogen depletion by microbes. Moreover, the pots had low water holding capacity and the soil got dried quicker than those pots with legume compost. This was because the cereal stubble had lower decomposition rate which eventually had lower surface area to volume ratio causing reduced water holding capacity of the soil. Water holding capacity increased with increase in decomposition rate and legume content in the compost.

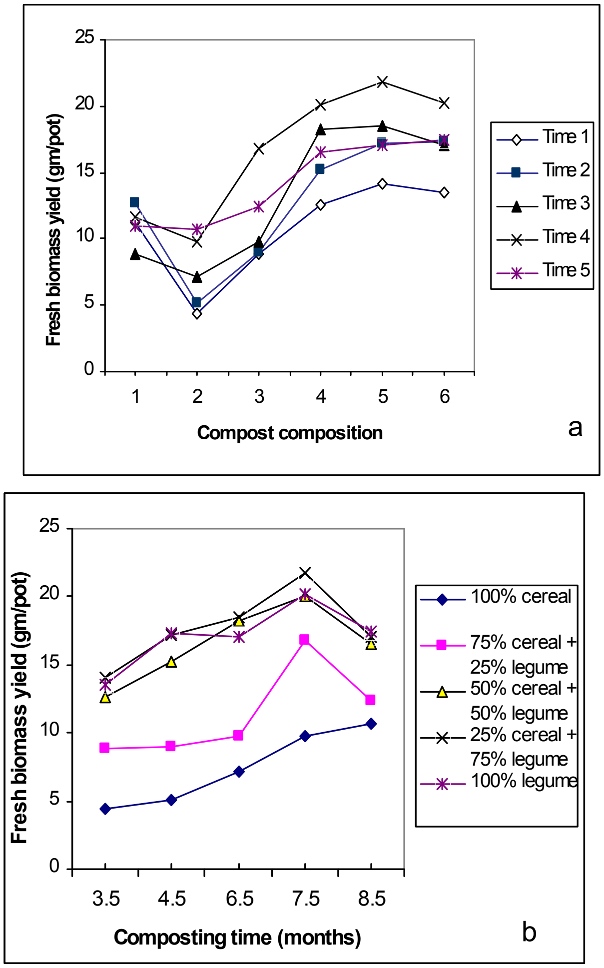

Figure 1. The effect of compost composition and composting time on fresh biomass yield of tef

However, as the cereal content in compost composition decreased and the legume content increased, fresh biomass yield also demonstrated an increasing trend. The increase was more linear up to the treatment containing 50% cereal and 50% compost. The increase showed a curvilinear trend beyond this treatment.

Almost for all treatments, fresh biomass yield increased up to composting time of 7.5 months (Figure 1b). As composting was proceeded further to 8.5 months, the compost from the same composting time gave diminished fresh biomass yield for all compost compositions except the 100% cereal compost. This particular treatment gave increased fresh biomass yield with increase in time of composting.

Dry biomass yield

Dry biomass yield exhibited similar response trend with the fresh biomass yield of tef (Figure 2a). The soil amended with 100% cereal compost gave lower dry biomass yield than the soil which did not receive any compost. As the legume level increased in the composting material, the dry biomass yield response showed a curvilinear increase up to treatment 5 which received compost with 25% cereal + 75% legume plant material. The treatment which received compost with 100% legume material (treatment 6) exhibited a diminished response than treatment 5 but was better than other treatments. Dry biomass yield as affected by composting time also exhibited similar trend with dry biomass yield (Figure 2b). It increased up to 7.5 months of composting and dropped beyond this time.

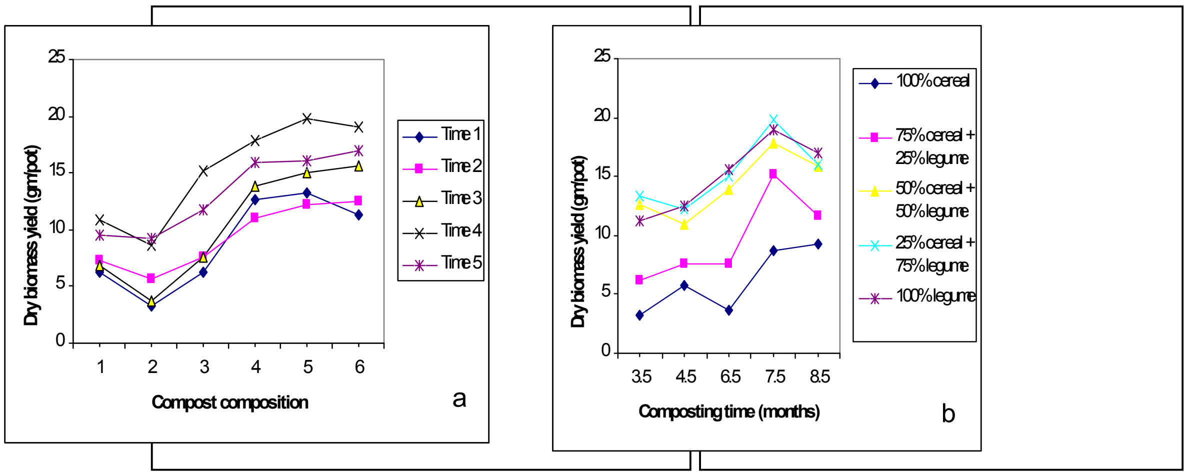

Figure 2. The effect of compost composition and composting time on dry biomass yield of tef

Grain yield

The treatments supplemented with compost containing 100% cereal straw gave lower grain yield values compared to the treatment which did not receive compost (Figure 3a). Other treatments, however, were better than the control treatment at all times of composting. The treatment with 25% cereal + 75% legume compost gave the highest yield almost at all times of composting followed by the treatment with 100% legume compost.

For all compost compositions, except the 100% cereal compost, composting time linearly increased grain yield of tef up to the 7.5 months of composting (Figure 3b). As composting time increased further to 8.5 months, grain yield declined. However, the 100% cereal compost exhibited an increase in grain yield as the time of composting extended.

Plant height

The treatment with 100% cereal compost gave lower plant height value than the treatment which did not receive compost at all (Figure 4a). However, the control treatment exhibited lower plant height value as compared to other treatments. As the legume composition was increased in the compost, plant height also increased.

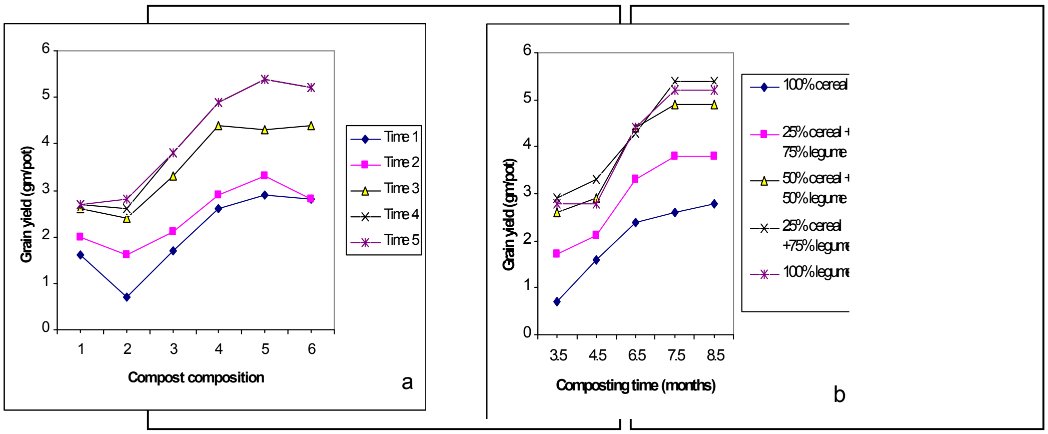

Figure 3. The effect of compost composition and composting time on grain yield of tef

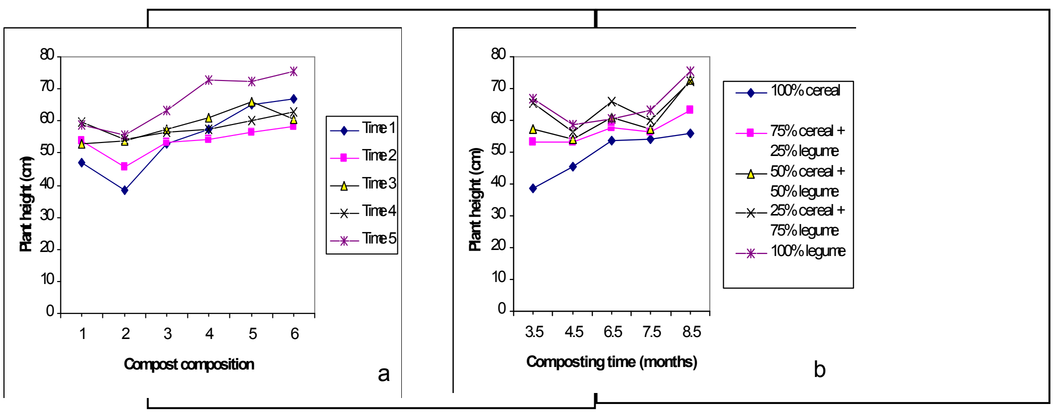

Figure 4. The effect of compost composition and composting time on plant height of tef

Plant height did not show a clear trend for composting time. However, it exhibited slightly linear trend with increase in time of composting (Figure 4b). The linearity of the trend was more superior for the 100% cereal compost than other combinations It was also noted that pots which received row compost were thinner and taller for most compost compositions. It was also clearly seen that pots which received 8.5 months old compost also tend to show increasing trend contrary to yield and yield components measured.

Comparison between mineral N fertilizer and compost

Pot experiment was also carried out to compare the effects of five rates of mineral fertilizer (0, 30, 60, 90, 150, 210 and 270 kg N ha-1) and the compost with the highest mineral nitrogen release (25% cereal + 75% legume) composted for 5 different durations, i.e., 3.5(T1), 4.5(T2), 6.5(T3), 7.5(T4) and 8.5 (T5) months. A rate of 90kg/ha mineral nitrogen gave the highest fresh biomass yield (51.7 gm/pot) among the mineral fertilizer treatments (Figure 5). When we compare the fresh biomass yield from this fertilizer rate with a 25% cereal + 75% legume compost composted for T1, T2, T3, T4 and T5 months, it was clearly seen that the mineral fertilizer gave more than a double fresh biomass yield advantage over the compost treatments. The compost composted for T4 months gave only 21.8 gm/pot fresh biomass yield.

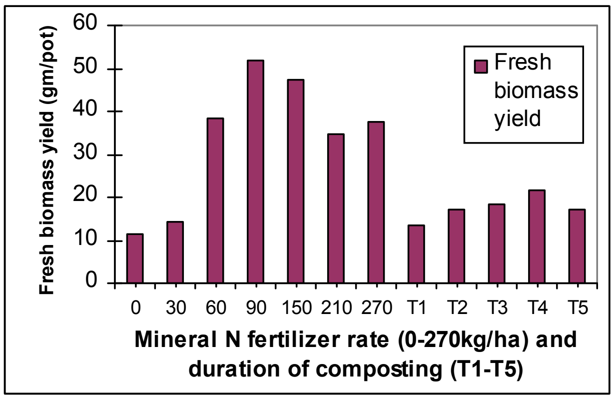

Figure 5. Comparison between fresh biomass yields of treatments that received different rates of mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

The rate of 90kg ha^{-1} mineral fertilizer rate also gave the highest dry biomass yield (Figure 6). The yield was 34.5 gm/pot which is a 14.7gm/pot dry biomass yield advantage over the 25% cereal + 75% legume compost with T4 composting time that gave the highest mineral fertilizer release.

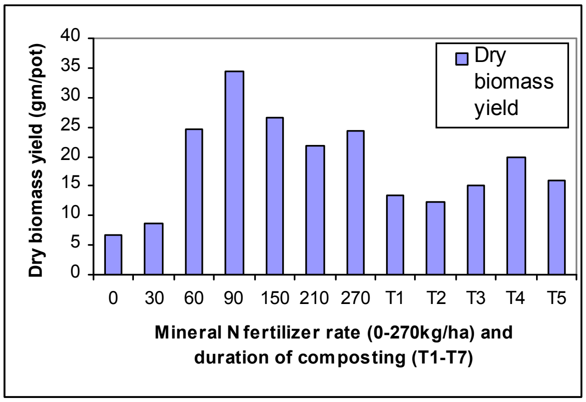

Figure 6. Comparison between dry biomass yields of treatments that received different rates of mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

When we look at the grain yield values obtained from mineral fertilizer rates and 25% cereal+75% legume compost composted for 5 different durations, it was clearly seen that the compost composted for 7.5 months (T4) gave the highest grain yield (5.4gm/pot) and the 90kg/ha mineral fertilizer rate treatment gave the highest grain yield (10.5gm/pot) (Figure 7). The yield from 25% cereal+75% legume compost composted for 7.5 months was higher than the yield from 30kg/ha mineral fertilizer rate but lower than the yield from 60kg/ha mineral fertilizer rate.

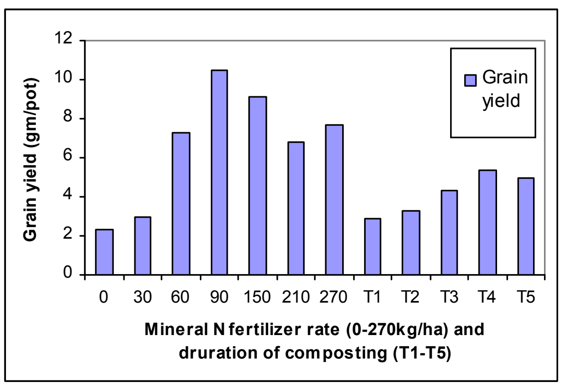

Figure 7. Comparison between grain yields of treatments that received different rates of mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

From the mineral fertilizer treatments, the highest plant height value (87.7cm) was registered from application of 90kg/ha mineral fertilizer. From the compost treatments, however, the highest plant height value was obtained from composting time of 8.5 months (72.1cm) (Figure 8). It is important to note that the differences in plant height among treatments were not wide enough as compared to the differences among treatments in fresh biomass, dry biomass and grain yields.

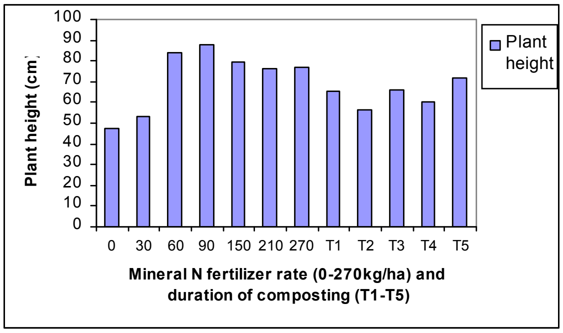

Figure 8. Comparison between plant height of treatments that received different rates mineral nitrogen and 10 tons of 25% cereal+75% legume compost composted for 5 different durations

Determination of inorganic fertilizer equivalency values of compost

The amount of available nitrogen release from the total N in the compost ranged from 3.76% in 100% cereal compost to 10.82% in the 25% cereal + 75%legume compost (Table 4). The amount of available N release demonstrated a curvilinear increase as the amount of legume in the compost composition increased. The amount of compost required to obtain 100kg of available nitrogen generally varied very widely. It ranged from 316.46 tons for the 100% cereal compost to 36.23 tons for the 25% cereal + 75% legume compost. This shows a negative correlation between cereal content in the compost and nitrogen release. As the composting time increased up to 7.5 months, the amount of nitrogen release increased and the amount of compost required to satisfy the inorganic nitrogen demand decreased.

Table 4. Determination of the amount compost required to obtain required available nitrogen content

Treat-ments	Composting time (Months)	Total N (%)	Available N (%)	Nitrogen release (%)	Compost to obtain 1kg available N (ton)	Compost to obtain 100kg available N (ton)
1	3.5	0.79	0.0316	4.00	3.16	316.46
	4.5	0.94	0.0353	3.76	2.83	283.29
	6.5	1.24	0.0496	4.00	2.02	201.61
	7.5	1.53	0.0614	4.01	1.63	162.87
	8.5	1.52	0.0603	3.97	1.66	165.84
2	3.5	1.06	0.0636	6.00	1.57	157.23
	4.5	1.09	0.0653	5.99	1.53	153.14
	6.5	1.32	0.0793	6.01	1.26	126.10
	7.5	1.6	0.0960	6.00	1.04	104.17
	8.5	1.58	0.0943	5.97	1.06	106.04
3	3.5	1.45	0.1454	10.03	0.69	68.78
	4.5	1.51	0.1498	9.92	0.67	66.76
	6.5	1.57	0.1544	9.83	0.65	64.77
	7.5	1.64	0.1682	10.26	0.59	59.45
	8.5	1.64	0.1497	9.13	0.67	66.80
4	3.5	2.01	0.2030	10.10	0.49	49.26
	4.5	2.39	0.2587	10.82	0.39	38.65
	6.5	2.59	0.2672	10.32	0.37	37.43
	7.5	2.67	0.2760	10.34	0.36	36.23
	8.5	2.68	0.2717	10.14	0.37	36.81
5	3.5	2.37	0.1949	8.22	0.51	51.31
	4.5	2.59	0.2582	9.97	0.39	38.73
	6.5	2.67	0.2617	9.80	0.38	38.21
	7.5	2.76	0.2757	9.99	0.36	36.27
	8.5	2.77	0.2683	9.69	0.37	37.27

Conclusions and Recommendations

From the results of the experiment it is possible to conclude the following;

1) The organic carbon contents in cereal and legume plant materials do not significantly vary among each other;
2) Legume plant materials have higher total nitrogen content and lower C/N ratios as compared to cereal plant materials;
3) As the composting time increases, the organic matter content and C/N ratio in compost materials decreases while the total N content and inorganic nitrogen release increases;
4) As the legume content in compost materials increases, the response of tef in fresh biomass, dry biomass, grain yield and plant height increases;
5) As composting time increases up to 7.5 months fresh biomass, the response of tef in dry biomass, and grain yield increases while there was no clear response in plant height.

6) The experiment clearly indicated that a huge amount of compost is required to obtain equivalent amount of nitrogen that could be obtained from mineral fertilizers.

From the results of the experiment it is possible to recommend the following:

1) The plant materials composition in compost need to be 25% cereals' and 75% legumes' stubbles. Increasing the proportion of cereal material above 50% could cause nitrate depression in the soil and subsequent yield reduction.
2) The optimum composting time for 100% cereal compost and 75% cereal + 25% legume is >8.5 months; for 50% cereal + 50% legume compost is 7.5 months; for 25% cereal + 75% legume compost is 4 months; and for 100% legume compost is 3 months. However, it is recommended that further study on nitrogen release dynamics of compost over years is required.
3) Since huge amount of compost is required to satisfy the nutrient demand of crops, compost should be applied in combination with mineral fertilizers for commercial purposes. This procedure will supply effectively the crop nutrient requirement as well as will improve the organic matter content and physical properties of the soil. However, for the subsistence type agriculture of Ethiopian farmers, compost remains to be very useful low cost organic fertilizer.

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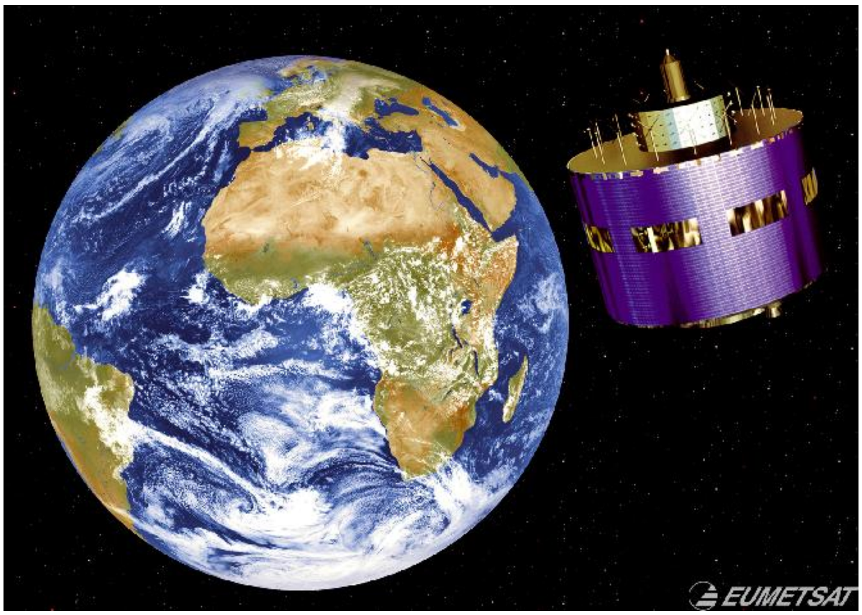

III) GIS and Remote Sensing Based Land Resource Studies

Relationship among environmental parameters (Physiognomic factors) and land cover in the Simen Mountains National Park, Ethiopia

Menale Wondie1, Werner Schneider2, and Demel Teketay
[1]Adet Agricultural Research Center, P.O.Box 08, Bahar Dar, Ethiopia; e-mail: menalewondie@yahoo.com
[2]University of Natural Resources and Applied Life Science, Vienna, Austria; e-mail: werner.schneider@boku.ac.at

Abstract

Environmental parameters (mainly altitude, aspect and slope) are responsible for distribution of land cover types. This paper shows the relationship of land cover distribution across environmental parameters through interpretation of satellite image of 2003 using the tools of GIS and remote sensing (RS). Digital elevation model (DEM) was used to generate elevation information and to georeference the Landsat image. With GIS and Remote Sensing land cover (LC) can be drawn and can have a potential for mapping the wildlife habitat and biodiversity in the park. Moreover, spatial analysis (using RS and GIS) are needed to support and get quick and economical acquisition of a vegetation map or LC with an appropriate balance between data accuracy and reasonable cost. Results of the satellite image analysis showed that forest cover is higher in steeper terrains; and agriculture and grassland are dominantly found above 3000m above sea level.

Key words: DEM, Environmental parameters, GIS, SMNP

Introduction

There are two major (primary) methods for capturing information on land cover (LC) or land cover change (LCC): direct field survey, and analysis of remotely sensed imagery (http://en.wikipedia.org/wiki/Land_cover 19/03/2007). GIS and remote sensing are important tools to understand various natural processes and socioeconomic situations both in space and time. GIS is a set of tools for collecting (acquiring), storing, analyzing, and displaying (visualizing) the spatial information. Particular uses of GIS comprise infrastructure and facility planning, land use planning, monitoring and assessment of environmental conditions, hazard mapping, urban change, land cover change (LCC), trend analysis of environmental alteration. With particular reference to land cover (LC) and LCC, GIS is used to understand the spatial and temporal patterns. Remote sensing (RS) is used in acquisition of information without physical contact of the source. Up-to-date global land cover data sets are necessary for various global change research studies, including climate change, biodiversity conservation, ecosystem assessment and environmental modelling (Giri et al., 2005). Since land cover is the actual distribution of physical and biological features of the land surface, up-to-date information on the status of the land surface is crucial for environmental planning and management (Melesse, 2004).

Remotely sensed image data are widely used in terrestrial, oceanographic, and atmospheric applications such as land cover mapping, environmental modeling and monitoring as well as updating of geographical databases of the specific area (Tso and Mather, 2001). Besides these, GIS and RS provide knowledge about the geographic distribution of land cover patches, which are important characteristics for evaluating the processes and effects of changes on the landscape and the watershed level.

In general, Tatem et al. (2003) noted that accurate information on land cover is required for both scientific research (e.g. vegetation change modelling, climate change modelling, and flood prediction) and for undertaking management interventions (e.g. habitat management, city planning, disaster mitigation etc). The assessment of the land cover type existing due to socioeconomic and ecological factors helps to qualify and quantify its status and has environmental implications on the ecological requirements of species. Particularly for Simien Mountain National Park (SMNP), it is necessary to know which kind of land cover type to know the threats or opportunities to the wildlife habitat, so that further decision making processes can be initiated, and to undertake management intervention for biodiversity conservation.

Disparate national and regional methods of statistics provide no definite data on where and when land cover changes occur. Furthermore, there is no universally accepted way to measure fragmentation and to assess the complex effects of the landscape pattern on ecosystems. Documentation of spatially referenced data on historic land cover/use practice and disturbance frequency is lacking for Ethiopia in general and the SMNP in particular. The acquisition of the corresponding information and data handling is often time consuming and requires many resources, especially in areas where there is little infrastructure, such as SMNP. Consequently, the environmental alteration is insufficiently perceived and understood by decision making bodies and the local users of natural resources in order to initiate further management interventions. Insufficient knowledge and lack of information on environmental change can lead policy makers to poorly justify and undertake unsound environmental decisions, which in turn can result in an inappropriate and unsustainable natural resources management (Viglizzo et al, 2002; Saadi and Abolfazl, 2003).

The primary criterion that distinguishes mountains, like SMNP, from other land surfaces is its significant positive relief (Ghosh, 2001) which creates different patterns of slope, aspect, complexity and heterogeneity of climate, vegetation, fauna and land use distribution patterns. The distribution pattern of land cover classes, land cover change and the ecological requirements of wildlife existing in the SMNP differ with respect to altitude, slope and aspect (Menale Wondie, 2007).

Despite all the ongoing effort, information gap still exists in the understanding of the spatial distribution of LC with respect to monitoring the dynamic changes of resources. Updated information on the status of the resources is required for sustainable management, especially biodiversity conservation and management. Therefore, this paper fills the information gap of LC across different environmental parameters (altitude, aspect and slope). It can further be used as a basis of information for a further identification of different wildlife habitats and future studies of biodiversity conservation and management. The main objective of this paper is to indicate the specific location and quantity of each land cover category in relation to environmental parameters with the help of GIS and remote sensing in the SMNP, northwestern Ethiopia.

Materials and methods

Description of the study site

Simen Mountains National Park is located in the northern edge of the Ethiopian central plateau. It is 820 km from the capital city of Ethiopia, Addis ababa. The altitude varies from 1900 to 4300m above sea level. The highest peak area of the SMNP is 4300m above sea level

The rainfall pattern is characterized by a unimodal rainfall (single rainy season), whereby the highest amount of precipitation is between June and September (Hurni and Ludi, 2000). Temperature ranges from -2^{0}C to 18^{0}C. In some cases, during the daytime there are strong and dry winds.

Due to difference in land use practice, geological event, topography and climate different soil types are found in the SMNP. Andosol is found on uncultivated land above 3000m a.s.l , whereas below 3000m and on cultivation land above 3000m a.s.l, the dominant type of soil are Phaeozem, Vertisol, Luvisol, Regosol and Leptosol (Hurni and Ludi, 2000). The grassland is dominantly covered with Andosol. The very small area, with no agricultural potential is attributed to Fluvisol. The Simen Mountain is made up of thick basalt deposited on Mesozoic sandstone and limestone, Precambrian crystalline basement, and harder rocks on the foot of the escarpment (Hurni, 1986).

The main source of income and livelihood strategy of the SMNP people is based on agriculture and livestock production (Endalkachew, 1999; Hurni and Ludi, 2000). The social status and economic background are contributing to the existence of various land cover types. In SMNP, different types of land cover are identified and categorized by the study of Hurni and Ludi (2000). These are cultivation land, grassland, bush land (shrubland), forest land and escarpment (“unusable land”). Hurni and Ludi (2000) indicate different habitats with respect to different land cover types. According to Nievergelt et al. (1998) agricultural activities and animal husbandry are the major two activities intensively undergoing in the SMNP.

Methods

Landsat ETM+ of 2003 dataset was acquired and used for image analysis to derive environmental parameters. Field observations were carried out to obtain Ground Control Points (GCPs) for georeferencing the images, to understand the features of the different LC classes, to support visual interpretation of the images and to select reference areas consisting of training areas (for supervised classification) and test areas (for accuracy assessment)). Representative samples were taken from agricultural land, grassland/pasture, forest, shrubland, settlement. In addition, Geographical Positioning System (GPS) data was used to create an independent dataset reserved for accuracy assessment. Physical description of different LC classes was carried out to be used as a reference during image analysis. The land cover categorization scheme was based on Hurni and Ludi (2000) & Amsalu et al. (2007) with some modifications (Table 1).

Table 1. Land cover classes used in classification scheme.

Cover class	Characterisation, features
Agricultural land /cultivation	Cultivated and fallow land, has a characteristic pattern, for example sharp edges between fields. Dark to grey colour in the Landsat image (4,3,2 colour composition), unless the land lies fallow. Hurni and Ludi (2000) and Amsalu et al. (2007)
Grassland/Pasture	Land under permanent pasture and grassland, grassland mixed with lobelia. Homogeneous, no pattern compared to agricultural land. Hurni and Ludi (2000)
Mixed and matured natural forest*	Natural forests and woodland with a composition of different tree species
Pure Forest*	One dominating species (*Ericaceous species*, >95% of the mix)
Shrubland*	Shrubs, bushes and young tree species, bright red on the Landsat 4,3,2 colour composite

*Based on field data, modification of the classification scheme of Hurni and Ludi (2000)

The Landsat ETM+ 2003 image was georeferenced using 69 GCPs. The 2003 ETM+ Landsat image was rectified to the UTM projection system WGS-1984-UTM-Zone37N. The total Root Mean Square (RMS) error was 0.95 pixels which is about 28 metres. The residual of individual GCPs vary from 0.16 to 1.76 pixels (4.8 to 52.8 m) . Due to the rugged topographic nature of the area and the existence of limited information on GCPs for SMNP, the RMS error is assumed to be satisfactory. The orthorectification resampling method used was the nearest neighbour which is better for land cover classification (Edward (ed.), 2000; McCloy, 2006).

The method used to classify the Landsat image to the respective LC was maximum likelihood supervised classification using ERDAS Imagine 9.1 software. Pixels were clustered into the categories of five known classes: agriculture mixed natural forest, pure forest (dominant by >95% *Ericaceous species*), shrubland mixed and/or young species of trees, grassland and one unknown category that remained as unclassified (or defined as shadow). In total six categories were identified. Areas of Interests (AOIs) were selected as training areas for classification. The training points are distributed in the area of each LC type. The number of sample AOIs for agriculture, natural mixed forest, pure forest, shrubland, grassland and shadow was 128, 50, 53, 65, 56 and 34, respectively. The overall approach of land cover mapping is shown in Figure 1 below

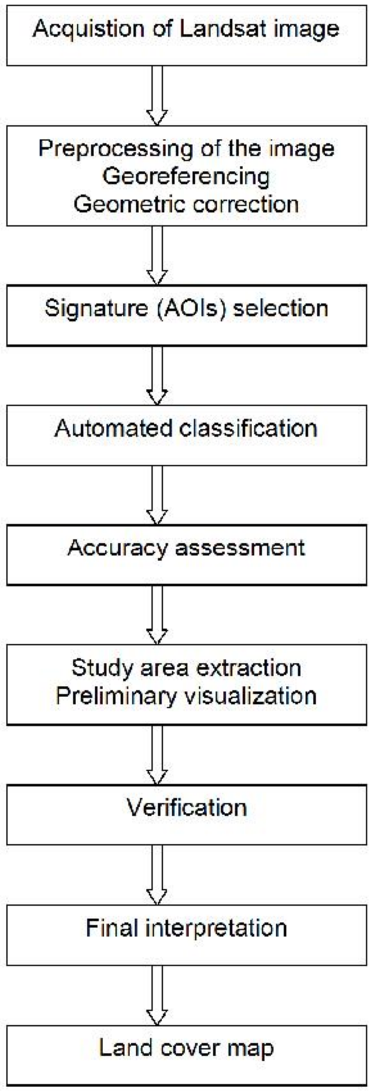

Figure 1: The approach adopted for LC mapping

Spatial analysis of LC types was undertaken to identify their distribution across the environmental parameters. Altitude, slope and aspect are categorized into five, six and eight classes, respectively. The distribution of each categories of LC is correlated to each class of environmental parameters.

Results and discussion

Land cover distribution across environmental parameters

The distribution pattern of land cover classes and the ecological requirements of both animals and plants differed with respect to different environmental situations such as altitude, slope and aspect. These three environmental parameters are considered to evaluate the distribution of different categories in the study site. Environmental parameters could sometimes be special species habitats and indicators of richness in biological diversity.

Altitude

Altitude is one of the parameters determining the distribution of land cover classes. The natural distribution of forests is sensitive to altitude due to the physiological requirement. These ranges are identified using an ERDAS^{TM} Imagine modeler. The altitudinal ranges are categorized into five classes with an interval of 500m. The categories are: below 2000m, 2000-2500m, 2500-3000m, 3000-3500m, 3500-4000m and 400-4500m a.s.l. The extent of each altitude category is indicated in Table 2 below.

Table 2. Extent of each altitude range across the study site.

	Total area in each altitude	
Altitude (meters a.s.l.)	ha	%
below 2000	225.00	1.62
2000-2500	2043.00	14.69
2500-3000	3449.34	24.80
3000-3500	4543.56	32.67
3500-4000	3590.10	25.81
4000-4500	56.34	0.41
Total	13907.34	100.00

About 98% of the study area lies between 2000 and 4000m. Only 2% are classified as lowland areas in the SMNP. The elevation category 3000-3500m is dominant (32.67%). In this elevation category 3000-3500m, 40.56% of the area is utilized for agriculture. 47% of the pure forest dominated by *Ericaceous species* is found in this range. About 55.92% of the grassland is concentrated between 4000-4500m. Land cover distribution across each slope category is indicated in Table 3 below.

Mixed forest and shrubland areas are concentrating between 2500 and 3500m. Pure forest dominated by *Ericaceous species* is a highland species, which are found mainly from 3000 to 3500m. The result shows that the increase of forest area proportionally with elevation that is higher forest was found at “Gich” plateau. The distribution of LC categories showed that the higher altitudes (between 3500 and 4000m a.s.l) are dominated by grassland and agricultural land. Agriculture and grassland has lower extent in the lower areas of the park as compared to the other LC classes.

Table 3. Distribution of LC over altitude.

Altitude (m)	Categories (ha)						
	Shadow	Mixed forest	Pure forest	Shrubland	Grassland	Agriculture	Total
Below 2000	4.23	45.45	3.42	69.57	30.96	71.37	225
2000-2500	80.91	697.86	109.17	603	190.17	361.89	2043
2500-3000	349.92	1003.86	551.88	772.83	217.17	559.98	3455.64
3000-3500	423.45	318.69	1014.12	559.8	378.27	1842.93	4537.26
3500-4000	129.51	94.59	492.93	303.75	2007.45	561.87	3590.1
4000-4500	0.09	0.09	1.62	1.08	52.38	1.08	56.34
Total	988.11	2160.54	2173.14	2310.03	2876.4	3399.12	13907.34

Aspect

Aspect is one of the environmental parameters which influence parameters such as exposure to sunlight, drying winds and evapotranspiration. Hence, aspect has implication to physiological and ecological requirement of the species. In this particular study, the aspect map of the SMNP is produced to illustrate the relationship between land cover distribution and aspect. Aspect regions are classified into eight groups (see figure 2 below) namely: north (337.5°–22.5°), northeast (22.5°–67.5°), east (67.5°–112.5°), southeast (112.5°–157.5°), south (157.5°–202.5°), southwest (202.5°–247.5°), west (247.5°–292.5°) and northwest (292.5°–337.5°). The difference between neighboring categories is 45°.

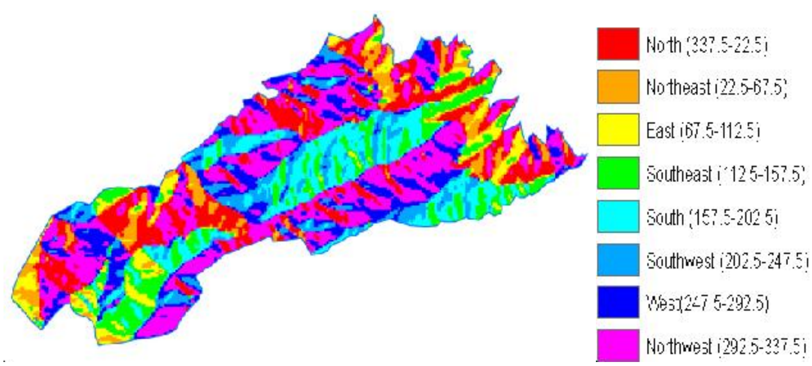

Figure 3. Distribution of the aspect categories in the SMNP

The spatial distribution of individual LC types across aspect is indicated in Table 4. As the result indicates, northwest and north directions favour the distribution of forest areas, but agriculture and grassland dominate between 112.5° to 247.5° which is southeast to southwest. Little or no flat land is found in the SMNP.

Table 4. Spatial distribution of individual cover categories across aspect.

		Categories (ha)						
Aspect	Azimuth (degree)	Shadow	Mixed Forest	Pure Forest	Shrub-land	Grass-land	Agri-culture	Row total
North	337.5 - 22.5	227.52	621.45	548.82	424.44	176.31	316.35	2314.89
Northeast	22.5 - 67.5	25.47	185.04	160.02	360.45	128.79	223.56	1083.33
East	67.5 - 112.5	8.46	65.97	53.64	311.76	146.88	317.79	904.5
Southeast	112.5 - 157.5	3.87	42.3	73.53	287.73	506.43	590.04	1503.9
South	157.5 - 202.5	3.96	35.91	127.26	193.77	723.78	549.36	1634.04
Southwest	202.5 - 247.5	32.49	136.44	101.7	165.15	426.69	401.58	1264.05
West	247.5 - 292.5	214.47	307.26	274.86	200.7	386.73	428.67	1812.69
Northwest	292.5 - 337.5	471.87	766.17	833.31	366.03	380.79	571.77	3389.94
	Column total	988.11	2160.54	2173.14	2310.03	2876.4	3399.12	13907.34

Slope

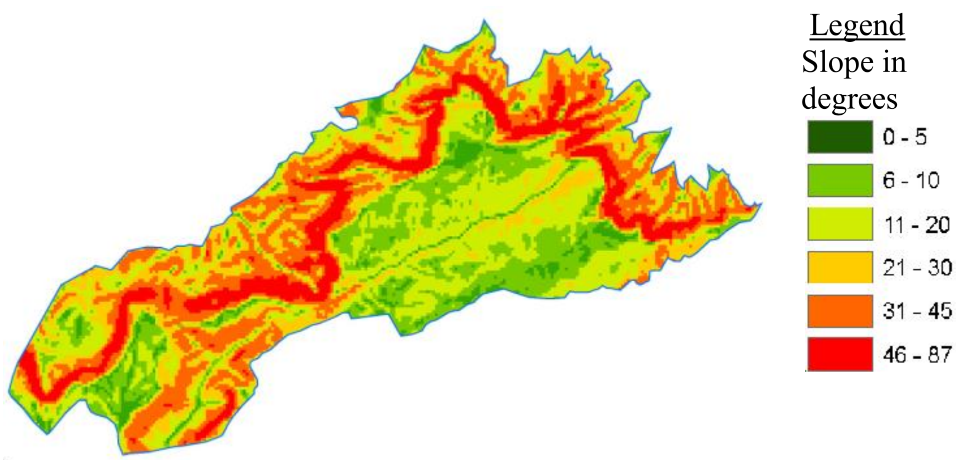

Figure 3. Categories of Slope in the SMNP

The slope map of the SMNP is categorized into six classes (Figure 3). In most of the cases the slope angle is directly related to land cover distribution and to the stability of plants. Theoretically, steeper topographic features are assumed to be not suitable to agricultural crops production and grazing land due to inaccessibility and fragility of the land.

The slopes are classified using the modeler of ERDAS. Table 5 showed the distribution each slope category According to the result slopes of 11-20 degrees are the dominating classes, but the extent of flat land is very small. 1420.92ha (65.77%) of the area of mixed forest, 1206.54 ha (55.52%) of the area of pure forest and 1241.55ha (53.75%) of the area of shrubland / young trees are situated on slopes of 21-45°. Relatively gentle slopes of 0 to 20° are covered by agricultural and grassland to the extent of 1941.93ha (67.511%) and 2177.37 (64.06%) respectively.

Table 5. Summary of area extent and percentage of each slope category

	Area coverage	
Slope category (degree)	ha	%
0-5	436.32	3.14
6-10	2298.96	16.53
11-20	3849.75	27.68
21-30	2707.83	19.47
31-45	3090.60	22.22
46-87	1523.88	10.96
Total	13907.34	100.00

Table 6. Spatial distribution of cover categories across slope

	Categories (ha)						
Slope (degree)	Shadow	Mixed Forest	Pure Forest	Shrubland	Grassland	Agriculture	Row total
0-5	1.89	11.25	8.91	25.56	233.64	155.07	436.32
6-10	10.98	70.74	76.41	156.6	1031.04	953.19	2298.96
11-20	43.11	454.05	557.82	659.7	910.89	1224.18	3849.75
21-30	90.45	696.42	525.42	644.58	254.43	496.53	2707.83
31-45	321.03	724.50	681.12	596.97	348.66	418.32	3090.6
46-87	520.65	203.58	323.46	226.62	97.74	151.83	1523.88
Column total	988.11	2160.54	2173.14	2310.03	2876.4	3399.12	13907.34

Major anthropogenic activities both agricultural activities and grazing land (grassland) are dominantly undertaken on the gentle slopes. Steeper slopes favour the survival of forests. According to table 6, the shadow increases from flat to steeper terrain. But the other LC categories have more or less a bell-shaped distribution along each slope category.

Discussion

Environmental parameters such as altitude, slope and aspect have been investigated and located. The DEM had artifacts. The artifacts became visible especially when displaying the slope, as slope patterns which never exist in nature occur in areas which obviously had been treated by the hole-filling algorithm in the CGIAR-CSI DEM. Areas of the DEM which showed artifacts were replaced by data interpolated from contour lines (isolines) of the map of Hurni (2003).

About 98% of the study area lies between 2000 and 4000m. Only 2% are classified as lowland areas in the SMNP. The elevation category 3000-3500m is dominant (32.67%) of the total area of the park. Since large areas of the SMNP are situated between 3000-4000 m a.s.l, the significant change is also observed in these altitudinal ranges. But the transformation of mixed forest and agriculture to shrubland is facilitated between the ranges of 2000 m and 3000m. Pure forest which is dominated by *Ericaceous species* increased in areas mainly at elevations from 2000 m to 3000 m. This could be due to decline of agriculture and grassland.

The slope map of the SMNP is categorized into six classes based on Hurni (1986) classification and using knowledge of the distribution of different land cover types. In most of the cases the slope angle is directly related to land cover distribution and to the stability of plants. Theoretically, steeper topographic features are assumed to be not suitable to agricultural crops production and grazing land for domestic animals due to inaccessibility and fragility of the land. But in the SMNP there are steep slopes used for cultivation of crops and used for animals grazing due to scarcity of land per household head. As indicated from the result of the study major anthropogenic activities (agriculture and grazing) are dominantly undertaken on the gentle slopes. However, steeper slopes favour the survival of the natural forests. The dominant LCC occurs at slopes between 11 and 45° slope. The conversion of mixed forest to pure forest and shrubland is higher in the steep slopes, mainly at 21 to 45°. The steep slopes were found to disfavour the expansion of agricultural and grasslands.

Aspect is one of the environmental parameters which influence exposure to sunlight, drying winds and evapotranspiration. In this particular study, the aspect map of the SMNP is produced to illustrate the relationship between land cover distribution and aspect.

The ecograms of the species can be developed by analyzing the altitude, aspect, slope and other environmental parameters and hence ecological management intervention can thus be facilitated. Wildlife habitat management and planning can be carried out in relation to environmental parameters and depending on the resource (land cover type) existed in the area. Different management activities of the major wildlife habitat conservation sites can be designed using the information of the location of altitude, aspect and slope in the SMNP.

Conclusion and recommendation

Using Landsat TM 1984 and ETM+ 2003 datasets, LC can be detected and categorized. The results of this study show that integration of GIS and remote sensing is effective in monitoring the overall status and analyzing land cover patterns as a function of environmental parameters such as altitude, slope and aspect. In general, the spatial distribution of the individual LC classes is the result of both human and biophysical nature of the SMNP.

Forests usually found on high and steep terrain where agriculture is scarce on steep terrain. The Landsat images proved notably useful in analysis of the ecological trends on a time-series basis and can be used for planning measures for restoration of the SMNP ecosystem. Detection of different environmental parameters might also help to know, plan and create a diversity of habitats available to plant and animal species, and finally contributes to overall increase of the species diversity. To meet the objectives of the SMNP, wildlife habitats, conservation sites, and management units can be identified and delineated with the help of GIS and RS to set up development strategies, design management activities and make decision on natural resources management.

Spatial analysis of LC indicates the overall situation and highlights the trends of the SMNP in terms of land cover. Therefore, this study can provide basic information for efficient and effective monitoring of land cover in relation to wild life habitat condition.

The resource managers can superimpose the land cover map to existing management and conservation zone maps and use it as a planning tool for the optimization of protection sites within the park, providing information on the status of wildlife and natural resources. Furthermore, the land cover map can provide information as an indicator of the overall environmental quality and direction of change of the SMNP. Environmental parameters may be used as hints to plan the restoration of the park and to support strategic decisions for conservation and development policy.

The ecograms of the species can be developed by analyzing the altitude, aspect, slope and other environmental parameters and hence ecological management intervention can thus be facilitated. Wildlife habitat management and planning can be carried out in relation to environmental parameters and depending on the resource (land cover type) existed in the area.
Land cover map analysis is used to display the overall situation, visualize and identify dominant LC categories, physical processes and trends in SMNP. Land cover map can be used to visualize the status of the SMNP both by indigenous people and policy makers, so that to feel the changes and suggest the possible solution.

Land use activities cannot be explained by image analysis in this study. Only the physical features of the park are displayed and analyzed. Therefore, deep investigations on the inherent characteristics of different LC classes have to be carried out. The carrying capacity of the park determines the prospective of the SMNP to conserve the biodiversity and to meet the social, ecological and economical needs of the indigenous people. To overcome this problem, it is necessary to investigate the interrelations of the environmental parameters, the land cover status, and the demand of the people. On this basis, it should also be possible to recommend an optimum size of the park to maintain the current biodiversity (mainly endemic and rare species in their specific habitats). A compromise between the stakeholders is needed to facilitate both policy issues and management strategies in relation to land cover. Management activities can be designed using the information of the location of altitude, aspect and slope in the SMNP.

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Economic and environmental Importance of wetlands of the Lake Tana Basin (LTB) and requirements for sustainable land management

Birru Yitaferu (PhD)
Soil and water research Directorate, Amhara Region Agricultural Research Institute (ARARI)
P.O.Box 527, Bahir Dar, Ethiopia (E-mail: birru_yitaferu2002@yahoo.com)

Abstracts
Economic and ecological relevance of wetlands in Ethiopia have not been well recognized. Traditionally, riparian lands in Ethiopia have been considered as problematic lands such as swap lands as a harbor to malaria; rivers as harboring of crop pests such as birds and wild beasts. However, with the ever increasing human population and the intensified demand for food grain, more riparian lands (particularly wetlands) are seen recently converted into intensive agricultural land use. As a result, the natural habitat of lakeshores, wetlands and riverine ecosystems have been seriously damaged and their land uses permanently converted. Apart from the loss of the main resources (wetland vegetation, water, biodiversity and habitats), there are interlinked and externalized consequences due to the degradation of these particular ecosystems through adverse loss of soil from the destabilized riverbanks, frequent flood occurrence, sedimentation and pollution of reservoirs downstream. In this paper, detailed definitions of wetlands, a range of benefits due to the management of wetlands were discussed thoroughly. Wetlands of the Amhara Region, dynamics and opportunities for sustainable management of the resources were discussed based on the case study carried out in the Lake Tana Basin (LTB). Thus, it was concluded that the sustainable management of wetlands in the basin was a complex combination of ecological, economic and social objectives determined by the participation of multiple stakeholders in a transdisciplinary research approach.

Key words: wetland, Sustainability, Amhara Region, Lake Tana Basin

1. Introduction

Wetlands are a very important aspect of the environmental resource base of Ethiopia. They produce a range of ecological and economic benefits in their natural state, which contribute to the well being of rural communities and the environmental security of the country. However, wetlands are often seen as wetlands that have no value and are best converted by drainage to allow agriculture or grazing. Such conversion may create some new benefits – increased food production and grazing, but will generally cause the loss of many other benefits. Indeed, in the end, the net result of converting wetlands can be serious environmental degradation and loss of benefits to the community. Economic analysis of the process of wetland conversions shows that wetlands are more vulnerable when used in a way that influences their natural functions (Wood, 2001).

The generally perceived wisdom is that wetlands should not be cultivated because they are fragile ecosystems which can easily be destroyed. Further it is understood that if wetlands are cultivated the hydrological system will be disrupted with increasingly erratic stream flows. However, the reality is that wetlands have become the "new agricultural frontier" in many African countries over the last few decades. Wetland farming has expanded as population growth and where land degradation has increased the pressure upon "upland" areas used for rain-fed cultivation. Wetlands now play an increasingly important role in food security, sometime as the new frontier for domestic production by poor people, but in other cases they have been appropriated by rural elites for market oriented production.

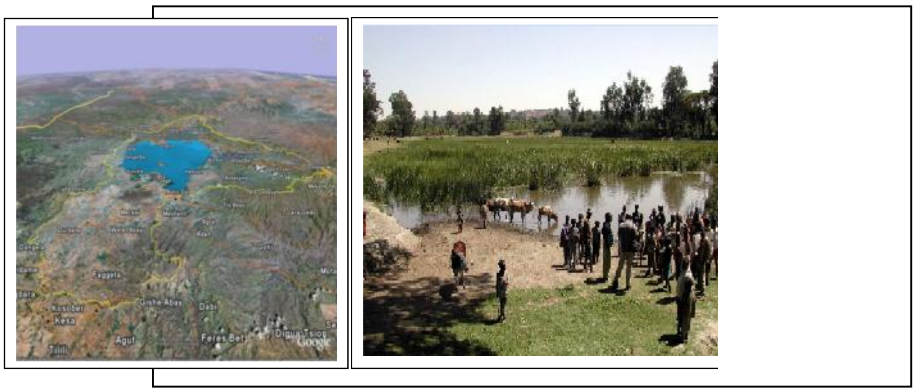


Figure 1: A 3-Dimensional view of the Lake Tana Basin (LTB) and characteristic nature of the wetlands in the basin

The livelihoods of many poor people in the developing world depend to a large extent on intact and functioning wetlands for the simple reason that many of the poor rely on wetlands for food, water, construction materials and for other necessities. Wetlands also act as wildlife corridors and provide protection against flood, drought and intrusion of pollutants – all functions crucial to environmental and food security. Hence the maintenance of healthy wetlands is important for poverty alleviation, and because wetlands are critical to water supply they are literally the source of life. Experience has shown that solutions to wetland degradation and over-exploitation must be based on a thorough understanding of how wetlands contribute to people's livelihood strategies. This concept challenges conventional approaches to conservation and development. Whereas in the past conservation of wetlands did not necessarily recognize the need to address local poverty issues, history and practice have shown that where wetlands have been degraded, poverty generally also increases, leading to even greater wetland degradation. With so many people directly dependent on wetlands and wetland resources for their livelihoods, protecting and restoring wetlands is clearly in the interests of reducing poverty and vulnerability to poverty.

While it may not be possible in all cases to identify ways in which wetlands can be used in ecologically sound ways, there is evidence from Ethiopia that some cultivation in wetlands is feasible with a high level of sustainability and maintenance of part of the hydrological regime (Wood et al., 1998). This is only possible if the natural dynamics of wetlands and their catchments are understood and efforts made to maintain and replicate these. In other words an approach is needed with replicates the ecology of the area in the agricultural system – an eco-agriculture approach. Thus, the main objectives of the present study are to show states and dynamics of wetlands in the LTB and to create awareness among stakeholders about values/functions of the wetlands for sustainable management of the resource.

2. Overviews of the concepts and principles of wetland management

Which land areas are said to be wetlands?

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. 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 (Wood, 2001). Some wetlands may be permanently flooded, whilst others may have water close to the surface for only a few months in a year. Wetlands are lands that are transitional between terrestrial and aquatic ecosystems wherein the water table is usually at or near the surface and the land is covered periodically by shallow water; those lands must have one or more of the following attributes (Sierra Club):

1. At least periodically, it supports predominantly hydrophytes;
2. Its substrate is predominantly undrained by hydric soil; and/or
3. Its substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

There are two major sources of water that determine the type of wetlands (Moorman and Breemen, 1978):

a) *Hydromorphic or phreatic wetlands*, which mainly receive water from ground water as well as precipitation.
b) *Fluvial wetlands*, which mainly receive water from surface water, runoff, streams, etc.

Functions/ values of wetlands

Even though wetlands vary in the values they bestow, depending on local variations in hydrology, soils, vegetation, and topography, healthy and functioning wetlands are vital for protection of the environment and public health. Simply put, wetlands are transitional areas that act as buffers between open waters and uplands and provide certain values/functions such as:

i. ***Environmental values/wetland functions***

- Water quality maintenance, aquatic productivity, microclimate regulation, etc.
- Fish and wildlife values (fish and shellfish, waterfowl and other birds, and furbearers and other wildlife)
- Filter pollution, purifying drinking water, and protecting rivers, lakes, and coastal waters from pollution, such as sediment, nutrients, chemical contaminants, and bacteria
- Recharge groundwater aquifers
- Provide habitat functions for plant and animal species, including threatened or endangered species, and a corridor function between the terrestrial and water bodies

ii. ***Socioeconomic values/functions***

- Flood control, erosion control, water supply, fishing and hunting, aesthetics, research, and education, etc.
- *Absorb floodwaters, protecting coasts and homes from flood damages*
- *Provide local tourism industries with opportunities to engage in activities associate with such wildlife*

What are the major causes of wetland degradation?

Degradation of wetlands is largely caused by human activities, and can result from hydrological degradation, pollutant inputs and removal of vegetation.

Hydrologic alterations

- Deposition of fill material for development.
- Drainage for development, farming, and mosquito control.
- Dredging and stream channelization for navigation, development, and flood control.
- Diking and damming to form ponds and lakes.
- Diversion of flow to/from wetlands.
- Increasing impervious surface areas, which increase pollutant runoff into wetlands.

Pollution inputs

- Runoff from urban, suburban, agricultural, silvicultural and mining activities.
- Air pollution from cars, factories, and power plants.
- Leaking landfills and dumps.
- Marinas, which cause increased turbidity and release pollutants.

Vegetation removal

- Vegetation removal associated with development activities.
- Grazing by domestic animals.

- Introduction of nonnative, invasive plan species.
- Removal of vegetation for peat mining
- Removal of vegetation for domestic use (energy, construction and others)

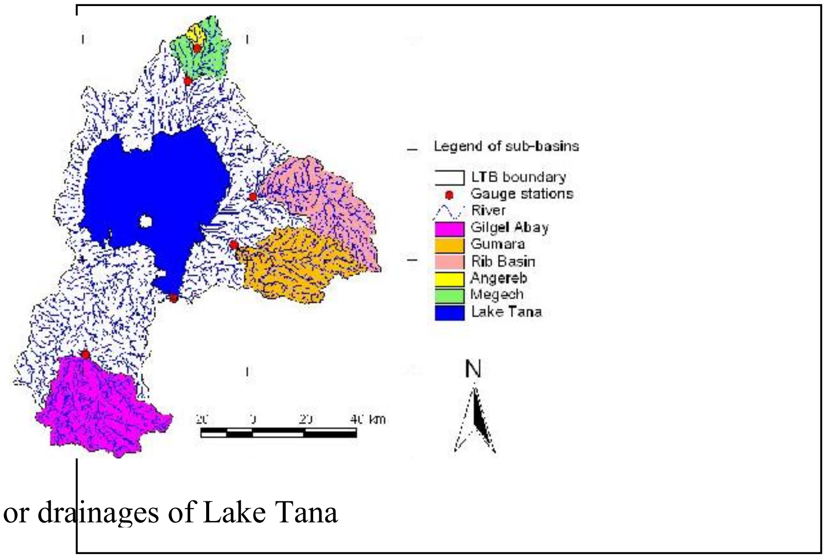
3. States and dynamics of the wetlands of the Lake Tana Basin (LTB)

The Lake Tana Basin (LTB) is the source of the Blue Nile that endowed with abundant water resources in the form of surface and groundwater. There are a large number of springs and rivers in the LTB draining from the mountain areas and flow to the wetlands and the lake. The central area of the basin is covered by the lake water that accounts for about 3,050 km^2 (20% of the basin). The mean annual rainfall of the basin is about 1400 mm (ranging from 900 to 2000 mm), which makes the basin water tower of the region.

3.1 Methodological consideration

The Lake Tana Basin (LTB) is part of the Nile River Basin situated at the upper course of the Blue Nile River in Ethiopia. The basin is bounded between latitude 10°58`–12°47`N and longitude 36°45`- 38°14`E. The LTB is divided into four major river sub-basins: River Gilgel Abbay in the south, River Gumara in the east, River Ribb in the northeast, and River Megetch in the north (Figure 2). However, including the perennial and other seasonal rivers and streams, the number of drainages that flow into the Lake Tana is estimated to be about 66 (Birru, 2007). Wetlands of the LTB were extracted from landsat images and by using SRTM topographic database (USGS, 2006). Flooded areas outside the lake were digitized using ArcView GIS software tool on images in October (see Table 1). The digital elevation model analysis is also provides major wetlands near the lake.

Degradation of the wetlands were studied based on conversion of the wetlands to crop cultivation, loss of native vegetation, expansion of invasive weeds in the wetlands and loss of the wetland functions. A participatory appraisal of the sustainable management of the riparian lands (wetlands, lakeshores and riverine systems) was carried out using the Multiple Objectives Decision Support System (MODSS) tool (Robinson, 2000). In the appraisal activity, major stakeholders including farmers and development agents were involved. The participatory appraisal data was subjected to a statistical analysis using Facilitotor software (Robinson, 2000) and land management practices or systems were selected based on their performance against average values of the evaluation criteria on sustainability of a land management practice or a land management system in question.



Major drainages of Lake Tana

Figure 2: Rivers and drainage basins within the LTB derived from the SRTM DEM database with resolution of 90 metres (SRTM) (USGS, 2006)

3.2 Major wetlands of LTB and their changes

During the dry season, agricultural people in the LTB used wetlands for dry season grazing and growing low moisture demanding crops such as Chickpea and Grass pea (*Vicia desycarpa*) late in the season. However, with the ever-shortage to arable land, wetlands are further threatened by draining their water for early cereal cropping. Since the topographical situation of wetlands is usually plain and sediment deposition, traditional irrigation system exploits the water very easily. Traditionally, these places are known as *'Bahire-shesh',* which means that farmlands the moisture which can support second cropping late in the season.

Ecological and economic functions and/or benefits of wetlands need to be recognized and widespread. They serve a buffering purpose for the perpetuation of both the water bodies downstream by absorbing various non-point source pollutants and sediments before reaching reservoirs. Speed of runoff will get lower; because of the slope of the lower plain and thick biomass effects of the wetlands. Lake Tana being surrounded by plain and wetlands is an opportunity to the lifespan of the lake and its economic and ecological functions, which otherwise could have been silted up by the agricultural soils that annually trapped in the surrounding plain and wetlands. In this regard, despite the serious land use changes, LTB is endowed with wetlands that cover about 159,800 ha of land (Table 1).

Wetlands of LTB are more of the fluvial type, which receive their water largely from surface runoff and streams. Being *fluvial wetlands* and richness of the basin with surface runoff and precipitation, in turn, make the wetlands more resilient. However, the problem remains for so long is that people perceive wetlands as a place of breeding malaria and other tropical diseases.

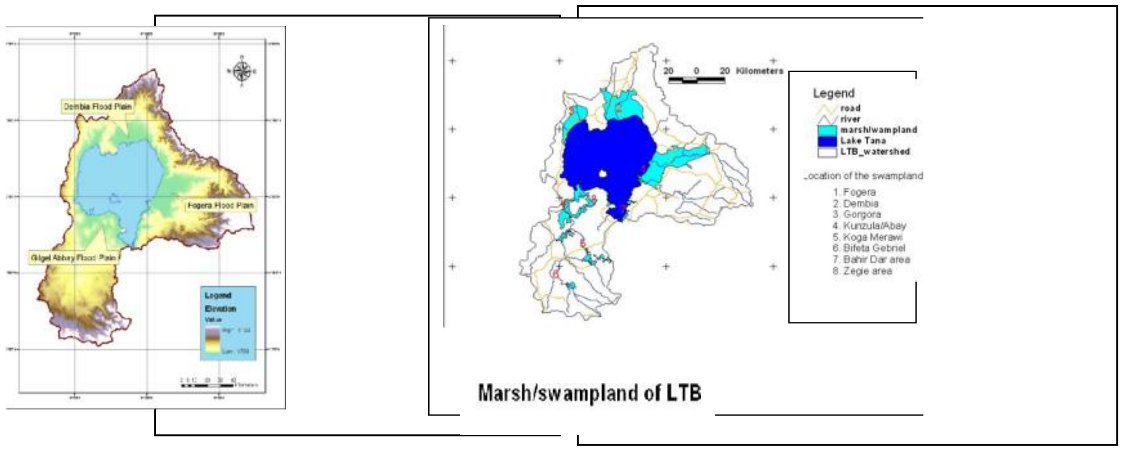


Figure 3: Wetlands and flood plains of the LTB situated across the basin that are currently seriously converted into croplands and grazing lands (Source: digitized from Landsat images (using etm+ image 169/52 for 01 Oct 1999, image 170/51 for 01 Nov 1999 and image 170/52 for 01 Feb 2001)

Fogera Floodplain: Flooding in the Fogera plain is caused by:

- bank overflow from the Ribb and Gumara rivers
- runoff from local rivers that end in depressions
- direct rainfall

Based on the main cause of inundation, the Fogera plain can be divided into three major zones: the upper, middle and lower zones. ***The upper Floodplain zone*** is mainly caused by spill from the Ribb river and a number of smaller tributaries, including the Sheni. In this area the floodwater does not stay long and it was observed to disappear at times even in 3 or 4 days. Most of the flood water quickly drains back to the river and from there to the lake. ***The middle Floodplain zone*** of the Fogera flood plain is the area where the Shesher and Welela Ponds are located in depressions. The major causes of flooding in this area are the local rainfall and the small local streams that end in these wetland areas. During large floods in the Upper and Lower Flood zones, there is additional spill from these zones into this area. Since this area does not have an outlet either to the lake or to the rivers, the flood water stays for a longer period and is mainly depleted through evaporation in the dry season. ***The lower Floodplain zone*** of the Fogera plain is mainly caused by spill from the Gumara River. Especially, the left bank of the river is prone to overflow but also spills over the right bank are observed, which sometimes join the inundated area in the Middle zone. The total maximum inundation area in three zones of the Fogera plain reached 597 km2 in 1999, whereas it was reported by the Tana-Beles study about 333.6 km2 for the 8-day average in 2003.

Dembia Flood Plain

In the Dembia floodplain, flooding occurs mostly in the lower part of the Megech, Dirma and Shenzli rivers (Figure 3). The maximum inundated area of the Dembia and Gorgora floodplain during the period in 1999 was about 459 km2 (Table 1).

Table 1: Wetlands of the Lake Tana Basin

No.	Location of swampland	Sub-basin	Area (ha)	Source: TM Landsat image
1	Fogera	Rib and Gumara	59700	169/52,01-10-99
2	Dembia	Megech	45900	170/51,01-10-99
3	Gorgora		21000	170/51,01-10-99
4	Kunzula-Abay	Gilgel Abbay	22800	170/52,01-02-01
5	Koga dam site	Koga River	5400	170/52,01-02-01
6	Bifeta Gebriel	Gilgel Abbay	1900	170/52,01-02-01
7	Bahir Dar Lakeshores	Lake Tana bay	2200	170/52,01-02-01
8	Zegie Lakeshores	Tana Shore	900	170/52,01-02-01
	Total		159,800	
9	Lake Tana	Water body	302,676	170/52,01-02-01
Grand Total			462,476	

Gilgel Abbay and Koga flood plains

In Gilgel Abbay and Koga area the flooding occurs in some flat plains along the rivers Gigel Abbay and Koga in the southern part of the Lake Tana. According to the Tana Beles report (SMEC International, 2008), some flood plains of Istumit district was considered. The flooding along the Gilgel Abbay is essentially caused by bank overflow from the Gilgel Abbay. The maximum area of inundation in the Gilgel Abbay and Koga floodplains was about 282 km2. Excluding the wetland of Bifeta-Gebriel and Koga Dam site, the Tana-Beles study report gave about 64 km2 occurred in 2006. However, starting from the wetland of Bifeta Gebriel at the foot of Gish Abbay highlands, there are a number of small wetlands along the River of Gilgel Abbay until it joins Istumit and Lake Tana.

There are also wetlands around Bahr Dar and areas away from the course of the major rivers, which accounted for about 22 km2. Thus, the LTB has a total wetland and floodplain areas of about 1,598 km2 or 11.9% of the area of LTB.

3.3 Major problems of the wetlands of LTB

The extended plain and wetlands in the north and north-east that connect the lake with the subsequent foot-slopes were intact until very recently and covered with dense grasses, sedges and shrubs that are typical of riparian vegetations. Since the largest part of the plain surrounding the lake has little altitudinal differences (about 10-15 m high) from the level of the lake, seasonal floods put these lands under water cover for some time after the rainy season, which made the area less important for main season cropping for so long. The other reason that could have kept the plain intact for so long might be the problem of malaria infestation of the place and the long existing fear of the highlanders to live in such hostile environment. According to some study reports (LURD of MoA, 1982), the eastern and northern swamplands were about 85 percent grassland before the 1980s. It is, thus, understood that the observed LUCCs in the lower plain area of the LTB, in the last 20 years, was largely attributed to the cultivation of the wetlands of the Fogera and Dembia plains. Even though it is difficult to clearly differentiate the wetlands under cultivation and areas uncultivated from the landsat images, our filed observation for the Fogera plain in 2005 confirmed that little or no land left uncultivated. In place of the wetland vegetation, invasive weeds were seen invaded the field.

The lake is one of the largest coverage of the physiographic units of the basin, which accounts for 20.32% of the basin area (Figure 4). The expansion of Bahr Dar City and the accompanied effluents, upstream land management practices, and lack of responsible institutions for the management and protection of the lake are some of the shortfalls. The sediment concentration of rivers flowing to the lake is also estimated at about 3.10 g/litre of runoff with the coefficients of the annual runoff of the rivers flowing to the lake varying from 14% to 53% (on average about 35%); thus, the total annual sediment yield reaching the wetlands and the lake system was estimated at about 9 - 15 million tons of soil per annum (Birru, 2007). Much of the sediments that have hitherto been trapped, because of the intact vegetation cover of the wetlands are now expected to pass to the lake water due to the fact that much of the wetlands are converted to crop cultivation and due to the loss of the riparian vegetation that would have been protected the lake from sedimentation and pollution. Thus, with the expansion of cultivated agriculture into the wetlands, ecological functions such as the loss of biodiversity and habitats and the loss of capacity of the wetlands to absorb the incoming sediments and pollutants are some of the problems encountered the unit.

The swamplands or wetlands in the LTB include landscapes that are seasonally flooded and lands that remain wet for a long time in the year. The land use/cover analysis revealed that the wetland or swampland is the one that is seriously threatened due to the recent expansion of crop cultivation; in the last 15 years, about 17.4% of the wetlands were converted to drained crop cultivation. On the other hand, this does not mean that the remaining wetlands are intact; rather, at present little or no swampy land is left uncultivated. Very recently, the expansion of paddy rice production in the north and north-east of the lake and irrigation-based vegetable production has attracted much attention of the farmers and the various state agents to exert unprecedented pressures on the wetlands of the basin. Thus, about 85% of the wetland and flood plains in the basin is used for intensive agriculture.

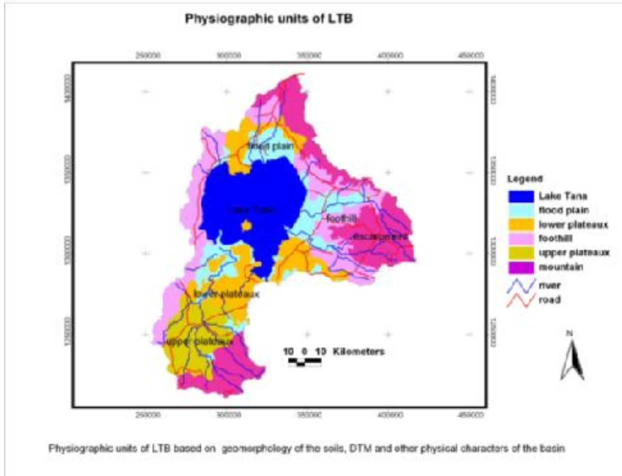


Figure 47: Major physiographic units of the LTB classified based on multiple criteria (soil geomorphology, DEM, hydrological units and landforms). Source: Birru (2007)

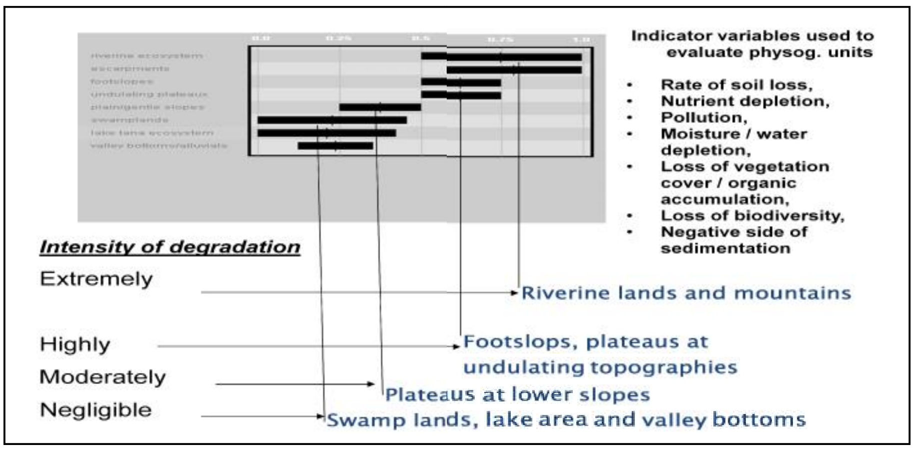


Figure 5: Expert-based evaluation of the physiographic units against land degradation criteria (the units in the figure is to be understood as meeting the maximum value of 1 or as 100 percent)

The riverine ecosystem of the LTB includes all the rivers and streams that have economic and ecological significance. The physiographic unit of "riverine systems", in this study, refers to the river courses and the assumed filter strips of usually 2-30 metres wide depending on the rate of soil loss, slope, soil erodibility, and soil erosivity factors (Karssies and Prosser, 1999). In this regard, for the purpose of this study, the riverine systems of the

LTB are arbitrarily divided into two zones: the first zone comprises the riverine systems that are situated in the higher topographies (>8% slopes), whereas the second comprises those found the lower topographies (<8%). Riverine systems in the mountain and foot-slope areas are the most erosion-prone places while their filter strips are removed as a result of expansion of crop cultivation and traditional irrigation cropping. The rivers, after leaving the rolling topography still serve as habitats to diverse species of flora and fauna and are sources of converged and voluminous water relevant for large scale irrigation and industrial purposes.

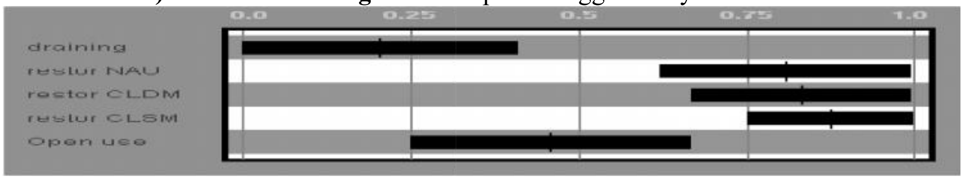
Responses of riverine ecosystems to the increasing human pressure should not be equally important in all the topographical units along the river course; deforestation of riverine vegetation and conversion of the landscape into crop cultivation were found to be serious at steeper slopes, which resulted into serious riverbank erosion and downstream flood hazards. At the present condition, no riverine system in the LTB, except for some inaccessible gorges, is covered by vegetation.

After identifying the states of land resources and the problems of degradation of the individual physiographic units, the units were further evaluated for the various degradation indicators. The indicators were: physical soil loss, in-situ nutrient depletion, pollution, loss of moisture and/or water, loss of vegetation cover or organic accumulation, loss of biodiversity, and impacts of sedimentation or siltation. As a result, the least scores were obtained for the Lake Tana and the swampy lands of the basin; however, both of them are at risk of the ever-intensifying agricultural land management upstream and the growing requirements of water for irrigation and other development interventions. The physiographic units of the LTB were grouped into four degradation contexts: (i) land units extremely prone to most of the degradation indicators (≥75%) that includes the mountain escarpments and riverine systems; (ii) land units highly prone to the degradation (50-75%), which include foot-slopes and the undulating highland plateaus; (iii) land units moderately prone to the degradation (25-50%) were those that are limited to the lower plateaus; and (iv) less prone (10-25%) are those that include the swamplands, the lake and the mountain foothills (bottom lands). However, classifying the LTB into these four degradation contexts does not imply that physiographic units that were at the extremely prone to degradation are the priority units for management interventions. On the other hand, degradation of some land resources may not have yet reached critical stages to feel the effects, but this does not mean that land resources are not in a state of degradation.

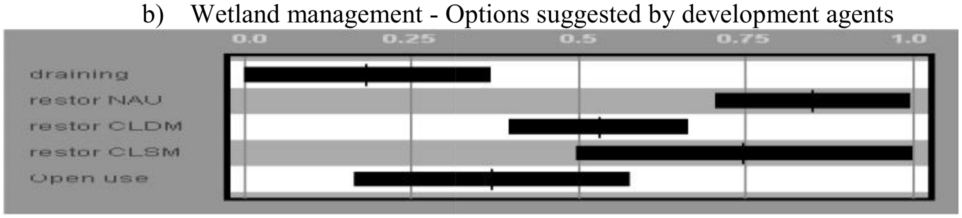
3.4 Options for the sustainable management of the wetlands of the LTB

There was a sensitization workshop held in Bahr Dar, Amhara Region (23rd January 2001) that tried to address the neglected resource – wetlands and their states and dynamics in the Region. Comparative economic advantage of utilizing wetlands in their natural and intact state was highlighted than converting them into drained crop and livestock grazing for short-term economic benefits.

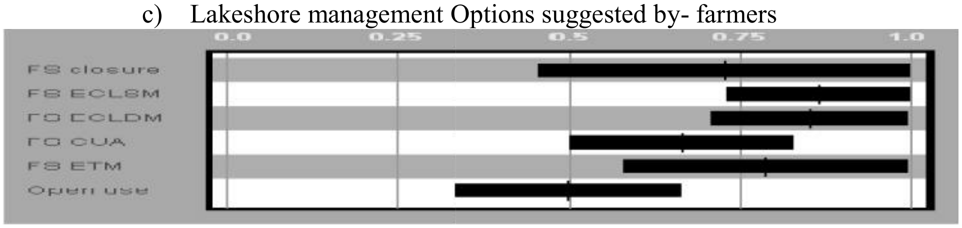
a) **Wetland management -** Options suggested by farmers



b) Wetland management - Options suggested by development agents



c) Lakeshore management Options suggested by- farmers



d) Lakeshore management - Options suggested by development agents

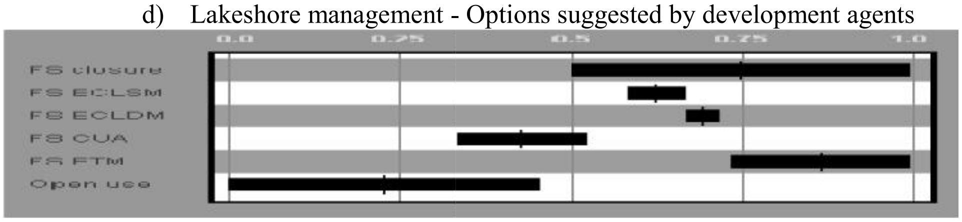


Figure 68: SLM[4] appraisals for the different physiographic units of the LTB; a and b are on the management of wetlands by farmers and development experts, and c and d are on the management of the lakeshore areas, respectively. The unit with which the individual management practice is measured in percentage

The key elements for sustainable wetland use include (Wood et al., 1998):

- only partial drainage, not draining the whole area,

[4] ***Wetland management***: NAU stands for restoring the filter strips with closure and regulated use access, CLSM for enriched closure with crop-livestock managed under the same land unit, CLDM for closure with crop-livestock managed separately. ***Lakeshore management***: FS CUS/A stands for filter strips managed under closure with regulated use access, FS ETM is for filter strips managed under eco-tourism, ECLSM for enriched closure with crop-livestock managed under the same land, ECLDM for enriched closure with crop-livestock managed separately

- maintaining areas of natural swamp vegetation within the wetland, especially at the head so it acts as a reservoir,
- maintaining areas of natural swamp at the outlet to prevent down-cutting and lowering of the water table,
- limiting drain depth and blocking of drains to retain water,
- protecting springs with areas of natural vegetation,
- use of taro or other water tolerant plants,
- maintaining well-vegetated catchments,
- fallowing with the natural vegetation to maintain soil structure and fertility,
- recreating the annual flooding – to maintain the natural hydrological cycle, and
- Control of cattle grazing, especially in the wet season.

In addition, the sustainable management of wetlands must consider economic and social benefits of the society in question. There are specific and positive economic potentials of wetlands by maintaining a tolerable ecological disturbance.

Hydrological degradation of the LTB includes increasing loss of runoffs, high runoff coefficients, and poor availability of water for the dry season irrigation, expansion of crop cultivation into swamplands, riverine systems and lakeshores. The fluctuating water volume of reservoirs and the increased sediment concentration along with discharges of the rivers are also indicators of the unsustainability of the land management systems/practices upstream, along riverine landscapes, and lakeshores.

Stopping cultivation on the steeply sloping mountains and land areas deep into riverbanks and enriching these with appropriate plant species would improve infiltration and allow safe runoff and sustainable discharges of rivers and streams in the basin. The sustainable management of the riparian systems is also possible by protecting the ecosystems of the wetlands and the lakeshores from loss of their natural flora and fauna, from conversion into other land uses, mostly into intensive crop cultivation and intensive grazing, and from the effects of sedimentation. This does not mean that the riparian areas should necessarily be kept for ecological purposes alone; rather, economic benefits need to be maintained by growing woody vegetation integrated with perennial fodder grasses. Of the potentials of the lower riparian region of the LTB (the lakeshores and the surrounding wetlands), perennial crops including coffee, fruit trees, timber production, pasture hay, eco-tourism, etc. can be mentioned.

In addition to planning the appropriate buffer strips, management requirements of riverine lands, wetlands, and lakeshores of the basin were assessed by a group of farmers and development experts using the MODSS model (Figure 6&7). As far as the management of wetlands is concerned, both farmers and development agents were least interested in the practice of draining excess water and the open access use of wetlands (Figure 6a and 6b,

Table 2: Sum of the Pair-wise Ranking (SPR) and weighted values (wt) of the evaluation criteria used in the appraisals of land management systems for the wetlands

Basic criteria	Desired impact	Farmers' group		Development agents	
		SPR	Wt	SPR	Wt
Ground water table	Maximize	3	0.96	9	2.80
Pollution effects	Minimize	7	2.24	10	3.11
Biodiversity	Maximize	4	1.28	7	2.17
Habitat preservation	Maximize	0	0.00	5	1.55
Initial cost	Minimize	4	1.28	3	0.93
Economic benefit	Maximize	10	3.21	4	1.24
Livelihood option	Maximize	9	2.88	6	1.86
Short-term shocks	Minimize	8	2.56	8	2.48
Land loss	Minimize	9	2.88	9	2.80
Aesthetic value	Maximize	1	0.32	2	0.62
Simplicity	Maximize	4	1.28	0	0.00
Risk	Minimize	5	1.60	1	0.31

Table 3: Sum of the Pair-wise Ranking (SPR) and weighted values (wt) of the evaluation criteria used in the appraisals of land management systems for the lakeshores

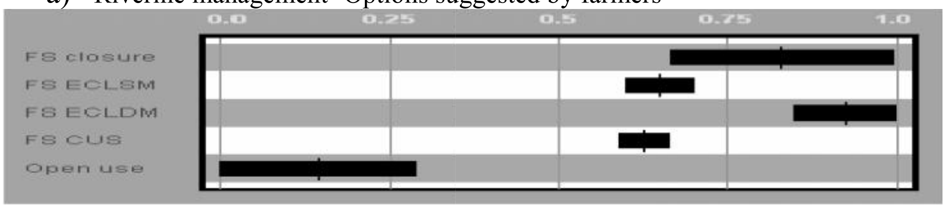
Basic criteria	Desired impact	Farmers' group		Development agents	
		SPR	Wt	SPR	Wt
Shoreline stability	Maximize	8	2.76	9	2.99
Pollution/sediment	Minimize	5	1.72	10	3.32
Biodiversity	Maximize	3	1.03	8	2.66
Habitat preservation	Maximize	6	2.07	7	2.33
Initial cost	Minimize	7	2.41	5	1.66
Economic benefit	Maximize	4	1.38	6	1.99
Livelihood option	Maximize	2	0.69	3	1.00
Short-term shocks	Minimize	9	3.10	4	1.33
Land loss	Minimize	10	3.45	6	1.99
Aesthetic value	Maximize	5	1.72	1	0.33
Simplicity	Maximize	1	0.34	1	0.33
Risk	Minimize	1	0.34	1	0.33

respectively). The group of farmers gave more emphasis to the economic objectives unlike the group of development agents, who were more interested in ecological objectives to be supported by the management options (Table 2). On the other hand, despite the wide variation between the farmers' and the researchers' groups requiring the desired impacts of the evaluation criteria (Table 3), during the assessment of the management options for the lakeshore systems, both groups believed in all the alternatives except for the open access use of the resource (Figures 6 c&d).

Furthermore, the sustainable management of hydrological and the riparian systems of the LTB require a holistic approach that may include improving the retention of rainwater in all the landscapes and land use types and the system of water balancing in the use of the water resources for various purposes. This is because, as a result of water consumption for varieties economic activities around the lake and due to much water was drained from the

Lake to satisfy the new hydropower plant (Tis Abbay hydro-electric power II), about one-third of the volume of the Lake Tana water was depleted and serious shocks were felt on the various functions of the lake. Similarly, the two major rivers of the LTB, namely, Gumara and Ribb, completely dried up in 2004 and 2005 as a result of widespread use of irrigation cropping (more than 300 pumps were installed along these rivers).

a) Riverine management- Options suggested by farmers



b) Riverine management- Options suggested by development agents

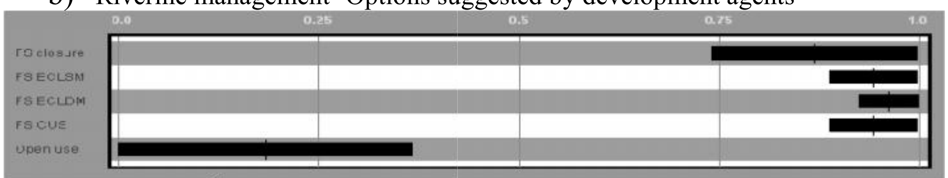


Figure 79: SLM [5] appraisals for the different physiographic units of the LTB; a and b are on the management of riverine systems by farmers and development experts. The unit with which the individual management practice is measured is a percentage

Table 4: Sum of the Pair-wise Ranking (SPR) and weighted values (wt) of the evaluation criteria used in the appraisals of land management systems for the riverine landscapes

Basic criteria	Desired impact	Farmers' group		Development agents	
		SPR	Wt	SPR	Wt
Soil conservation	Maximize	7	2.02	6	1.97
River bank stability	Maximize	9	2.59	11	3.61
Runoff effects	Minimize	8	2.31	10	3.28
Biodiversity	Maximize	1	0.29	2	0.66
Habitat preservation	Maximize	1	0.29	5	1.64
Initial cost	Minimize	6	1.73	6	1.97
Offsite impact	Minimize	5	1.44	6	1.97
Onsite impact	Minimize	11	3.17	6	1.97
Short-term shocks	Maximize	10	2.88	8	2.62
Land loss	Minimize	9	2.59	8	2.62
Aesthetic value	Maximize	1	0.29	0	0.00
Simplicity	Maximize	3	0.86	2	0.66
Risk	Minimize	3	0.86	4	1.31

[5] ***Riverine land management***: FS stands for filter strip, ECLSM for enriched closure with crop-livestock managed under the same land, ECLDM for enriched closure with crop-livestock managed separately and FS CUS for closed filter strips managed under private use access.

Of the list of management options, the farmers' group were more interested in the use of filter strips enriched with perennial-based crop-livestock production with the crop and the livestock managed in different land units (FS ECLD) (Figure 7a). In the process of evaluation, priority objectives of the farmers were found to be minimizing on-site negative impacts and economic shocks in the short-term (Table 4). On the reverse, the development agents were more interested in ecological objectives such as managing runoff effects and maintaining stability of riverbanks (Figure 7b).

Conclusions

Traditionally, the wetlands in Ethiopia are considered as problematic lands such as swap lands as a harbor to malaria; rivers as harboring of crop pests such as birds and wild beasts. However, with the ever increasing human population and the intensified demand for food grain, more riparian lands are recently converted into intensive cropping. As a result, the natural habitat of lakeshores, wetlands and riverine ecosystems have been seriously damaged and their land uses permanently converted. Apart from the loss of the main resources (riparian vegetation, water, biodiversity and habitats), there are interlinked and externalized consequences due to the degradation of these environments through loss of soils from the destabilized riverbanks, frequent flood occurrence, drying of streams, sedimentation and pollution of reservoirs downstream. Since the sustainable management of wetlands in the Lake Tana Basin (LTB) is the attribute of complex combination of ecological, economic and social objectives, a participation of multiple stakeholders in a transdisciplinary research approach is found to be a priori. A use regime is also required to be developed that ensures the fullest range of benefits for the local community in a framework that also maintains the sustainable functions of the wetlands.

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Application of GIS and Remote Sensing Techniques in Land Suitability Evaluation for Agricultural Use

Belay Tseganeh[1], Parmjit Singh Sehra[2] and Anil Sood[3]

[1]Researcher, Amhara Regional Agricultural Research Institute, Ethiopia; [2]Professor of Agrometeorology, Punjab Agricultural University, Ludhiana-141004, Punjab, India; and [3]Scientist, Punjab State Remote Sensing Centre, Ludhiana, Punjab, India

Abstract

A study on land use / land cover status and land suitability for important crops of the Balachaur watershed, in Nawan Shahar district of Punjab State, India was carried out using GIS and Remote sensing techniques. Land suitability analysis for important crops of the study area, viz., maize, and wheat was performed based on the limitation concept of the FAO methodology for land evaluation combined with parametric classification approach and multiple overlaying technique in a GIS environment.

The major land use / land cover categories that are identified and mapped are agricultural land, forestland, wasteland, water body and built-up land. About 42 per cent of the watershed is under agricultural land category, 49 per cent is moderately dense forest, 6 per cent is wasteland, while settlements and rivulets cover 3 per cent. The suitability analysis for wheat crop showed that 37, 13, and 50 per cent of the total area of the watershed is moderately suitable, marginally suitable and permanently unsuitable, respectively. With respect to maize crop, 0.7 per cent is found to be highly suitable, 36.6 per cent is moderately suitable, 13 per cent is currently unsuitable, and 50 per cent is permanently unsuitable.

Major limitations of the watershed are found to be low soil fertility, low water holding capacity of soils, erosion hazard on steep slope land units, and inadequate water availability during the intermediate growing period. The study showed that GIS and Remote sensing techniques are powerful tools to integrate various data layers and to assess the potentials and limitations of physical land resources for scientific land use planning and decision supporting systems in crop specific modeling of agricultural production.

***Key words**: Land suitability, Land use planning, parametric classification approach, GIS and remote sensing*

1. Introduction

Any land use planning for sustainable development requires identification of the type of the current land use with respect to the socially relevant utilization types and their requirements and comparison of recommended land-utilization types with existing land use. For the purpose of such analysis, a systematic land suitability evaluation is required. Land evaluation is the process of assessment of the potentials and limitations of the land performance when used for specified agricultural uses. It involves the execution and interpretation of land resources surveys and studies of land form, soil and climatic factors in order to identify and make a comparison of most promising kinds of land uses.

Land suitability classification is an approach in land evaluation that involves the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. It takes account of important attributes of land and compares them with the requirements of the crops to give a picture of the potentials and constraints of the land for crop production. The approach allows creation of unique ecological land units or agro-ecological cells within which optimum land decision can be made. Delineating land units into homogeneous suitability classes is an effective way of allowing the users and decision makers to see at glance which areas are highly suitable, moderately suitable, marginally suitable or unsuitable for a given land utilization or crop production.

Recently, geographical information system (GIS) and remote sensing techniques have showed advancement and provide greater benefits in mapping and monitoring of natural resources. Remote sensing is the science of acquiring information about an object or feature from a measurement made at a distance without making physical contact with an object or feature under investigation, while GIS is a decision support system involving the interaction, analyzing and displaying spatially referenced data in a problem solving environment. Many of conventional approaches of handling multi thematic information to arrive at optimal solutions and rational decision-making are being computerized using geographic information system. The powerful query, analysis and intervention mechanism of GIS makes it an ideal scientific tool to apply it for land use planning.

Therefore, the objectives of this study were, to assess and analyze the suitability of land for major crops (land utilizations) of the study area, to delineate the watershed into homogenous agro-ecological cells or land units and to apply GIS and remote sensing techniques in land suitability analysis and to generate land use and land suitability maps.

2. Materials and Methods

The study area, Balachaur watershed, is located between 31^0 10’ N latitude and $76^{\,0}$ 10’ to $76^{\,0}$ 25’ E longitude in Nawan Shahar district of Punjab State, India. It covers an area of 2082 ha at an altitude of about 355 meters above sea level. The area receives annual rainfall of about 1129 mm. The maximum and minimum temperatures are $30C^0$ and $16C^0$ respectively and the mean annual temperature is $23C^0$.

IRS1D-LISS-III imagery (Fig 1.) was visually interpreted to identify land use categories of the watershed and land suitability analysis was performed based on the limitation concept as described in FAO guideline and framework for land evaluation combined with parametric classification approach. This involved overlaying of two basic information layers i.e. land use requirements and land qualities. Rain fed maize and wheat are identified as the main land utilization types of the study area. Land use requirements of these crops were reviewed from various publications mainly from FAO (1983), FAO (1996), Sys (1993), Sehgal (1996) and Sarkar (2003).

Land suitability evaluation model for each crop was defined by a land suitability index, which is a combined soil-climate index, computed as the product of the individual rating values of all land qualities (diagnostic factors multiplied by 100) i.e. land suitability index = A x B x C x. ……x 100. (A, B, C are rating values of diagnostic factors). Multiple overlay operation using ARC/INFO GIS was applied to generate resultant polygonal layers from the thematic layers of diagnostic factors. The land suitability evaluation model was applied to the resultant polygonal layers. The values obtained from the model are matched with a pre-defined land index-scoring table (Table 1), which provided the final suitability class of each land unit for each crop type.

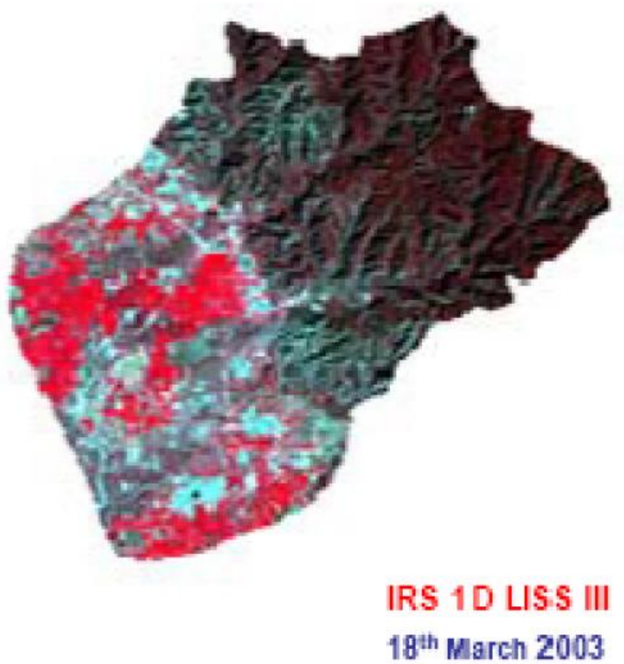

Fig. 1 False Color Composite (FCC) of Balachauer watershed (describe the different colors of the image)

Table 1: Land index scoring for suitability classification

Land Suitability index	Suitability class	Description
75-100	S1	Highly suitable
50-75	S2	Moderately suitable
25-50	S3	Marginally suitable
12-25	N1	Currently not suitable
0-12	N2	Permanently not suitable
-	NR	Not relevant

3. Results and Discussion

3.1 Land use /Land cover status of the watershed

Visual interpretation of satellite image (IRS-1D LISS-III) data provided current information about the land use /land cover status of the watershed. The major land use /land cover categories that are identified and mapped are agricultural land, forestland, wasteland, water body and built-up land. The land use /land cover categories and their area statistics is given in Table 2. A color-coded land use/land cover map of the watershed, which shows the geographical distribution of the identified land use / land cover classes, is also indicated in Fig. 2.

Agricultural land

Agricultural land constitutes part of the watershed primarily used for food production. It covers about 42.32 per cent of the total area. Two sub-classes namely, crop land and plantation are identified under this land use /land cover category at level II as shown in Table 2. Most of the piedmont plain of the watershed is under crop cultivation. Some cereals, oilseeds and pulses are being grown in the watershed. Crop yield is very low and uncertain due to climatic and soil related constraints. Irrigation facilities are not available. Besides crop cultivation, some patches of plantation are also identified. Plantation is found to be practiced mainly on marginal lands of the piedmont plains such as choe affected and eroded land units.

Forest land

This land use/land cover category constitutes about 49.4 per cent of the watershed. At level II it is categorized as moderately dense forest land coverage which consists of naturally grown shrubs and scattered trees. This land use category is the extension of the Siwalik Hills of the Kandi Chains of Punjab.

Wasteland

About 5.82 percent of the watershed is under wasteland category. A level II, it consists of two sub-classes namely barren land with scrub and barren land without scrub. These land units are located along the river beds and choe affected marginal lands. Deposition of sands by choes and erosion during the monsoon season and mismanagement by land users are the main causes for such wastelands.

Built-up land

This land use/land cover category consists of the inhabited areas of the watershed. There are about eight rural villages namely Shebazpur, Noanowal, Bhanewal, Bhungri, Bhaddi, Lohar Majra, Raju Majra and Aduana within the study area, which covers about 1.64 per cent of the total area of the study watershed.

Water body

This land use/land cover category consists of seasonal streams /choe. It constitute about 0.84 per cent of the watershed.

Table: 2 Land use/land cover classes and area statistics (Balachauer Watershed)

Land use/ land cover status			Area (ha)	Per cent of total area
	LEVEL I	**Level II**		
1.	Agricultural Land	1.1 Crop Land 1.2 Plantation	872.36 8.77	41.9 0.42
2.	Forest Land	2.1 Moderately dense	1028.6	49.40
3.	Waste Land	3.1 Barren land with scrub 3.2 Barren land without scrub	78.51 42.16	3.80 2.0
4.	Built-up Land	4.1 Rural	34.1	1.64
5.	Water Body	5.1 Seasonal Rive /choe	17.5	0.84
Total			2082	100

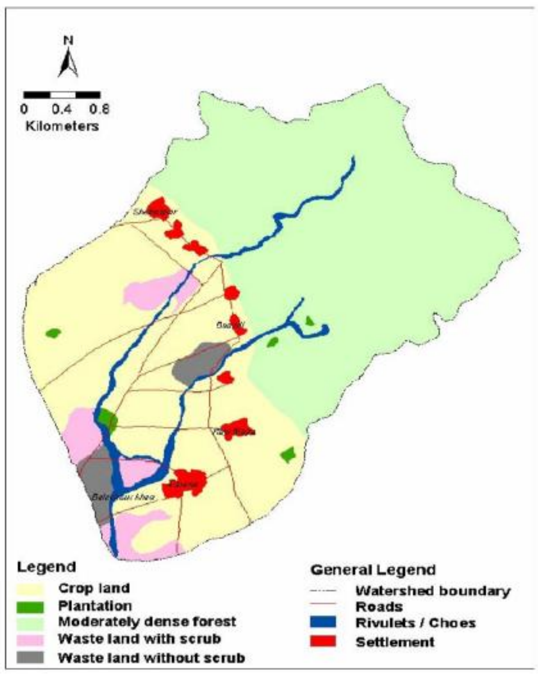

Fig. 2 Land use / land cover map of Balachauer watershed

3.2 Physiography

Physiography (land form) of the study area is investigated by visual interpretation of the remotely sensed imagery of the watershed. Accordingly, the watershed is divided into three physiographic units namely, Siwalik Hills, piedmont plain and seasonal river /choe (Fig 3).

The sub-mountain tract of Punjab and the adjoining undulating piedmont plains in the south of Siwaliks locally known as the Kandi Zone covers the watershed. The Siwalik Hills cover about 1028.6 hectares of the watershed and the piedmont plain and choes constitute about 1032.9 and 17.5 hectares of the area respectively. Topographically, about 13 per cent of the area has gentle slope, 37 per cent has nearly level to gently slope and 49 per cent of the area is under steep to very steep slope category. Due to the topography and lithological constraints, the irrigation facilities are not available and hence crop production is being carried out under rainfed conditions.

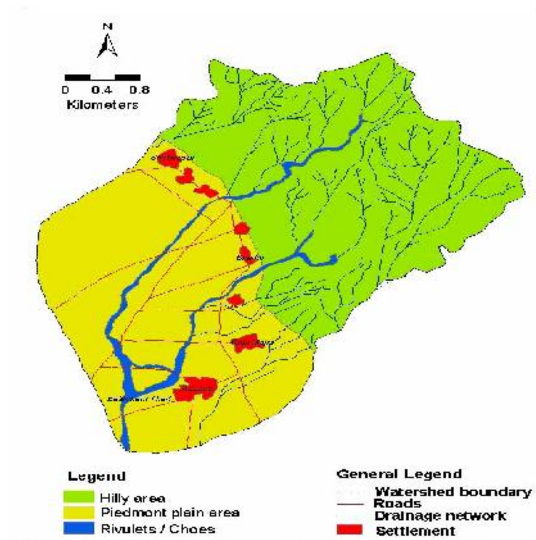

Fig. 3 Physiographic map of Balachauer watershed

3.3 Edaphic factors

The soil textural class of the watershed ranges from fine to coarse soils. About 265.8 ha of the watershed has sandy soil texture, 416.4 ha has loamy sand soils, 338.4 ha has sandy loam soils, 12.8 ha has loam soils, 2.5 ha has silt loam soils and 1028.6 ha of the area has association of sandy loam and loamy sand textural classes. Soil texture controls not only the water holding capacity but also nutrient supply, aeration, drainage and workability and hence it is an important land characteristic in land suitability analysis. Oxygen availability to roots mainly depends based on soil drainage classes. About 33 per cent of the watershed area has somewhat excessive to excessive drainage classes. These drainage classes are associated with loamy sand and sand soil textures respectively. Some what excessive drainage class implies that water is removed from the soil rapidly in relation to supply while excessive drainage class indicates that water is removed from the soil very rapidly in relation to supply. The remainder 33 per cent area of the watershed has soil drainage class of well to moderately well drained, which are associated with the sandy loam, loam, and silt loam classes. In moderately well drained soil classes, water is supposed to be removed moderately slowly to readily slowly to keep the sub soil wet for a sufficient part of the growing season. While in well drained soil classes, water is expected to be removed from the soil readily but not rapidly and hence soils have intermediate available water storage capacity.

Assessment of rooting conditions in terms of effective soil depth indicate that 49 per cent of the watershed area has shallow to medium deep soils and the rest has very deep soils. The soil depth determines the volume of the soil, which the roots can exploit for plant growth. Nutrient availability and retention capacity are assessed through soil reaction and organic carbon contents of the soil resources. Soils are said to be normal when it is slightly alkaline in pH and the organic carbon content is low to medium, calcium carbonate is either absent or present in a very small amounts.

Fig.4 shows a generalized soil resources map of the watershed (study area). The watershed is classified in to six soil mapping units / land units (Table 3). Land unit which is a term of convenience to cover any unit of land used for evaluation, is applied in this text instead of soil mapping unit. A land unit is defined as an area of land, usually mapped, with specified characteristics and employed as a basis for land suitability evaluation. Examples of land units employed in evaluation for rainfed agriculture are land system, soil series, soil association and other soil-mapping units (Dent and Young 1981).

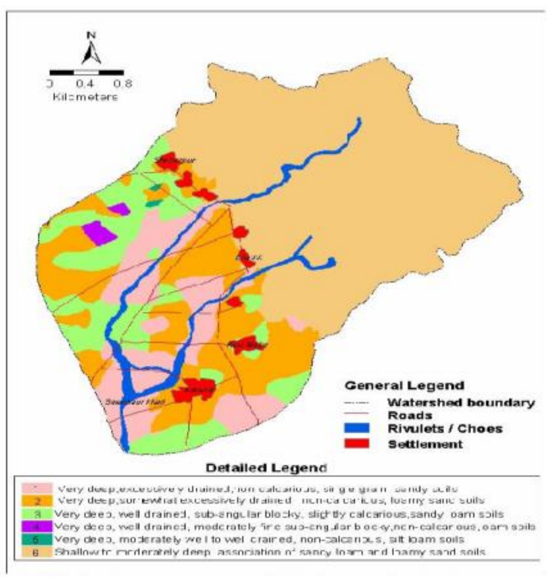

Fig.4 Soil resources map of Balachauer watershed

3.4 Agro-climatic resources

Water availability and temperature regime are the most important land qualities related to the agro-climatic environment of rainfed agriculture which have significant influence on suitability and adaptability of crops of the study area. The concept of the growing period and water balance is used as a framework to assess the potentials of these climatic resources.

Growing Period

The length of the growing period, which is expressed in terms of the major climatic factors, viz., temperature, rainfall and evapotranspiration, provides a realistic simulation of the crop growth cycle. The length of the growing period indicates the period of the year when moisture and temperature conditions are favourable for crop growth. It is determined by a water balance model, which compares rainfall with potential evapotranspiration (Fig. 5).

The time when rainfall equals or exceeds half of the potential evapotranspiration is the beginning of the growing period and the time when the rainfall decreases and falls below half the potential evapotranspiration is considered as end of the growing period. Therefore length of the growing period indicates the period during the year when precipitation exceeds half the potential evapotranspiration provided that the prevailing temperature is conducive to crop growth (mean temperature $\geq 5^oC$). Two growing periods namely intermediate and normal growing period are identified in the study area.

Intermediate growing Period

The intermediate growing period starts in December and extends up to the first week of March. In the intermediate growing period, precipitation does not exceed the full evapotranspiration which implies that there will be no surplus of soil moisture but since it exceeds half of the potential evapotranspiration, crop production is still possible with a narrow range of available moisture period. The total amount of the rainfall and potential evapotranspiration during this period is 144 mm and 265 mm respectively which shows moisture deficit of about 121 mm. But assessment for the distribution shows that the rainfall amount for each standard meteorological week (SWM) during the intermediate growing period is slightly higher than half of the potential evapotranspiration amount of the corresponding meteorological weeks. The highest monthly rainfall amount during the intermediate growing period is about 41 mm in February and the corresponding half potential evapotranspiration is 38.5 mm. The mean temperature during this period is found to be 15^oC with maximum temperature of 27^oC during the 10^{th} standard meteorological week and minimum temperature of 4.7^oC during the 3^{rd} standard meteorological week. This shows that mean temperature is not a constraint for crop production during this period as it is above the base mean temperature ($>5^oC$).

Even though, it is possible to cultivate less water consuming crops during the intermediate growing period of the study area, the precipitation is still lower than the potential evapotranspiration which implies the fact that the full water requirement of crops can not be satisfied with the available rainfall resource. Therefore, crop production during the intermediate growing period of the study area is being carried out under insufficient available water condition which leads to a reduction of the maximum attainable yield potential of the crops.

Normal Growing Period

The normal growing period starts during the 26th standards meteorological week (last week of June) and extends till the 38th meteorological week (end of September). The total rainfall amount during this period is 843 mm and the potential evapotranspiration is 403 mm. From the total rainfall and corresponding potential evapotranspiration demand during the normal growing period, it can be concluded that it is a humid period when the available water resources exceeds the crop water requirement. The highest rainfall of the period occurs in July and August, which have rainfall amount of 319 mm and 322 mm respectively while the maximum water demand during the same growing period is in July, which has potential evapotranspiration of 116 mm. The mean temperature during the normal growing period is 29°C with maximum temperature record of 36°C during the 26th SMW (last week of June) and minimum temperature of 20°C during the 39th SMW (last week of September). Since the rainfall exceeds the full potential evapotranspiration and the mean temperature is higher than the base temperature value (>5°C), the normal growing period can be considered as conducive and suitable for crop production keeping other environmental conditions constant.

The climatic water balance of the area also indicates that it accumulates potential evapotranspiration (PET) of 1308 mm annually with rainfall of 1129 mm, which implies water deficit of 179 mm. During the monsoon season (July, August and September), however, the rainfall exceeds the potential evapotranspiration and hence the annual water deficit will occur during the remaining period of the year.

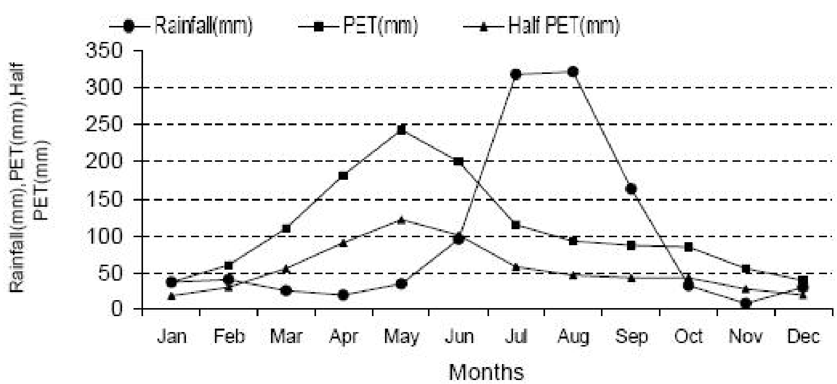

Fig. 5 Growing period at Balachauer watershed

3.5 Land suitability assessment for major crops

Land suitability assessment for important crops of the study area, viz., maize, wheat and mung bean was made following the FAO methodology of land evaluation for rainfed agriculture. This involved comparison of the inherent land qualities with the land use requirements of the crops. The land suitability assessment is expressed in terms of suitability ratings based on how far the land qualities meet the crop requirements. The land suitability rating is derived from the degree of limitations of each land quality. The land suitability rating, therefore, indicates the partial suitability of a given land unit for the specified crop type based upon consideration of one land use requirement and its corresponding land quality. Combining the suitability ratings of individual land qualities by means of a land suitability index provided the overall /final suitability class of a land unit for each crop under consideration. The degree of suitability of each land unit for the given crops is indicated by different levels of suitability, namely, highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently unsuitable (N1) and permanently unsuitable (N2). A rating of S1 indicates that the land quality is optimal and suppression of potential yield is assumed to be slight. Ratings of S2 and S3 indicate that the land qualities are sub-optimal for crops and potential yield would be suppressed.

Land suitability for Maize

The final suitability analysis showed that the watershed is divided into four levels of suitability, viz; highly suitable (S1), moderately suitably (S2), currently unsuitable (N1) and permanently unsuitable (N2) with respect to the climatic and soil requirements of the maize crop and the potentials of the inherent land qualities (Fig. 6). These land suitability classes constitute 0.7, 36.3, 12.8 and 49.4 per cent of the watershed area, respectively. In terms of area coverage, highly suitable area constitute of Major limiting factors for this crop are found to be topography (slope), erosion hazard and soil texture.

Table 4: Land suitability index and overall suitability of Balachaur watershed for maize

Land unit	Land suitability index	Degree of suitability	Designation of suitability class
1	22.16	Currently unsuitable	N1
2	63.25	Moderately suitable	S2
3	74.41	Moderately suitable	S2
4	87.54	Highly suitable	S1
5	83.17	Highly suitable	S1
6	7.50	Permanently unsuitable	N2

Table 5: Maize suitability area under different classes

Suitability class	Area (ha)	Percentage of total area
Highly suitable (S1)	15.3	0.7
Moderately suitable (S2)	754.8	36.3
Currently unsuitable (N1)	265.8	12.8
Permanently unsuitable (N2)	1028.6	49.4
Non-relevant (NR)	17.5	0.8

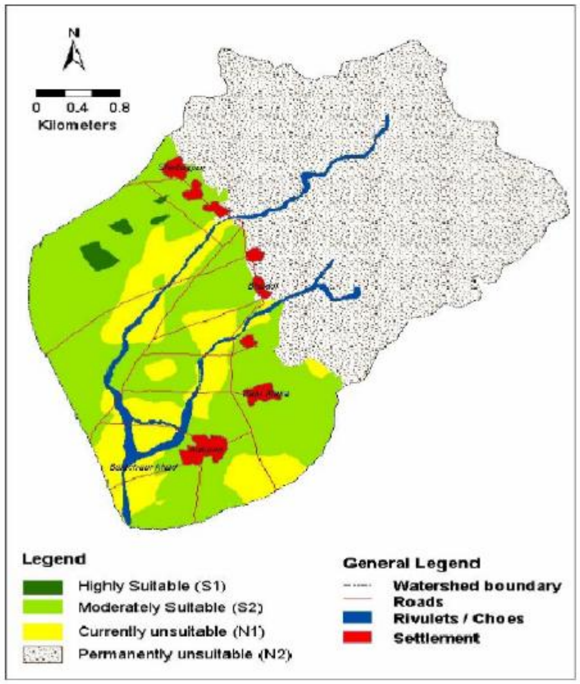

Fig.6. Maize suitability map for Balachauer watershed

Land suitability for wheat

The overall climatic and land resource suitability analysis for wheat indicates that the watershed is divided into three suitability classes namely moderately suitable (S2), marginally suitable (S3) and currently unsuitable (N2), with respect to the land use requirements of the crop. These suitability classes constitute about 13, 37 and 49 per cent of the total area of the watershed respectively. The land suitability map for wheat which is generated in a GIS environment by multiple overlaying techniques of various thematic layers of the land qualities and reclassified based on the values of the land suitability index is shown in Fig. 7. Major limiting factors for this crop are found to be topography (slope), erosion hazard, water availability, soil depth and organic carbon content.

Table 6: Land suitability index and overall suitability of Balachauer watershed for wheat

Land unit	Land suitability index	Degree of suitability	Designation of suitability class
1	38.06	Marginally suitable	S3
2	57.14	Moderately suitable	S2
3	63.31	Moderately suitable	S2
4	63.31	Moderately suitable	S2
5	60.14	Moderately suitable	S2
6	9.38	Permanently unsuitable	N1

Table 7: Wheat suitability area under different classes

Suitability class	Area (ha)	Percent of total area
Moderately suitable (S2)	770.1	37
Marginally suitable (S3)	265.8	12.8
Permanently unsuitable (N2)	1028.6	49.4
Non relevant (NR)	17.5	0.8

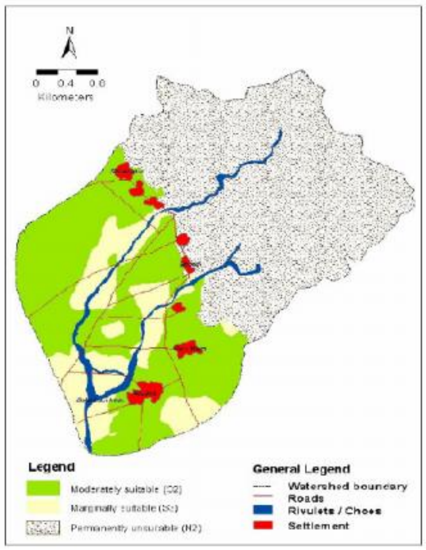

Fig. 7 Wheat suitability map of Balachauer watershed

Conclusion

The productivity potential of an area can only be realized when crop production decisions are based on adequate characterization of the inherent variables of land mainly climate, soil and land form. Sustainable and maximum production can be achieved when the land user knows the potentials and limitations of these natural resources and take appropriate farm management decisions. This study was, therefore, conducted to assess land suitability for important crops of the study area with respect to potentials and constraints of the land qualities using the potential application of GIS and remote sensing techniques.

The current land use / land cover status of the study area was studied by visual interpretation of the satellite image. The major land use / land cover categories that is identified and mapped are agricultural land forest land, wasteland, water body and built up land. Assessment for agroclimatic potentials of the area with respect to growing period and water balance showed that it has experienced two growing periods, namely, intermediate and normal growing periods. The intermediate growing period starts in December and extends up to the first week of March. The precipitation is lower than the potential evapotranspiration and hence the full water requirements of crops cannot be satisfied with the available water resources. Crop production during the intermediate growing period is, therefore, being carried out under insufficient available water condition which leads to a reduction of the maximum attainable yield potential of crops. The normal growing period starts during the 26th standard meteorological week (last week of June) and extends up to the 39th meteorological week (end of September). During this period, the rainfall exceeds the potential evapotranspiration demand and hence it is a humid period when the available water resource exceeds the crop water requirement leading to loss of surplus of water by means of surface runoff. Monthly climatic grouping of the area based on moisture index also revealed that 2 months (July and August) are extremely wet and 3 months (April, May, and November) are extremely dry, while other months are under semi moist to dry condition.

The land suitability assessment for important crops of the study area, viz., maize and wheat was carried out following the FAO methodology for land evaluation. The methodology involved integrating climate, soil and crop information in the process of matching the land use requirements of the crops with the properties of mapped land units by means of the inherent land qualities and characteristics. The suitability analysis for wheat crop showed that 37, 13, and 50 per cent of the total area of the watershed is moderately suitable, marginally suitable and permanently unsuitable with maximum attainable yield of 57 to 63, 38 and 9 per cent respectively. With respect to maize crop production, only 0.7 per cent of the total area is found to be highly suitable with productivity potential of 83 to 87 per cent. About 36.3 per cent of the area is found to be moderately suitable, 12.8 per cent is currently unsuitable, while 50.2 per cent is permanently unsuitable.

The major limitations of land qualities of the watershed are found to be related with low nutrient availability of soils, low water holding capacity, erosion hazard on steep land units, and inadequate water availability during the intermediate growing period. This study furthermore showed that GIS and remote sensing techniques are powerful tools for integrating various data layers (climate, soil and crop information), and to assess the potentials and limitations of the physical land resources for improved scientific land management planning and decision supporting system in crop specific modeling of agricultural production.

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IV) Forestry and Agroforestry

Population Status and Socioeconomic Importance of *Acacia senegal* Tree Species in Abderafi Woreda of North Gondar Zone

Tatek Dejene1, Kibruyesfa Sisay, Behonegn Akalu, and Enyew Adgo2
1Gondar Agricultural Research Center. P.O. Box 1337
2 Bahir Dar University P.O.Box

Abstract

*In Ethiopia, A.senegal is widely distributed in the southern and north-western lowland dry forests. However, in spite of its wide distribution, few studies have been made to document its status and potential. Hence, the main focus of this study was to acquire information on the status of A.senegal (L.) Willd species in Abderafi woreda of North Gondar Zone and to provide baseline information for the development and utilization of the resource. Both primary (socio-economic survey and vegetation inventory) and secondary data sources were used for the study. Three sites were assessed for vegetation inventory and a total of 35 households were sampled and assessed purposively for the survey. The population status of A.senegal and associated tree species were examined by estimating dominance, density, abundance, frequency, importance value index and population structures. The findings of the socioeconomic survey revealed that all households living in and around the woodland somehow use the species for various purposes. However, more dependency was observed on the utilization of six main types of NTFPs. Nevertheless, the local communities have not been used to generate income as they are not aware of the economic importance of the species. This might be due to the presence of an alternative livelihood means i.e. agriculture. They only use its wood for making farm implements, fencing, charcoal, and fuelwood***.** *The production of gum from A.senegal is not common by the locals***.** *On the other hand, the diameter distribution indicated that indeed there is a possibility to start the production of gum arabic with the existing harvestable number of A.senegal trees in the area, and this will have the potential to supplement the income from agricultural production. The inventory of the woodland in the study area also indicated that, the density, frequency, dominance, abundance and importance value index for A.senegal is high in all the three sites as compared to the associated tree species. Moreover, the population structure of A.senegal showed large population in the lower size classes (good regeneration); however, small number of individuals existed in the upper higher size classes, this may be attributed to the continuous harvesting of matured trees for the purpose of firewood and charcoal production. In addition some trees missed in some diameter class of the associated species and the population structure assumed a J-shape which signals their instability. Therefore, if appropriate management measures are taken, then, to the stand, the nature of the population structure of most of the tree species including A.senegal will be stable.*

Key words: Abderafi, Population structure, Acacia Senegal, Gum Arabic, Socio economic

1. Background and Justification

Drylands are parts of the earth's surface where rainfall is very low, erratic, and rates of evaporation are high. Such lands account for 54% of the globe and 61% of Africa's productive landmass (UNDP, 2005). Dry tropical forests, as the forests in these areas are referred to, encompass 42% of all tropical forests (Murphy & Lugo, 1986), and are the largest forest type in some African countries such as Ethiopia (Tefera et al., 2005). They contain a wealth of unique biodiversity (Janzen, 1988) and directly support the livelihoods of close to one billion people worldwide (UNDP, 2005). Nonetheless, dry forests are suffering from severe degradation due to anthropogenic pressures, for the reason that they are among the least managed and protected ecosystems (Janzen, 1970; Janzen, 1988).

Increasing human pressure in recent years in the Drylands and on dry forests is initiating the rapid advance of desertification. Furthermore, the effects of global climate change, which prevails in the dryland regions, are further intensifying problems - making them more arid, vulnerable and difficult for habitation (Williams, 2002 as cited by Mulugeta et al., 2004).

The *Combretum–Terminalia* and *Acacia–Commiphora* deciduous woodlands belong to the category of dry forests, and form the largest vegetation cover in the Horn of Africa and the Sudano-Sahelian zone (Friis, 1992). These forests mainly are composed of various species of *Acacia, Boswellia* and *Commiphora* that are known to produce commercial plant gums and resins such as gum arabic, frankincense and myrrh (Mulugeta & Demel, 2003), respectively. The wood and non-wood products from these species play a significant role in the livelihood of many people in the dryland regions of Africa.

Ethiopian natural vegetation resources are composed of several species of potential importance. For instance, the *Acacia-Commiphera* woodlands in the dry lands of the country that are dominated by *Acacia, Boswellia,* and *Commiphera* species are well known for their economically valuable products, largely oleo-gum resins such as gum arabic, frankincense, myrrh, and karaya (Abeje, 2002 ; Mulugeta etal ,2003; Tilahun ,1997; Wubalem etal,2004).

Acacia senegal (L) willd (family Leguminosae, Mimosoidea) is one of the promising multipurpose tree species in arid and semi-arid areas of Ethiopia, which can render various socioeconomic and ecological benefits. The species is highly valued for gum arabic production (Mulugeta et al, 2004) in which the gum exudates from trunks, branches and twigs. In Ethiopia natural stands of *A.senegal* found in the *Acacia-Commephora* woodlands in the western and southern lowlands of the country; West Tigray, Amhara, Benshangul, Shoa, Afar plane and Borena zone of Oromia (Azene, et al 1993; Vivero, 2002). Unfortunately, in spite of its wide distribution, few studies have been made to document the status and potential of the species. The fact that, on one hand, there is a growing demand, attractive international market, and considerable socioeconomic benefit from the resource and lack of information on the distribution and abundance of the resource on the other hand has triggered a great need for an assessment of the resource in North Gondar zone. These underline the purpose of this study.

2. Objectives

2.1. General objective

The main focus of this study was to acquire information on the status of *A. senegal* (L.) Willd Species in Abderafi woreda of north Gondar Zone

2.2. Specific objectives

- To investigate the population status of *A. senegal* land associated tree species.
- To assess the effect human encroachment on the population of *A. senegal* and the associated tree species;
- To investigate the socio economic importance of *A.senegal* tree species in the study area.

3. Materials and Methods

3.1. Study Site description

The study was conducted in north Gondar zone of Abderafi woreda which lies within an altitudinal range of 950 to1100m above sea level and with a mean annual rainfall of 885mm, and with and the annual mean temperature of 27.8 ºC. It has a unimodal rainfall and most of the rainfall is received during the months of July and August. The soils are predominantly black with some soils displaying vertic properties. Seasonal water logging, especially during the heavy rainfall months, is also high. The vegetation zone of the study area is categorized under the *Combretum–Terminalia* or Broad-Leaved Deciduous Woodland (Abeje, 2002; Ogbazghi, 2001).

3.2. Data Collection and Measurements

A reconnaissance survey was made across the woodland in the study area, in order to obtain a contemplation of the condition of the vegetation of the site. Then three sites, which represented three vegetation conditions namely intact, relatively intact (exposed to grazing), and partially farm fields were selected. The site considered as intact, relatively intact and partially farm field are referred in this paper as site one, site two and site three respectively.

After the selection of the sites, sample plots were randomly laid out on parallel transect lines of 200m apart from each other. On each transect line of the study sites, sample plots each with an area of 400m2(11.3 radius) and spacing of 200 meters were laid. A total of 21, 31 and 31 sample plots were taken from site one, two and three respectively. In each plot, the total number of individuals of *A. senegal* and other associated species were counted and recorded. The height and diameter at breast height (DBH) of each individual, with heights of 1.5 m or more, were measured using hypsometer and diameter tape, respectively. For individuals with a height of less than 1.5 m, their basal diameters and heights were measured using caliper and calibrated sticks (rods), respectively (Abeje et al., 2005).

The socio-economic survey involved various data collection techniques, such as informal discussion, semi-structured questionnaire survey, focus group discussions and observations. Before the survey began, local people were contacted to explain the purpose of the survey and to develop trust. For the questionnaire survey, 35 sample households were purposively selected. Using the criterion of dependency on the woodland for NTF products, a semi-structured questionnaire was developed and pre-tested, and interviews were finally undertaken with the selected households. During the interview, the objective of the study has been made clear for the informants. Moreover, informal discussions and focused group discussion were held with individuals, offices and local elders. During the selection of elders for group discussion, consideration was given to age.

3.3. Data Analysis

3.3.1. Vegetation

The status of populations of *A. senegal* and associated species was examined by estimating dominance, density, abundance, frequency, importance value index (IVI) and population structure.

Density was calculated by the number of individuals of a species per unit of area (Abeje et al., 2005). Abundance is defined as the number of stems per plot. Two sets of abundance values were calculated, i.e., average abundance per plot were calculated by dividing the sum of the number of stems per species from all plots by the total number of plots (maximum frequency). Local abundance was calculated as the ratio of the total number of stems of a species divided by its absolute frequency (Tadesse, 2003). Frequency is defined as the presence or absence of a given species in sample quadrants (Lamprecht, 1989). Absolute frequency of a species was obtained by counting the number of plots in which the species was recorded (Kent and Coker, 1994; Tadesse, 2003). Relative frequency of a species was done by calculating the ratio of the absolute frequency of the species to the total number of study plots (which is equal to maximum frequency) (Getachew, 1999; Tadesse, 2003*)*. Importance Value Index (IVI) allows a comparison of the ecological significance of species in a given forest type and depicts the sociological structure of a population in its totality in the community (Lamprechet, 1989). Therefore, it is a good index for summarizing vegetation characteristics and ranking of species (Kindeya, 2003). The IVI was calculated as the sum of the relative dominance (%), relative abundance (%) and relative frequency (%) of *A. senega*l and associated species (Lamprecht, 1989). The IVI of each species was converted in to a 100 per cent scale (Kindeya, 2003).

The term dominance refers to the degree of coverage of a species as an expression the space it occupies. Dominance is usually expressed by stem basal area. This may be expressed as the absolute dominance (=the sum of the basal areas of the individuals in m2 per ha) and relative dominance (= the percentage of the total basal area of a given species out of the total measured stem basal areas of all species) (Lamprechet, 1989). Basal area is the cross sectional area of a tree trunk measured at diameter breast height (DBH, 1.3m). Basal area was calculated for *A. senegal* and associated species. The basal area of a tree was calculated as follows:

BA=Πd2/40000
Where BA = Basal area in m2, d = Diameter at breast height in cm.
Π = 3.14

Population structure is the numerical distribution of individuals of different size or age within a population at a given moment of time (Peters, 1996). To determine the population structure of A. senegal and associated species, all individuals of the species encountered in the quadrants were arbitrarily grouped by 4 cm diameter classes (0 – 4 cm, 4 – 8 cm, 8 – 12 cm, 12 – 16, 16 - 20…32 – 36 and >36) and by 2 m height classes (0 – 2 m, 2 – 4 m, 4 – 6 m …8 – 10 and >10m). The population structure was depicted using frequency histograms of both diameter and height–class distributions (Abeje et al., 2005). The overall shapes or slopes of these frequency histograms were then compared visually. The histograms were classified into two groups. These are: Group I – represented by species with high number of individuals in the lower size classes with a more or less inverted ''J'' shaped frequency distribution of the diameter and height classes (Tefera et al., 2005) and Group II – represented by species, which exhibited a sort of distribution with highest and lowest number of individuals at different size classes periodically (Abeje et al., 2005).

4. Results and Discussion

4.1. Floristic Composition of the Vegetation

The diversity of tree and shrub species in the study area is very low; about nine tree and shrub species were recorded from all of the three sites in the present study (Table 1). The total number of tree species registered at the three studied sites was more or less the same. However, sites one (intact) found to own relatively higher number of tree species (9) than sites two (8) and site three (7) (Table 1). The low diversity in tree species composition may be due to ecological limitations associated to low and erratic rainfall and soil condition, in the area.

The density, abundance, frequency, dominance and importance value index (IVI) of the tree species in the study sites also revealed a pattern depending on the degree of disturbance (Table 1). Density of tree species is the highest in site one (404 stems/ha) and lowest in the site three (152 stems/ha). In terms of density of each species, *A. senegal* is the species with the highest density in all study sites, with the density range from 100 -317 stems/ha (Table 1). This indicated that *A.senegal* is dominant in terns of tree density and it constituted about 71.77% of the vegetation and the remaining 28.23% is comprised by *Acacia syal,* Chamda, *Diorostachys ginerea,* Kitrite, G*rewia ferruginea, Balanytes aegyptica*, Zana and *Dalbergia melanoxylon* tree species. In terms of abundance, *A. senegal* is the most abundant in site one, followed by site two and site tree. In addition, *A. senegal*, is known to hold multipurpose including high economic significance is observed to dominate the abundance, and own highest density in all study sites. In general, site one has higher regeneration of woody plants than the remaining sites. *A. senegal* is the most frequent and ranked first in all the study sites. The remaining tree species vary in their frequency and rank accordingly in each study sites (Table 1). This may be linked to the preference of other trees by local people for their forage, charcoal making and fuel wood uses. So individuals of the species are purposely made to have large size, which make it to be dominant in most of the sites (Site 1 and 3).

Acacia senegal rank first in IVI in all sites (Table 1). This shows that *A. senegal* is the most ecologically important tree species in the study area. In fact, each tree species has different total IVI in each study site. This indicates that each species has different ecological importance in different ecosystem. Stands that yield more or less the same IVI for the characteristic species indicate the existence of the same or at least similar stand composition, structure, site characteristics and comparable dynamics (Lamprechet, 1989).
Population structure data have long been used by foresters and ecologists to investigate the regeneration characteristics of tropical trees. Since it is difficult to determine the age of tropical trees, studies on population structure are based on size class–distributions. Most analysis of these groups has found that tropical tree populations are characterized by a limited number of different size class–distributions (Peters, 1996). The height and diameter class (Distribution of the population) which in turn defines the population structure which refers to the regeneration status as well as past and recent regeneration patterns of the species (Demel, 1996). Population structure is an extremely useful tool for orienting management activities and, perhaps most importantly, for assessing the impact of resource extraction (Peters, 1996).

Table 1. Density, abundance, frequency, dominance and importance value index (IVI) of the tree species in the Abderafi Woreda.

Site No. 1											
No	**Species**	**D/ha**	**RD (%)**	**N**	**%N**	**LN**	**F**	**%F**	**Do**	**% Do**	**IVI (%)**
1	*A.senegal*	317	78.5	12.7	78.7	12.7	21	42	1.1	19	66
2	*A.Seyal*	17	4.2	0.7	4.1	2.8	5	10	1.2	22	6
3	Chamda	6	1.5	0.2	1.5	1.3	4	8	1.6	28	4
4	*Diorostachys ginerea*	4	1.0	0.1	0.9	1.0	1	2	0.1	2	1
5	Kitrite	15	3.7	0.6	3.8	6.5	2	4	0.0	1	4
6	*Grewia ferruginea*	6	1.5	0.2	1.5	2.5	2	4	0.0	0	2
7	*Balanytes aegyptica*	10	2.5	0.4	2.4	2.7	3	6	1.3	24	4
8	Zana	11	2.7	0.4	2.7	1.5	6	12	0.1	2	6
9	*Dalbergia melanoxylon*	18	4.5	0.7	4.4	2.5	6	12	0.1	2	7

Site No. 2											
No	Species	D/ha	RD (%)	N	%N	LN	F	%F	Do	% Do	IVI (%)
1	*A.senegal*	158	70.22	6.32	70.25	6.32	31	52.5	0.90	31	64
2	*A.Seyal*	21	9.33	0.84	5.21	5.20	5	8.5	0.51	18	8
3	Chamda	10	4.44	0.42	2.61	2.17	6	10.2	0.26	9	6
4	*Diorostachys ginerea*	9	4.00	0.35	2.20	1.83	6	10.2	0.23	8	5
5	Kitrite	10	4.44	0.39	2.41	12.00	1	1.7	0.03	1	3
6	*Grewia ferruginea*	8	3.56	0.32	2.00	3.33	3	5.1	0.11	4	4
7	*Balanytes aegyptica*	5	2.22	0.19	1.20	3.00	2	3.4	0.82	28	2
8	*Dalbergia melanoxylon*	4	1.78	0.16	1.00	1.00	5	8.5	0.03	1	4

Site No. 3											
No	Species	D/ha	RD (%)	N	%N	LN	F	%F	Do	% Do	IVI (%)
1	*A.senegal*	100	65.8	4.00	66.0	8.3	15	38	0.52	12.89	56
2	*A.Seyal*	33	21.7	1.32	8.2	3.4	12	30	1.10	27.34	20
3	Chamda	2	1.3	0.06	0.4	1.0	2	5	0.15	3.83	2
4	*Diorostachys ginerea*	5	3.3	0.19	1.2	3.0	2	5	0.03	0.78	3
5	Kitrite	4	2.6	0.16	1.0	1.3	4	10	0.69	17.11	5
6	*Balanytes aegyptica*	7	4.6	0.29	1.8	2.3	4	10	1.45	36.09	5
7	*Dalbergia melanoxylo*	1	0.7	0.03	0.2	1.0	1	3	0.08	1.95	1

No = No of species; D = Density per ha; RD = Relative Density; N = Average abundance per plot; % N = Relative abundance of the species; LN = Local abundance; F = Absolute Frequency; % F = Relative frequency; DO = Absolute Dominance (m2 ha–1); % DO = Relative Dominance; and IVI = Importance Value Index.

The vegetation population structure of the study sites showed Group I distribution both in their diameter and height (Figure 1 & 2) except little irregularity is shown in the height distribution of site two. Moreover, good regeneration is seen in site one and site three as compared to study site two. Conversely, it is indicative of good status of progressing towards stable population structure (Tefera et al., 2005) and a healthy population (Banda et al., 2006). Moreover, in these sites

4.2. Population Structure

Smaller numbers of individuals are present as we move to higher classes both in the diameter and height distribution class. This shows that there is high extraction of trees for fuel wood, charcoal, and other purposes which are common in the area. Generally the vegetation structure of the three study sites showed that good regeneration and good status for populations in site one as compared to site two and three this may be due to the difference in absence as well as presence of interference from human activities in the study area.

Acacia senegal shows an approximately Group I size class–distribution in both diameter and height in all three sites. The remaining tree species show an approximately Group I size class–distribution and Group II size class (Irregular) in both diameter (Figure 3 - 8). Generally, a Group I size class–distribution (as the groups are described in the materials and methods section) is indicative of good regeneration status progressing towards stable population structure (Tefera et al., 2005) and a healthy population (Banda et al., 2006).

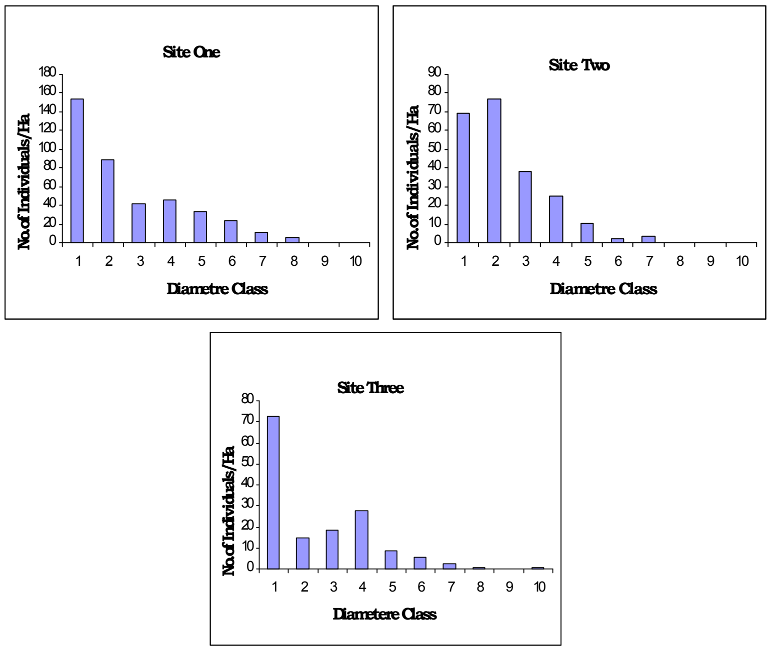


Figure 10. Distribution of trees in different diameter classes of the three sites of Abderafi woreda **6**

6(Diameter Classes: Class 1 = 0 – 4cm; Class 2 = 4 – 8cm; Class 3 = 8 – 12cm; Class 4 = 12 – 16cm; Class 5 = 16 – 20cm; Class 6 = 20 – 24cm; Class 7 = 24 – 28cm; Class 8 = 28 – 32cm; Class 9 = 32 – 36cm; Class 10 = >36).

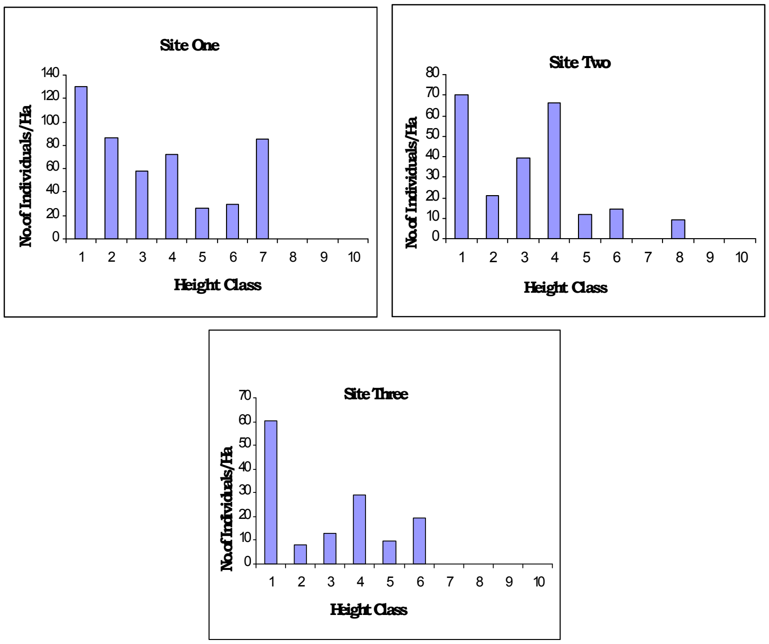


Figure 2.11 Distribution of trees in different Height classes of the all three sites in Abderafi Woreda 7

But as seen in the histograms of the present study, even though there is a positive regeneration for the species that show Group I size class–distribution, small number of individuals existed in the higher diameter and height classes for some tree species due to the reasons discussed at the population structure of the vegetation. Thus, urgent action is needed to maintain acceptable number of individuals at higher diameter and height classes to use them for the desired end–use like NTFPs and environmental benefits. Therefore there is a need for in depth study on their regeneration mechanisms and environmental factors affecting their population, and to devise appropriate methods and following management actions to facilitate and increase their regeneration.

7 (Height Classes: Class 1 = 0 – 2m; Class 2 = 2 – 4m; Class 3 = 4 – 6m; Class 4 = 6 – 8; Class 5 = 8 – 10; Class 6 = 10 – 12; Class 7 = 12 – 14; Class 8 = 14 – 16; Class 9 = 16 – 18; Class 10 = >18).

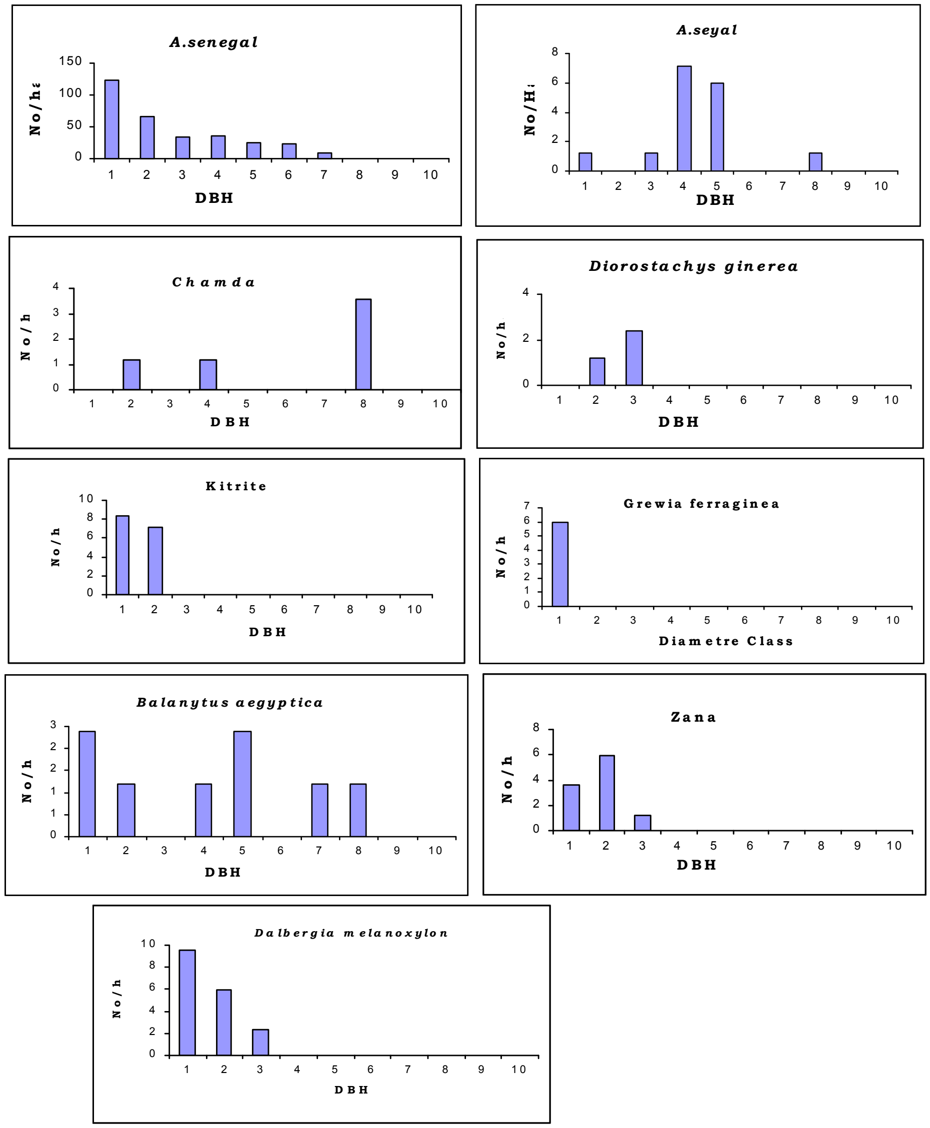
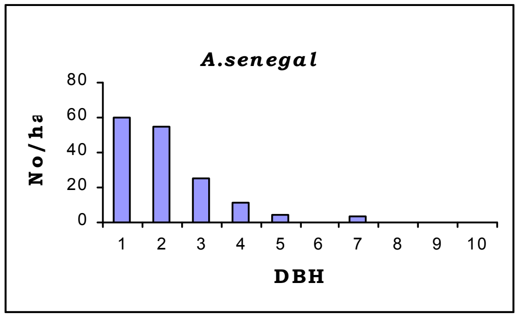
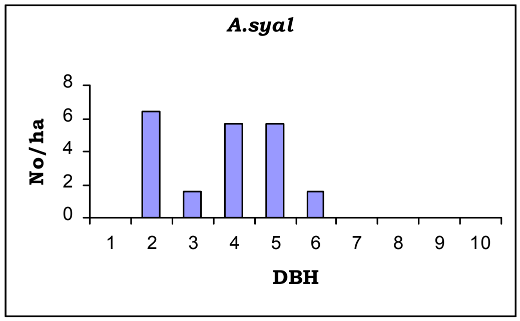
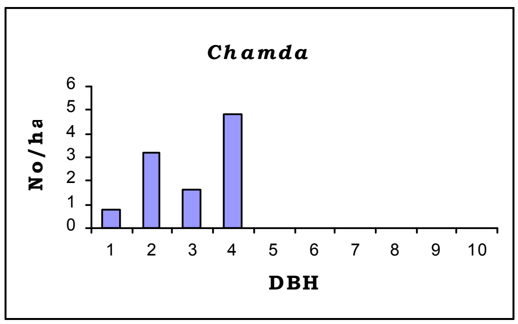


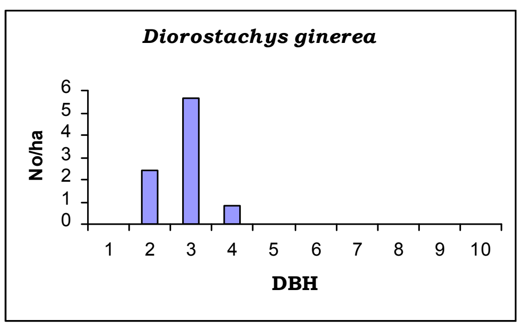
Figure 3. Distribution of different tree species in different diameter classes at site one[8]

[8] Diameter Classes: Class 1 = 0 – 4cm; Class 2 = 4 – 8cm; Class 3 = 8 – 12cm; Class 4 = 12 – 16cm; Class 5 = 16 – 20cm; Class 6 = 20 – 24cm; Class 7 = 24 – 28cm; Class 8 = 28 – 32cm; Class 9 = 32 – 36cm; Class 10 = >36.


A.senegal
No/ha
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10
DBH


A.syal
No/ha
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10
DBH


Chamda
No/ha
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10
DBH


Diorostachys ginerea
No/ha
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10
DBH

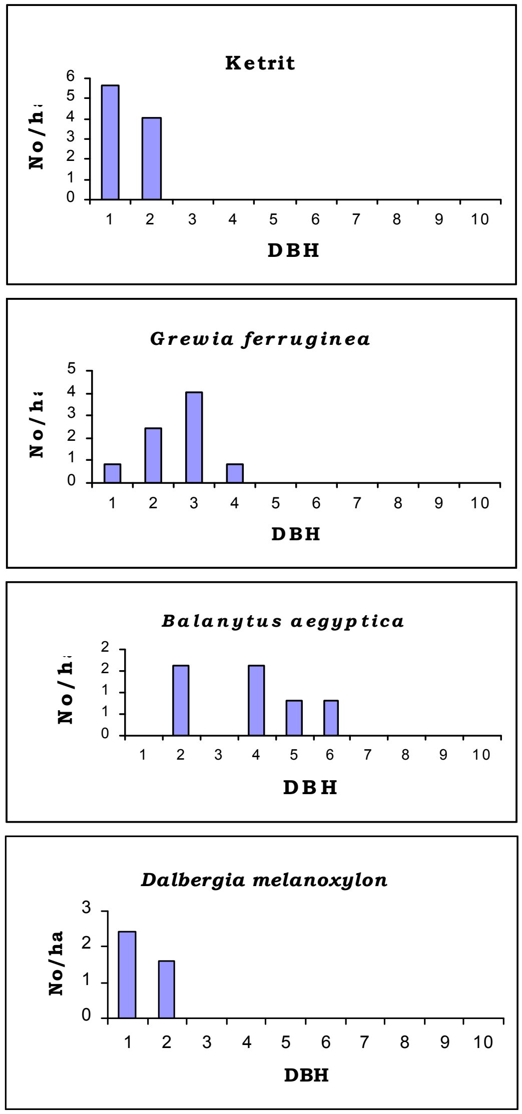
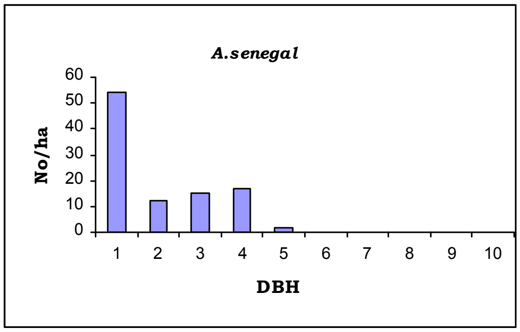
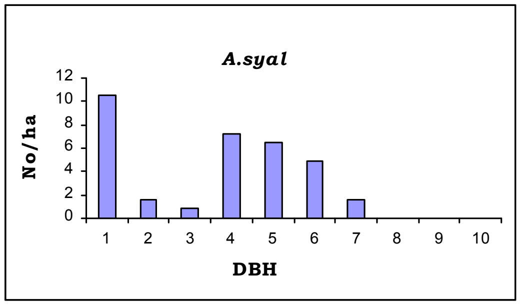
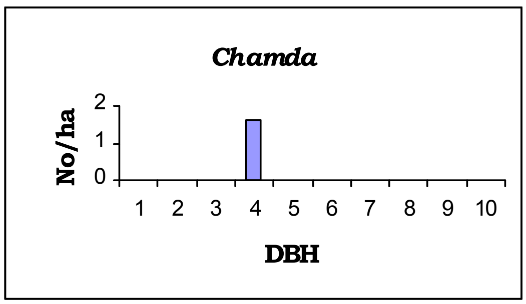


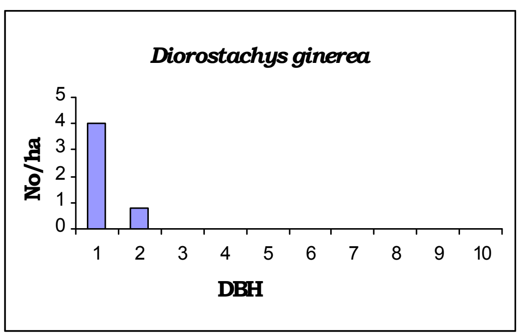
Figure 4. Distribution of different tree species in different diameter classes at site two[9]

[9] Diameter Classes: Class 1 = 0 – 4cm; Class 2 = 4 – 8cm; Class 3 = 8 – 12cm; Class 4 = 12 – 16cm; Class 5 = 16 – 20cm; Class 6 = 20 – 24cm; Class 7 = 24 – 28cm; Class 8 = 28 – 32cm; Class 9 = 32 – 36cm; Class 10 = >36.


A.senegal
No/ha
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10
DBH


A.syal
No/ha
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10
DBH


Chamda
No/ha
2
1
0
1 2 3 4 5 6 7 8 9 10
DBH


Diorostachys ginerea
No/ha
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10
DBH

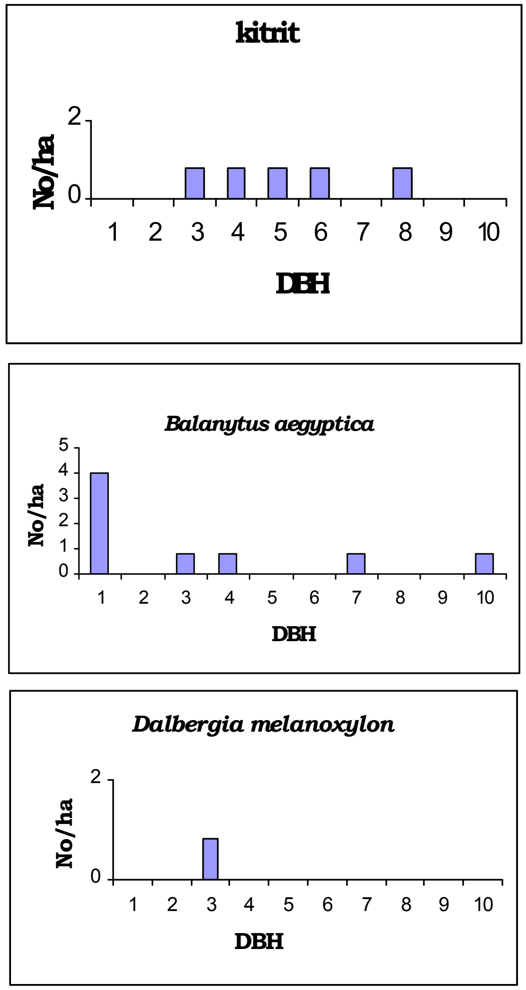
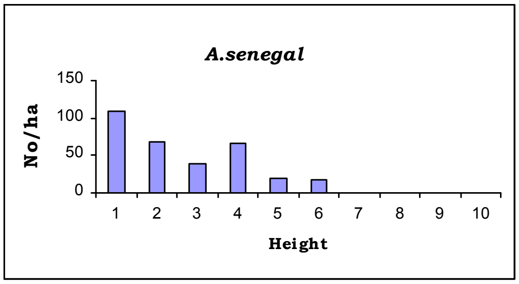
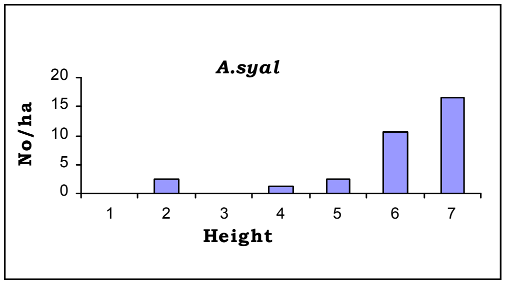
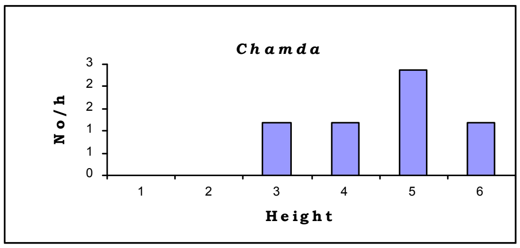


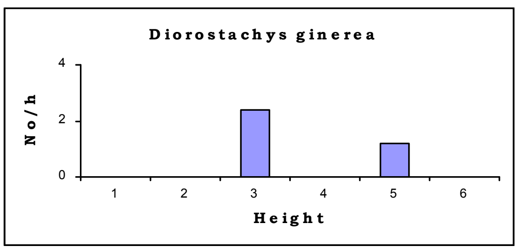
Figure 5. Distribution of different tree species in different diameter classes' at site three[10]

[10] Diameter Classes: Class 1 = 0 – 4cm; Class 2 = 4 – 8cm; Class 3 = 8 – 12cm; Class 4 = 12 – 16cm; Class 5 = 16 – 20cm; Class 6 = 20 – 24cm; Class 7 = 24 – 28cm; Class 8 = 28 – 32cm; Class 9 = 32 – 36cm; Class 10 = >36.


A.senegal
No/ha
150
100
50
0
1 2 3 4 5 6 7 8 9 10
Height


A.syal
No/ha
20
15
10
5
0
1 2 3 4 5 6 7
Height


Chamda
No/h
3
2
2
1
1
0
1 2 3 4 5 6
Height


Diorostachys ginerea
No/h
4
2
0
1 2 3 4 5 6
Height

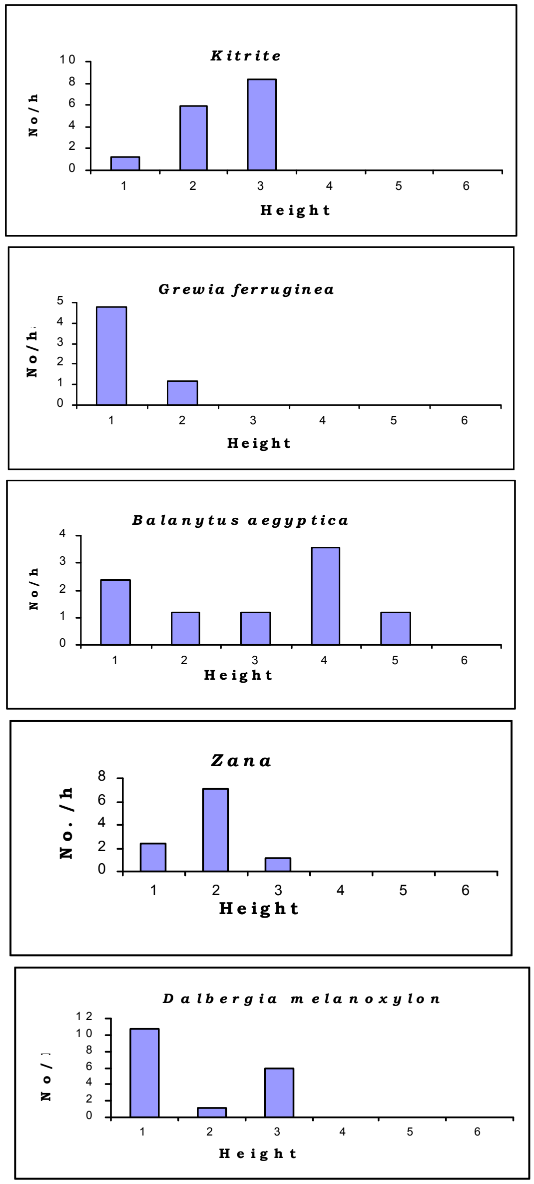


Figure 6. Distribution of different tree species in different height classes at site one[11]

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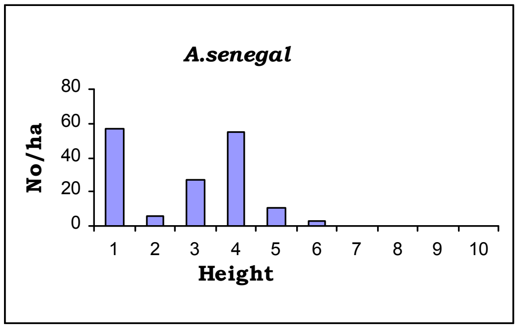
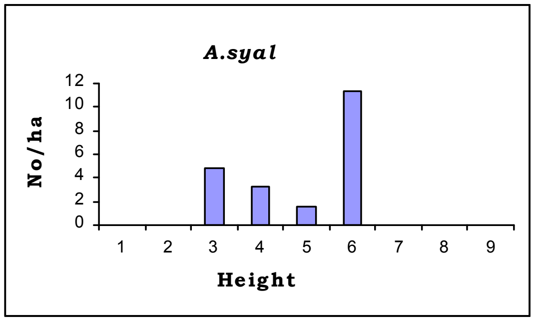
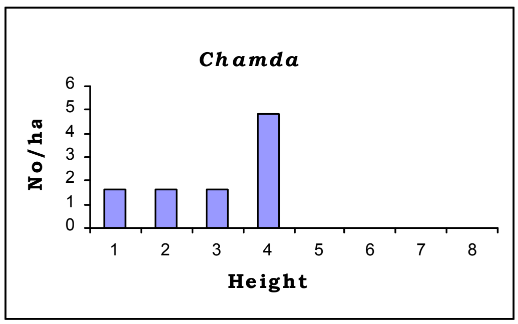
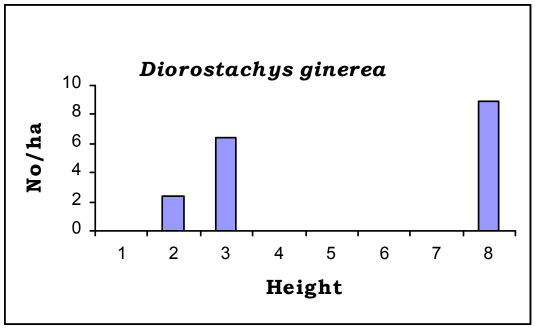
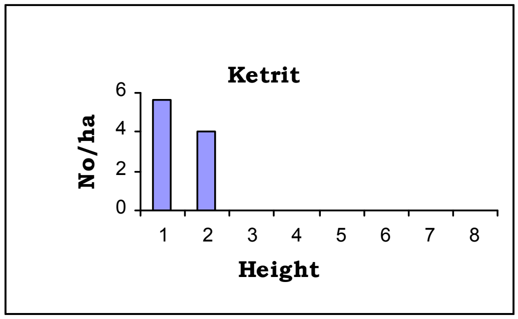
[11] Height Classes: Class 1 = 0 – 2m; Class 2 = 2 – 4m; Class 3 = 4 – 6m; Class 4 = 6 – 8; Class 5 = 8 – 10; Class 6 = >10

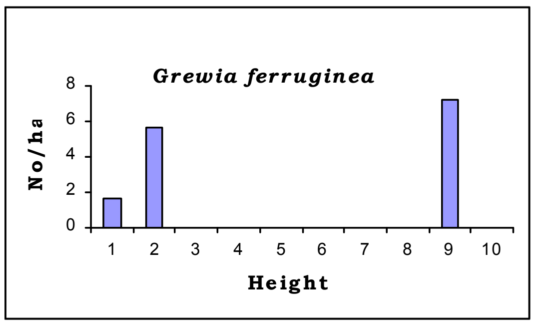

A.senegal
No/ha
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10
Height


A.syal
No/ha
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9
Height


Chamda
No/ha
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8
Height


Diorostachys ginerea
No/ha
10
8
6
4
2
0
1 2 3 4 5 6 7 8
Height


Ketrit
No/ha
6
4
2
0
1 2 3 4 5 6 7 8
Height


Grewia ferruginea
No/ha
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10
Height

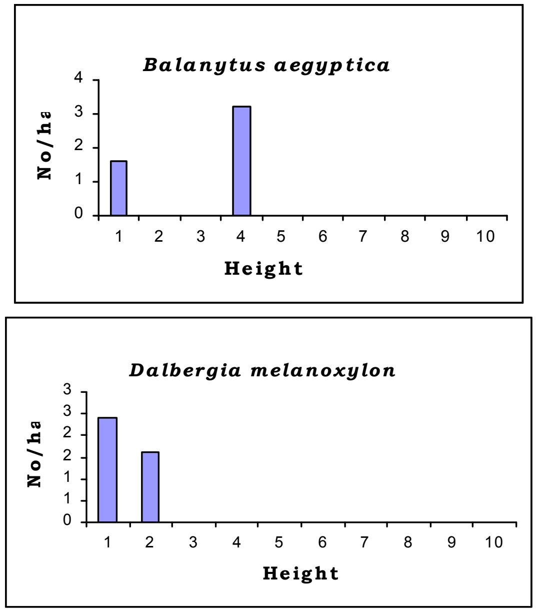
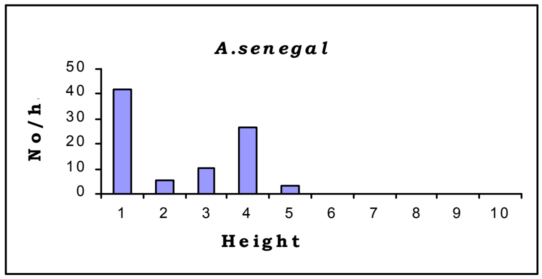
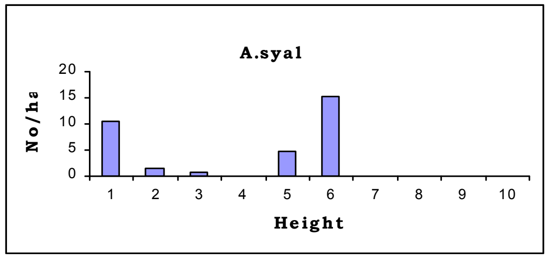
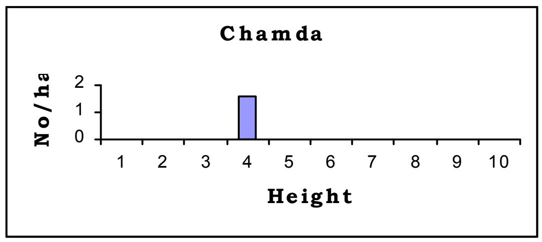


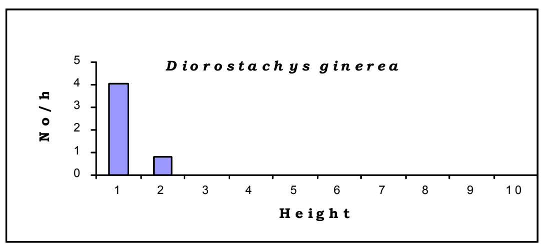
Figure 7. Distribution of different tree species in different height classes at site two**12**

[12] Height Classes: Class 1 = 0 – 2m; Class 2 = 2 – 4m; Class 3 = 4 – 6m; Class 4 = 6 – 8; Class 5 = 8 – 10; Class 6 = >10


A.senegal
No/h
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10
Height


A.syal
No/ha
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10
Height


Chamda
No/ha
2
1
0
1 2 3 4 5 6 7 8 9 10
Height


Diorostachys ginerea
No/h
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10
Height

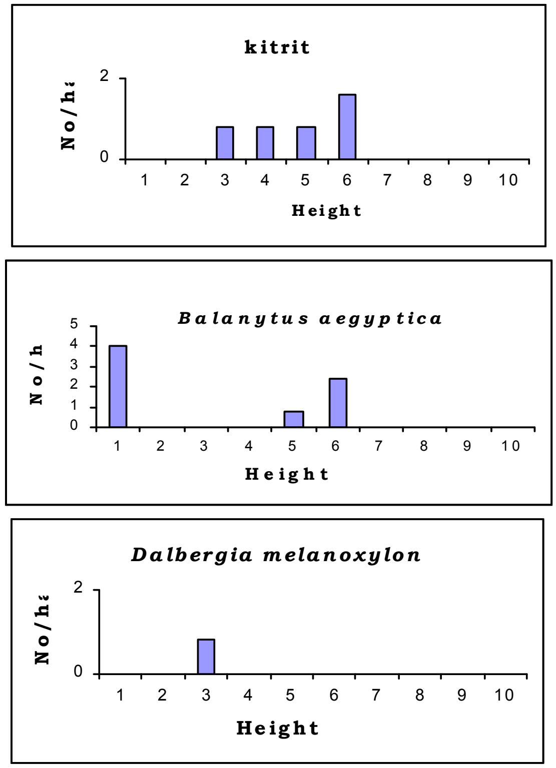


Figure 8. Distribution of different tree species in different height classes of site three**13**

From the height structure of the tree species presented above it is easily observed that *A. senegal* exhibits Group I size class–distribution and some tree species exhibits the normal J shape structure (*A.syal,* kitrit and Zana). This may be associated to the different factors affecting the populations of the species through time. Therefore, periodic monitoring of population structure of a species can be used to assess the ecological health of a tree population and to guarantee the long–term sustainability of NTFPs (Peters, 1996).

4.3. Potential of **A.senegal** *tree stands for Gum production*

Acacia senegal trees can tapped beginning from smallest size class, less than 5 cm diameter, by making incisions in the stems and branches by stripping away the bark to accelerate exudation of gum arabic (Mohamed, 2005). To determine harvestable number of

[13] Height Classes: Class 1 = 0 – 2m; Class 2 = 2 – 4m; Class 3 = 4 – 6m; Class 4 = 6 – 8; Class 5 = 8 – 10; Class 6 = >10

A. senegal trees for gum arabic production in the study area, trees having diameter greater than and equal to 4 cm are counted. Harvestable number of *A. senegal* trees per hectare in the study area are 194, 98 and 46 in site one, two and three respectively. This number is less as compared to the number of harvestable size of *A.senegal* trees of the central rift valley region which is ranging from 12 – 209 per hector this due the inclusion of individuals at diameter class of greater than or equal to 2cm for harvesting of gum arabic from the stand. Even though, this study excludes those individuals with diameter class of less than 4cm from harvestable size class, still the stand of the *A. senegal* in the study area indicated that there is sufficient number of trees to launch commercial harvesting of gum arabic from the study area. There fore, it is encouraging to start the gum arabic business in the area.

4.4 Socio Economic Importance

The socio economic survey result showed that most of the inhabitants were farmers and growing cash and food crops, rearing animals, trading and daily labour were their main sources of income.

Crop production is the major source of income for the local people. Large portions of the population grew cash and food crops. Sesame and cotton are the main cash crops grown in the study area of which sesame is an exportable crop. Previously, shifting cultivation was the common traditional farming system practiced by almost all individuals. The main reasons for shifting cultivation were weed problem, reduction in soil fertility and the need to grow sorghum.

All households living in and around the wood land area of Abderafi used the woodland in one or other ways. However, more dependency was observed on the utilization of six main types of NTFPs. These are, honey, fuelwood, farm implements, gum, traditional medicines and household utensils. No villager generated income from the sale of forest products. This might be due to the presence of an alternative livelihood means in the study area i.e. agriculture. Locals were not aware of the economic importance of *A.senegal* tree species. Hence, they have not been using the tree economically. They only used its wood for making farm implements, fencing, charcoal, and fuelwood. The production of gum from *A.senegal* is not common by the locals. Lack of awareness in the production system and marketing of gum arabic were mentioned as the major constraints in the study area. However, some people from the neighboring country (Sudan) regularly harvest gum arabic from the *A.senegal* stand near the Ethio-Sudan boarder.

The presence of large grazing lands including the woodland encourages the locals to rear large sizes of livestock. Livestock are kept as a source of animal power, to diversify income source and to use it at the time of crop failure and sickness. Also, the size of a livestock herd is a mark of social prestige and a mark of economic well-being. Draft power is used for ploughing, collecting and transporting fuelwood, fetching water, transporting food and other materials to and from markets, etc. Free grazing is the most common practice at study site in which the woodland is the main grazing area for livestock. But, due to annual burning of the vegetations and the introduction of large cattle population size, shortage of animal feed during the dry season is common.

5. Conclusion

The population status of tree species of Abderafi woreda generally shows the presence of good regeneration. However at higher size classes the number of individuals dramatically falls probably due to high rate of harvest taking place in the area. In addition some trees unfortunate in some diameter class and showed the normal J-shaped structure which is the sign of their instability in the stand of *A.senegal* in the study area. Nonetheless, *A. senegal* is found to have higher density, good regeneration, and high IVI in the three sites where the inventory were done. If appropriate management activities are applied, the nature of the population structure of most of the tree species including *A. senegal* will take stable type. Indeed, there is a possibility to start the gum arabic business with the existing harvestable number of *A. senegal* trees, as this could supplement the income from agricultural production in the study area. There is a possibility of recruiting harvestable number of *A. senegal* trees in the near future since there is very high regeneration of *A. senegal* trees in the area. The socio economic survey also indicated that farmers use different tree species for different purpose, however, the population structure of each species depicted that there is selective cutting of trees at a certain diameter class in the stand. This adversely affects the status of each species which will have impact to the over all status of the stand.

6. Recommendations

- Improved management of the woodland is needed to improve the vegetation structure of the study area.
- Study on soil seed bank and regeneration potential of the associated tree species should be done to see the main cause of their irregularity in their structure.
- Yield study should be followed in order to determine weather the amount of gum arabic produced from the area satisfies for commercialization purpose.
- Market studies should go hand–in–hand with the development of the countries' *A. senegal* resource base for gum arabic production.
- Assessments of other gum bearing tree species in the study area are needed.

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Study on the Diversity and Socio-economic Importance of Woody Trees on Farm lands, a case of North Gondar

Abrham Abiyu1, Tatek Dejene, Kibruyisfa Sisay, Bihonegn Akalu, and Enywe Adgo3
1 Gondar Agricultural Research Center, Gondar
3 Bahir Dar University

Abstract
Investigating the existing diversity, niches, use and socioeconomic importance of farmland trees is imperative. This underlines the objectives of this study. The study was conducted in Enfranz and Metema. The principle of functional ecological groups was the guiding rule in the data collection process. For every tree species encountered on a farm, information was collected by interviewing household members involving farm walks, and data recording using questionnaire. All answers were post-coded during data entry in the databases that were created for data analysis and storage. Several farms × species matrices were formed by inserting abundance > 0 in a specific matrix cell. 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. Moreover, diversity indices were also used to calculate diversity directly from information on species' presence and absence. Six types of use groups were identified based on the purpose of species. Analysis of species by sample matrix showed, growing trees for construction has the highest frequency. It has been mentioned 876 times. 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 showed fuel wood is the most important use group followed by construction. Interestingly, fuel wood has the highest in species average. Moreover, analysis of species by sample matrix 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. On the other hand, degraded hills, gully, river banks, and soils conservation structures showed low species- average value. 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. Source of seedling showed 66.70 % from government nurseries and 50.94% from their neighbor and the rest from their own. Low seedling survival due to drought and free grazing mentioned as limitations for tree growing. The most important tree management activities (in order of decreasing importance) are side pruning, lopping, hoeing, weeding, manuring, and fencing. Generally, low diversity compels diversification by means of addition of a new species or adaptation of a species performing well in similar conditions. Making more germplasm available, niches or use groups with low diversity and the socio-economic factors should be taken in to consideration to increase the diversity.

Key words: Farmland, Tree diversity, Niches, socioeconomic, Enfranz, Metema

1. Introduction

North Gondar, which was once regarded as a place of dense and diversified vegetation cover and is now losing its green cover. Patches of natural forests around places of worship are indicators of this fact. Trees in forests have been subjected to repeated man-made and natural disaster as a result it is decreasing in size and quality from time to time and land degradation and deforestation has been widespread in the area. Experience in general and observation in North Gondar zone indicates that uncontrolled removal of forests and demographic pressures have been the major causes of natural resource degradation. The rural fuel wood and fodder needs in the area are largely meeting from the forests, which do not appear to be capable of providing these increased demands. Furthermore, as a result of clearing of the forest cover, there is a very sever soil erosion. Large areas of agricultural lands are in the formation of big gullies and rock out crops. This has undoubtedly posed many social and economic problems and the need for the food, fodder, energy, biomass, and wood continues unabated.

Farmers plant or deliberately leave trees in farmland and homesteads in pursuit of their livelihood goals of income generation, risk management, household food security and optimum use of available land, labour and capital (Lengkeek, 2003). The many products, services and roles needed by people to be fulfilled by trees can not be provided by only a few species. Currently there is critical decline of tree species in conventional forests in Africa in general and Ethiopia in particular. North Gondar zone is a typical example for such occurrence. Consequently farmers are planting and deliberately leaving different tree species on agricultural land such as homesteads, farm boundaries, inside farmlands, wood lots and grazing lands in the zone. However, there is no scientific way of managing such agroforests. In some cases mono-crops are dominating the others vanishing. In most cases, only over aged trees are found in agricultural land mainly on farmlands and on grazing lands. In some cases, good structure of trees of different species is observed.

In light of the above problems, some studies on the forest resource in the area hints that species that can provide diversified benefits to the local people are disappearing gradually and this implies not only at the future fuel wood, fodder and other forest products crises but also a serious ecological disaster that the area is a heading for.

Despite the benefits that could be obtained from the proper development and utilization of the farmland tree species, knowledge on the diversity, phonology, propagation technique, characteristics and the socio economic importance of most farmland tree species is limited. As a result the species are disappearing at an alarming rate even before we have a chance to study them. There for this study is proposed to meet the following objectives;

2. Objectives

- Investigate the existing diversity of woody plants on agricultural land
- Investigate and document the Silvics, Biology, use and socioeconomic importance of farmland trees
- Recommend the possible conservation, utilization and management of woody tree diversity on farm lands.

3. Materials and methods

The study was conducted at Enfranz and Metema, North Gondar zone. 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 questionnaire. 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.

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.

Table 1. Summary of sampled watersheds and household characteristics

Location of watershed	No of HH visited	Average land holding (Ha)	N of Female HH
Enfraz	28	0.69	4
Metema	30	0.62	6

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. 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 Ha were calculated directly from information on species' presence and absence. The Renyi 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).

4. Result and discussion

This study identified different types of use groups based on the purpose of different species for the farmers in the study area. This includes the fuelwood, Income, Honey, charcoal, shade and fertility. From the analysis of the data, it was found that the use group for fuel wood has a higher diversity value followed by income and shade (table 2). The use group income has a highest evenness value.

Table 2 result for diversity and evenness indices for the different use groups

	N2 diversity	N1 richness	N2/N1 evenness	N of species	Shannon' diversity (H)	Log (N)	H/log (N) evenness	Total
Fuel wood	7.06	9.22	0.77	17	2.22	2.83	0.78	119
Income	7.01	8.32	0.84	12	2.12	2.48	0.85	87
Honey	4.34	5.37	0.81	9	1.68	2.20	0.77	70
Charcoal	2.01	3.34	0.60	8	1.21	2.08	0.58	23
Shade	5.14	7.53	0.68	11	2.02	2.40	0.84	31
Fertility	4.17	5.12	0.82	8	1.63	2.08	0.79	41

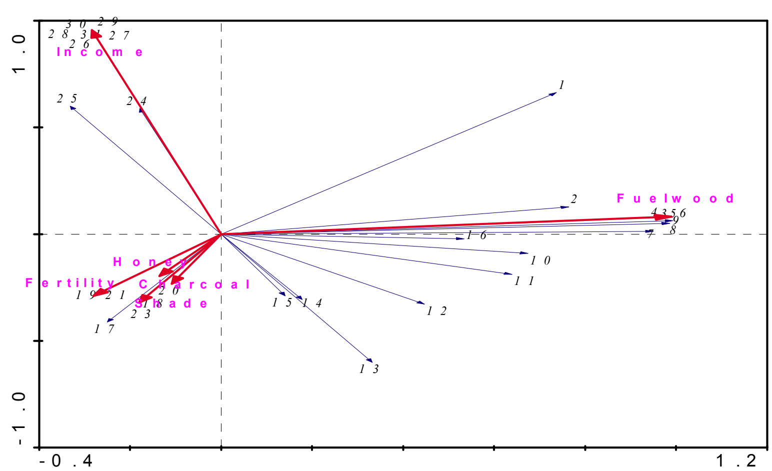

Fig 1 canonical correspondence analysis (CCA) showing the distribution of Species in use group.

Note: *1.E.camaldulensis, 2.V.amygdalina, 3. C.aurea, 4.H.revolvtum, 5.G.ferruginea, 6.D.angustifolia, 7. E.abyssinica, 8. J.procera 9.P.persica, 10.Olia africana, 11. F.toninngii, 12.M.senegalensis, 13.Serkin, 14. C.macrostachyus, 15.A. digitata, 16.A.seyal, 17.F.vasta, 18.A.indica, 19.A.albida, 20.B.adysen, 21.S.sesban, 22. B.adysen, 23.S.molle, 24.C.africana, 25.S.guineese, 26.F.sur, 27.R.prinoi, 28.Coffe, 29.C.edulis, 30.Citrus, 31.*Papaya.

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. 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. 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.

Table 3 Characteristics of the different use-groups

Use group	Occurrence[14]	Farm occurrence[15]	Species average[16]
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

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. Note only are homesteads important tree growing niches, they are also diverse as they have higher

[14] *Occurrence: number of times the use was mentioned;*

[15] *Farm occurrences: number of households where the use was mentioned;*

[16] *Species average: number of species per farm and per use for those farms where the use was mentioned*

species-average result, that is the number of species per farm and per niche for those farms where the niche was mentioned.

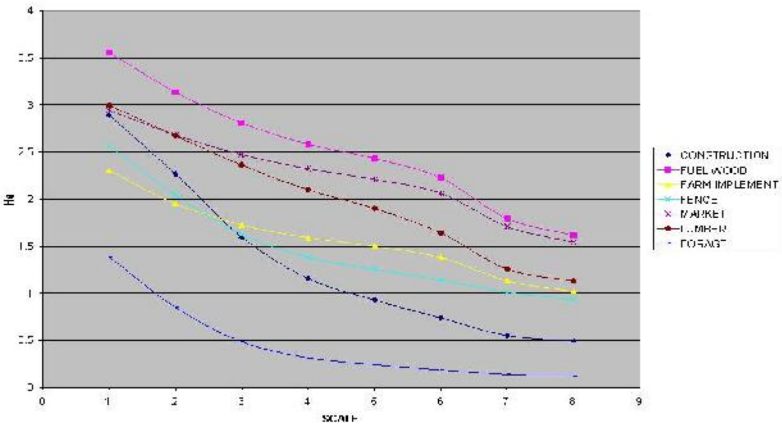

Figure 2 diversity profile values for the different use-groups

Table 4 Characteristics of tree growing niches

Tree growing niche	Occurrence[17]	Farm occurrence[18]	Species average[19]
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

[17] Occurrence: number of times the niche was mentioned;
[18] Farm occurrence: number of households where the niche was mentioned;
[19] *Species average: number of species per farm and per niche for those farms where the niche was mentioned*

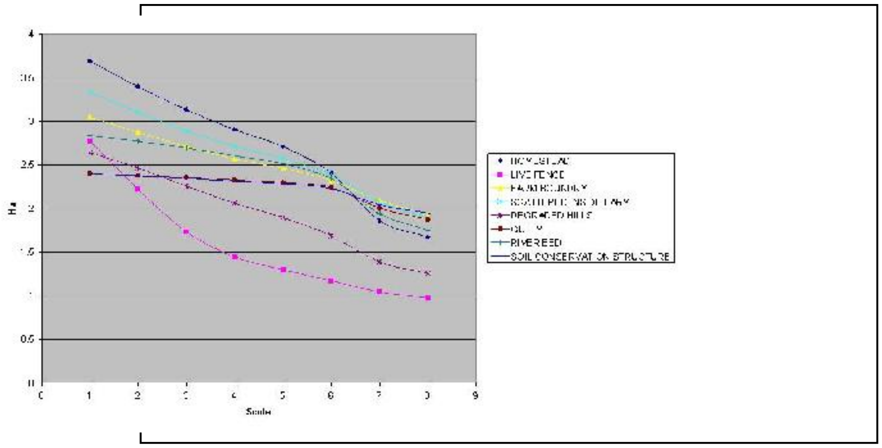

Figure 3 Diversity profile values for the different tree growing niches

On the other hand, 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.

Farmers get planting materials from different sources. For instance source of seedling by ownership showed 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 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.

Table 5: 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

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.

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%.

5. Conclusion and recommendation

In general low diversity is observed for 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.

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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Study on propagation techniques and population structure of *Boswellia papyrifera* (Del.) Hochst in North Gondar Zone

Tatek Dejene, Abrham Abiyu and Kibruyisfa Sisay
Gondar Agricultural Research Center. P.O. Box 1337

Abstract
This research has been designed with the purpose to investigate the current population structure of Boswellia stands, examine the possibility of raising stock plants from mature trees of Boswellia papyrifera; to determine the best length, diameter and planting time of cuttings for successful establishment. The study was conducted in North Gondar, Ethiopia. Specifically the population structure study conducted at three woredas, namely Armachiho, Metema and Quarra. Where as the artificial propagation study from cuttings was done at Metema only. To study population structure from stem diameter size distribution, inventory of representative forests was done. For this purpose sample plots measuring 20x20 m^2 were used for inventory. Sample plots have been laid on transect lines stretched along the slope. Moreover, cuttings were taken from branches of healthy looking trees. The branches were taken during the time of planting and pit preparation. Each branch cutting was planted in a pit that has a 50 cm depth and a cross section area of 900m^2. The experimental design was a factorial arrangement of three levels of length of the branch cutting (1 m, 1.5 m and 2 m), two levels of cutting diameter(10-15 cm, 16-20 cm and 21-25 cm), and four levels of planting season (first week of May, second week of July, third week of October, and third week of March). In each plot, 7 branch cuttings were planted in raw at a spacing of 2 m and 4 m spacing has been used for between rows. Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000). The result showed most of the sites have tree densities of between 200 and 300 individuals trees with DBH > 10 cm per ha. Moreover all sites studied showed a similar hump shaped distribution. The hump shaped curves overestimated the frequency of the small individuals in the populations and underestimated the large individuals. In most populations the number of small individuals was extremely low, suggesting a lack of regeneration. The cutting trial also showed that among the treatments, planting season and its interaction with the height of the cutting found to bring significant difference.

Key words: Boswellia papyrifera, Population structure, propagation techniques, Metema

1. Introduction

Boswellia papyrifera (Del.) Hochst. is an oleo-gum resin producing, deciduous multipurpose tree species with a paperacious bark that peels in flakes. It is one of the 17 genera described in the family *Burseraceae*, which is estimated to encompass about 500-600 species (Vollesen, 1989; Hedberg and Edwards, 1989). It is found in woodlands and wooded grass lands, on steep rocky slopes, lava flows or sandy river valleys, at an altitude between 950 - 1800m a.s.l. and with an annual mean temperature of 20-25^{o} C and an annual mean precipitation of less than 900 mm (Von Breitenbach, 1963; Anonymous, 1997, Azene, 1993; Fitchel and Admassu, 1994).

Boswellia has an immense ecological and economic significance (Azene, 1993). It is found to be highly suitable for future reforestation establishments or restoration efforts in moisture deficit arid and semi arid areas (Kindeya et al., 2005). This species produces frankincense, an oleo-gum resin valued for its industrial, folk medicine, cultural and religious uses (Girmay, 2000). It has wide demand in domestic and international markets.

In ANRS, the woodlands dominated by B. papyrifera is identified in nine zones covering 34 woredas and 151 PAS. The total area covered by Boswellia stand is estimated to be over 600,000 ha (Girmay, 2000; Anonymous, 1997) and was observed in the lowland areas of the Nile and Tekeze basins and the western lowlands. According to the Regional Bureau of Agriculture (Anonymous, 1997), about the 69.4 % (419,216 ha) of the Boswellia stand occur in North Gondar Zone (NGZ) where it is found abundantly in Metema, Quara and Armacheo woredas of NGZ. If the resource is managed properly a wide range of various benefits could be obtained as creation of new employment, new industries, foreign exchange as well as land conservation and rehabilitation.

Ethiopia is one of the world's largest producers of Frankincense (olibanum), the exploitation of olibanum is one of the top income and employment generating activities in North Gondar and therefore a very important source of revenue for the country and the rural people (Mulugeta, et al. 2003). Due to this exploitation the potential range of forest communities with Boswellia is greatly reduced and is classified as an endangered species (Kindeya et al., 2002; NCSS, 1993). A major concern is the missing or hampered natural regeneration and the increased vulnerability to pests and other damages caused by tapping (Ougbazghi, 2001, Tilahun, 1997; Marshall, 1998; Kindeya et al 2002). In response to this challenge tree population structure and propagation by cutting studies has been conducted in North Gondar, Ethiopia. Hence, this research has been designed with the purpose to investigate the current population structure of Boswellia stands, examine the possibility of raising stock plants from mature trees of *Boswellia papyrifera*; to determine the best length, diameter and planting time of cuttings for successful establishment.

2. Materials and methods

The study area

The study was conducted in North Gondar, Ethiopia. Specifically the population structure study conducted at three woredas, namely Armachiho, Metema and Quarra. Where as the artificial propagation study from cuttings was done at Metema only.

Tree population structure study

To study population structure from stem diameter size distribution, inventory of representative forests was done. For this purpose sample plots measuring 20x20 m^2 were used for inventory. Sample plots have been laid on transect lines stretched along the slope.

Study of artificial propagation from cutting

In order to study artificial propagation from cuttings, cuttings were taken from branches of healthy looking trees. The branches were taken during the time of planting and pit preparation. Each branch cutting was planted in a pit that has a 50 cm depth and a cross section area of 900m^2. The thick end of branch cuttings that would be buried in the ground has been cut slant to increase the exposure of the surface areas of the cambial layer. The cutting was placed in the pit in an oblique manner so that the slant cut lower end will get maximum contact with the pit. After planting the cuttings, a thorough ramming of the fine earth was done to eliminate air voids.

Experimental design and data analysis

a. population structure

From the inventory result, the total population was summarized with a table of frequency, where the first column represents the diameter class and the second the total number of trees per hectare with in that diameter class. The diameter class was divided into two cm. The stem diameter size distributions obtained in this way have been used to fit in to Weibull distribution curves.

$F(x) = 1 - e^{-(x/\beta)\alpha}$

This distribution is characterized by the distribution function F(x), the number of trees at DBH class x, the scale parameter β, the slope parameter α, and the DBH(x) in cm. This function is very successful in fitting stem-size distribution data (Bailey & Dell 1973, Alder 1995; Vanclay, 1994) and is popular with modelers dealing with uneven-age stands (Hyink & Moser 1979; Kamziah et al. 2000; Zhang et al, 2001). Most forms of the distribution show either a simple decline or a unimodal form. Depending on the shape parameters, the distribution is skewed to the left, symmetrical, or skewed to the right. The scale parameter (β) is approximately equal to the median DBH while the shape parameter controls the skewness of the distribution. When the shape parameter becomes less than 1 the curve approaches an inverse J-shape distribution. Model parameters were determined by means of linear regression and maximum likelihood methods (Sheil and Salim, 2004). The disparity between the observed and the predicted distribution and between sites was explained by the responsible ecological factors (Lykke, 1998; Swaine, 1998).

b. Study of artificial propagation from cutting

The experimental design was a factorial arrangement of three levels of length of the branch cutting (1 m, 1.5 m and 2 m), two levels of cutting diameter(10-15 cm, 16-20 cm and 21-25 cm), and four levels of planting season (first week of May, second week of July, third week of October, and third week of March). In each plot, 7 branch cuttings were planted in raw at a spacing of 2 m and 4 m spacing has been used for between rows. The following model has been used for data analysis

Y=m+B+L+D+S+(S*H)+eijk

Where
M=the overall mean
B= block
H= length of cutting
S= planting season
S*H= interaction of season and the length of the cutting

Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000). When there were no interactions and terms that were not significant in the full model, the reduced model was employed for analysis. The terms indicating the effects of diameter and its interaction with season of planting and cutting length were not included in the statistical analysis.

3. Results

Population Status

To be able to assess the current status of the *Boswellia papyrifera* populations in the study region, we have compiled data for a large number of sites in Metema, Quara and Abderafi woredas. These sites lie within the Sudanian and Sahelian zones (White 1983; Ogbazghi, 2001) and represent the main *Boswellia papyrifera* growing region in the Horn of Africa. In all sites inventories of the standing populations have been made, in most cases in a large number of plots. Tree diameters have been measured and densities calculated. In Table 1 a number of characteristics of the sites and of the Boswellia populations are given.

Table 1 Overview of the *B. papyrifera* sites covered in this chapter, with site specific information

Study area	District	No. Sample plots	Plot size	No. trees per ha
Dubaba	Quara	8	20 X 20 m	234
Shinfa	Quara	5	20 X 20 m	155
Surferdin	Quara	8	20 X 20 m	243
Yiergaminch	Abderafi	7	20 X 20 m	54
Akzion	Abderafi	5	20 X 20 m	165
Gelealewan	Abderafi	9	20 X 20 m	92
Jejebit	Metema	8	20 X 20 m	228
Lemlem Terara	Metema	20	20 X 20 m	165
Zewudie Badma	Metema	11	20 X 20 m	65

The sites are found along an altitudinal gradient from 800 m till 2000 m above sea level, and in areas with average temperatures of between 14°C and 35°C. Most of the sites have tree densities of between 100 and 300 individuals trees with DBH > 10 cm per ha with the exception of Zewdie Badema, Gelealewan and Yiergaminch with only 65, 92 and 54 individuals per ha respectively.

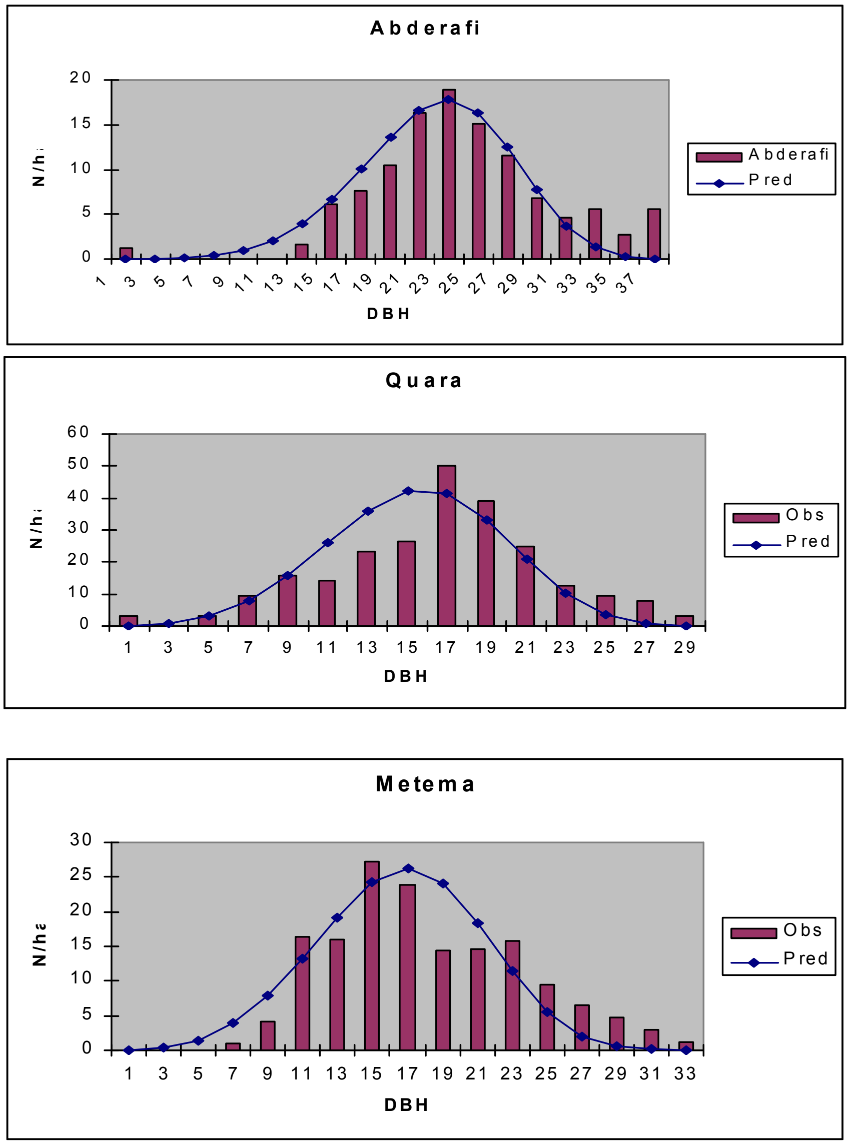

Fig 1 Population structure of *Boswellia papyrifera* in the three study sites

All sites studied showed a similar hump shaped distribution (Figure1). The hump shaped curves overestimated the frequency of the small individuals in the populations and underestimated the large individuals. In most populations the number of small individuals was extremely low, suggesting a lack of regeneration.

Cutting survivals

The GLM analysis of the SAS showed that, among the treatments, planting season and its interaction with the height of the cutting found to bring significant difference. Cutting size doesn't show correlation with the planting season.

Table 2. Model ANOVA

Source	DF	SS	MS	F Value	Pr > F
Model	15	142.1635860	9.4775724	3.70	<.0001
Error	71	182.0591704	2.5642137		
Corrected Total	86	324.2227564			

R-Square	CV	Root MSE	Mean
0.438475	22.57923	1.601316	7.091988

Table 3. ANOVA of season, diameter and height

Source	DF	SS	Mean Square	F Value	Pr > F
Block	3	22.28049321	7.42683107	2.90	0.0410
Season	3	72.21816491	24.07272164	9.39	<.0001
Diameter	1	0.82067623	0.82067623	0.32	0.5734
Height	2	8.33657055	4.16828527	1.63	0.2040
Season*Height	6	38.50768113	6.41794686	2.50	0.0297

Table 4. Least square mean and the probability values

Season	Height	LSMEAN	Standard Error	Pr > |t|
1	1	4.29324900	0.94618859	<.0001
1	2	5.83479812	0.66193478	<.0001
1	3	6.03599312	0.60725933	<.0001
2	1	6.64741830	0.56615078	<.0001
2	2	7.21377412	0.56615078	<.0001
2	3	8.22845633	0.56615078	<.0001
3	1	7.38496766	0.56615078	<.0001
3	2	8.58983185	0.56615078	<.0001
3	3	8.80102044	0.56615078	<.0001
4	1	7.94271541	0.60735196	<.0001
4	2	5.61197642	0.56615078	<.0001
4	3	6.45172079	0.56615078	<.0001

From the analysis of the cutting survival, it was observed that larger diameter has got the highest value in terms of survival (~51.06%). Smaller diameter branches showed lower survival rate (~47.32%). The survival value of (~57.14%) was observed for lager height size cuttings and medium and smaller height size showed lower survival rate, (~47.32%) and (~42.41%) respectively. Seasons showed much difference in terms of survival of cuttings was observed. Those cuttings planted on March and May showed the survival rate of (~57.14%) and (~70.83%) respectively. The poor survival rate was observed for October and July planting season which is equivalent to (~22.02%) and (~45.83%) respectively.

The GLM analysis of the SAS showed planting of cuttings at planting season of three is the best as compared to other planting seasons. Larger size of cuttings also most favorable for better survival of cuttings at any diameter class

Discussion

Population structure

The number of mature trees per hectare varied from 200 to 300. The most abundant family was *Fabacaea* and the most abundant species were*: Acacia etbaica (17 - 44 trees/ha), Lannea fruticos (7 – 10 trees/ha), Terminalia brownie (4 – 16 trees/ha), Combretum hartmannianu (2 trees/ha) and Ximenia americana (2 trees/ha).*

The most striking result from the stem diameter size distributions of *B. papyrifera* in all the study sites is the under-representation of individuals in the lower diameter classes and the over-representation of individuals in the higher diameter classes. More than half (~ 65 %) of the total population of *B. papyrifera* is in the range of 16 – 24 cm and 13 – 15 cm DBH respectively. The extremely low density of individuals in the lower diameter classes suggests that recent regeneration is severely lacking and that the population is under serious threat on the long run.

Should the observed regeneration structures in *B. papyrifera* raise the alert level? It should indeed, if regeneration indeed is lacking. However, it is still possible that the populations are in a steady state condition, as it occurs in many dry types of woodland. In some Acacia woodlands, for instance, very few individuals can sufficiently replace the standing vegetation without negatively affecting the viability of the population (Ashkenazi, 1995; Wiegand, et al. 1999). In many cases, however, population structures as shown by *Boswellia* indeed indicate lack of regeneration. Dynamic, monitoring studies are highly needed to be sure about this.

A lack of regeneration can be caused by a number of factors. First we have to distinguish between regeneration via seeds or via root suckers. If via seeds, several steps can lead to reduced regeneration. Trees may not produce sufficient seeds. Seeds may not be viable, due to seed quality (e.g. lack of embryo) or to high seed infestation by insects already on the mother tree. Once on the ground, seeds may not be able to further disperse because they are highly infested by insects and/or eaten by vertebrate herbivores and destroyed. Germination may be hampered by sub-optimal environmental conditions (too cold, too dry). Once germinated, the resulting seedlings may be trampled or eaten by grazers, or show very low growth rates due to low light availability, low water or nutrient availability. Also seedlings may be susceptible for herbivorous insects, or fungi. The alternative route of regeneration is via root suckers. In the following we treat most of these possibilities for the case of Boswellia.

There is no agreement on the origin of the observed seedling and sapling populations in different areas. Bond and Midgley (2001) distinguished two modes of regeneration: recruitment by means of seeds and persistence by means of root sprouting. Root sprouting is thought to be the preferred mode of regeneration in frequently disturbed environments. For *B. papyrifera* both seedlings reproduced sexually from seed and asexually from root suckers are found (Ogbazghi, 2001; Abeje, 2002, Yitebitu & Mengistie, 2005). However, the main route of regeneration is variable. Some studies reported root suckers as the main route of regeneration (Yitebitu & Mengistie, 2005) while others found sexually produced seedlings to be the main route of regeneration (Ogbazghi, 2001; Abeje, 2002).

In view of the seed properties of this species, such as absence of a soil seed bank reserve (Abeje, 2002), absence of seed dormancy (Tilahun and Legesse, 1999), the susceptibility of the seeds to insect attack and the production of non-viable and embryo-lacking seed (Ogbazghi, 2001), regeneration from root suckers as a main route of regeneration is a sensible speculation. This is substantiated, though not strongly quantified, by several authors and personal communications. However, there is not enough information on either the origin of observed seedlings (either from seed or roots sucker) or the differential performance of these seedling groups. We hypothesize that seedlings from root sucker origin may perform better as we expect these seedlings to be continuously nursed by the mother tree for moisture and nutrients.

Cuttings

This study in general reveled that diameter size has not strong impact on the survival of *Boswellia papyrifera* from cuttings rather cutting heights showed strong correlation with survival. This study also identified the best planting season for *B. papyrifera* cuttings. High survival rate was observed for planting seasons of three and four. This may be due short drought period for cuttings.

Conclusion and Recommendation

The present study showed *Boswellia* is one of the denser tree species in the study sites. The tree is actually represented in adult trees where main production and reproduction of the tree rely. The smaller sizes or seedlings are absent or few in the study sites indicating the regeneration status of the tree is severely limited. This extremely low density of individuals in the lower diameter classes suggests that recent regeneration is severely lacking and that the population is under serious threat in the long term. Of those factors contributed, the conversion to agriculture land contributes more for the degradation of the Boswellia woodland. Generally two theories have been forwarded in connection with the rapid transformation of the *Boswellia* woodland to agricultural lands in the Amhara Region. These are the institutional weakness and denial of involvement of local people to participate fully in the management and utilization of the resource and the existence of better economic returns from other pending land use. These both may offer no incentive to conservation of the *B. papyrifera* woodlands, rather, they instigates clearance of the woodlands and their conversion to other forms of land use, because this is a better option for the local people to benefit from the land resources. Generally, efforts should be made to conserve the resource base (co-management) and to increase the socio-economic importance of the tree by reconsidering the regulations that permit the collection and marketing of incense through license. Most interestingly the result of this study indicated that it was possible to get better survival of *Boswellia papyrifera* from cuttings, however there is a need for further investigation of this result in the field condition to facilitate the development and rehabilitation of *Boswellia* stands in the study sites so as to be able to reap multiple benefits from this resource base.

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Identification of traditional agroforestry practices, their challenges and opportunities, the case of East Belessa Woreda

Tatek Dejene1, Behonegn Akalu, and Kibruyesfa Sisay
1Gondar Agricultural Research Center. P.O. Box 1337

Abstract
The present study was proposed to inspect the existing indigenous Agroforestry practices, their challenges and opportunities in the east Belessa of north Gondar zone. Both primary and secondary data sources were used for the study. A total of 120 individuals from three kebele were used for the survey work. Open and closed type questionnaire has been used for the interview and it involved stakeholders like DA, woreda's experts and farmers. Moreover, observation of the study area was conducted to examine the different practices. The results showed that scattered trees on farm lands, trees on homestead, wind break, road side plantation and trees on soil conservation structure as the indigenous agroforestry practices. Moreover subsistence crop production and livestock rearing were identified as part of these practices. Different types of exotic and indigenous MPT species were identified in combination with agricultural crops. Farmers use various products from the trees, crop and livestock components for subsistence as well as commercial purpose. The fodder bank around the homestead provides a dry season feed for the livestock. Nevertheless, these practices were struggling to become established and to meet the expectations of households. The practices have the potential to address for the further dissemination and mitigate the natural resource problems and its repercussions. Therefore, there is a need for further investigation of the potentials and bottlenecks in agroforestry practices and in the cultivation of individual components (i.e. trees/shrubs, agricultural crops and animals/pasture), and for the planning of follow-up activities based on the findings of such investigations, so as to be able to reap multiple benefits from the practices.

Key words: Agroforestry practice, livestock, crop, tree, Belessa

1. Introduction

One of the greatest challenges currently facing human kinds is the alleviation of poverty while maintaining life support systems on which we depend (Richard et al., 2003). Billions of peoples are dependent on natural resources that are often unsustainably used by poor people themselves or by other powerful stakeholders as a result a range of large scale environmental problems is threatening the long term performance of many of agricultural, forestry, livestock and fisheries system (Campbell, 2003).

Due to socio economic incentives and environmental necessities, agroforestry as a new system come into view for the sustainable management, development and utilization of the natural resources (Richard et al., 2003) with a form of multifunctional and ecological utilization of environmental resources for the combination of agriculture and forestry

(Young, 1989). It gives an opportunity for intensive land management using of the advantage of the biological interaction that occurs when there is combined cultivation of tree and/or shrubs with crops and/or domestic animals (Garrett et al., 1994 as sited by Richard et al., 2003).

The major environmental and natural resources management issues that Ethiopia has faced is land degradation and the associated threats to the ecological support system underpinning agricultural production (EPA, 1998). Among an array of techniques, the indigenous agroforestry practices are the first coping strategy and one of the pragmatic options of improving land use and could also be taken as an option to mitigate adverse environmental consequences following pressures exerted from any source as agricultural land expansion, people relocation etc to the environment.

Belessa Woreda is one of the dryland areas in the Amhara National Regional State, where the rain fall amount is very low and erratic and natural resource degradation due to anthropological reason is high. However, agroforestry practices with all their virtues as indicated above are likely to evolve in the study area where land degradation threatens to unfold and where multiple benefits are required. Therefore, identification of the indigenous agroforestry practices that serves as the first coping strategy in association to degradation of the environment with their constraints and potential will provide baseline information and opportunity for the future development and dissemination of these technologies in the study area. Thus the objectives of this study underline this idea.

2. Objectives

- To identify the indigenous agroforestry practices in the study area
- To see the major challenges and opportunities of the existing agroforestry practices
- To suggest the possible recommendation for the future development and dissemination of the existing practices widely in the study area

3. Materials and methods

3.1 Description of the study area

East Belessa is one of the Woreda in North Gondar administrative zone of Amhara region. It is bordered with Janamora and wogera in the north, Ebinat in the south, west Belessa in the west and wagehamera zone in the east. Geographically it is located between $35^0$52' to $38^0$39'E and $11^0$38' to $13^0$32'N. It has a total area of *ca* 1,563km2; the capital of the Woreda Gohala is located *ca* 180kms from Bahir Dar the capital of ANRS. The total population of the Woreda estimated to be *ca* 119,000 with average family size and population density of *ca* 6 and 76 persons/km^2 respectively.

Like other woredas of the region, agriculture is the mainstay of the Woreda economy and a means of livelihood for more than 95%of the Woreda population. Majority (90%) of the

Woreda is "Kola'' agro climatic zone and the rest (10%) is Woyena dega. The mean annual temperature and rainfall ranges between 20 to 25^{0}c and 600 to 800mm respectively. Most of the rain falls received in the area during June to the end of August.

Red soils (Litosols) and black Clay soils (Vertisols) are the two major soil types in the Woreda. Owing to the low vegetation cover, intensive cultivation for several years, no addition of nutrients and organic matter, and lack of adequate conservation measures, continued soil erosion have resulted in soils with shallow to very shallow depth and poor fertility.

3.2 Methodology

3.2.1 Data Source, Sample Selection and Data Collection

Data for the study were collected from both primary and secondary sources. Secondary sources were mainly published and unpublished sources, such as annual reports of the agricultural and rural development office of the Woreda, and a literature review was also used to complement and refine the information that had been collected. On the other hand, the primary sources included both socio-economic survey at household level and interviews with elders and visiting of farmer's farmland, backyard and homestead. For this study, three representative kebeles were selected with the criteria of accessibility and availability of indigenous agroforestry practices and different agroforestry components. The study kebeles were namely *Hamusit, Achekan* and *Dengor*. After selecting representative households, a semi-structured questionnaire was conducted at household level and interviewing also conducted with elders, Woreda experts and developmental agents, with aiming at collecting the necessary information regarding the objective of this study as well as to learn about the indigenous agroforestry practices in the study area. Different household farmlands, homesteads and backyards were also visited to see the different agroforestry practices and components developed by the local farmers. A total of *ca* 120 individuals were used for this purpose from the three kebele.

3.2.2 Data analysis

The data collected through the interview from the elders, experts and DA from the three kebeles was summarized together. The data collected through household survey, by administering a semi-structured questionnaire were crosschecked to correct errors, summarized and coded for analysis. To analyze the coded data from the semi-structured questionnaire, the Statistical Package for Social Sciences (SPSS) version 11 was used. The open-ended questions in the semi-structured questionnaire were also summarized. Finally the results presented as mean value, and percentage form.

4. Result and Discussion

4.1 Socio - economic Characteristics

4.1.1 Demographic Characteristics

Among the interviewed households, the average family size is *ca* 6. This ranges from *ca* 4 to 12 individuals per households. Majority (54.17%) of the households has a family size of *ca* 5 – 8 (Table 1). The majority (85%) of the respondents were between 14–50 years of age, while 15% were above 50 years of age, which shows that the majority are in their active working age (15–50 years), so that labour might not be a problem at household level.

Table 1. Family size of the interviewed households in the study area

Family size	Count	%
1–4	21	17.5 %
5–8	65	54.17 %
>8	34	28.33 %

Illiteracy is high; 72.53% of interviewed farmers were uneducated, i.e. unable to read and write, while the rest had attended school and able to read and write.

4.1.2 Subsistence and Land holdings

Only *ca* 1% of the sampled households are known to satisfy their subsistence needs for the entire year from own farm production, and the remaining *ca* 99% indicated that they face seasonal food shortage for an average of 6 months in a year. Out of those interviewed households, about *ca* 91.8 % reported relief and food for work (SWHISA, 2006) as the primary gap filler for household subsistence, and 85.4 % reported livestock sales as the secondary gap filler.

From the survey results it was also known that *ca* 43 % of the respondents have less than 1 ha, *ca* 44% have between 1.0 and 2.0 ha, and the remaining *ca* 14% have greater than 2.0 ha of land. The range lies between *ca* 0.25 and 5ha, and the average land holding across the three kebele was *ca* 1.32 ha.

4.1.3 Livelihood activities and income sources

All the respondents (100%) were farmers, self-employed in farming and have more than one sources of income. However, the major income sources for the households are agriculture (crops, fruits and livestock) and other tree products (fuel wood). In addition to these, farmers involved in other limited sources of income as labor, petty trading and beekeeping. The major source of income in all cases is agriculture, which on aggregate provides *ca* 87% of the gross annual household income.

The agricultural activity mentioned above includes mixed farming system where crops and livestock are managed in combination. The main crop types cultivated in the study area are Tef, sorghum, Chickpea, Shallot and sesame.

4.2 Indigenous Agroforestry practices

When a formal survey was conducted to asses the traditional agroforestry practices, six practices were reported and observed in the study area. These are scattered trees on farm lands, trees on homestead, wind break, road side plantation and trees on soil conservation structure. Moreover, crop production and livestock rearing were also taken as part of these practices. The detail of each practice is presented below.

4.2.1 Scattered trees on farmlands

This practice widely exists and dominant in all farmland of the study area. The common tree species are widely scattered haphazardly, or according to some systematic patterns on bunds, terraces or field boundaries. Most of the tree species are left on Tef and sorghum farmlands. Typically farmers prefer the indigenous trees to be left on farmland because of less rivalry with the crops growing together. The most common trees and shrub species were: *Acacia abyssinica*, *Acacia bussei*, *Acacia etbaica*, *Acacia Sieberiana*, *Acacia tortilis*, *Olea species*, *Acacia seyal*, *Balanites aegyptiaca*, *Faidherbia albida*, *Zizyphus spina-christi*, *Schinus molle*, *B.papyrefrea*, *Moringa spp*, and *E.camaldunesis.* In addition to the fertility that these trees provide for the soil on farmland, farmers use the trees for various purposes. These include fuel wood, charcoal, shade, construction materials, farming implements, and fodder for livestock. Furthermore, farmers use some selected trees for putting beehives and traditional medicine uses and food (*A. tortilis, B. aegyptiaca* and *Zizyphus spina-christi*)

4.2.2 Trees on Homestead

Homestead trees are found in the form of live fence, woodlots and intercropped with crops in the backyard of the household. Indigenous multipurpose trees are the most dominant tree component of this practice. Most trees are left in this practice due to their provision of shade, fodder, fuelwood and easily establishment ability of the trees. These all criteria are taken by the farmers to select trees as a homestead tree in the study area. The most common tree species in this practice are *Schinus molle, Moringa spp, Eucalyptus camaldunesis, Acacia abyssinica, Acacia etbaica, Acacia sieberiana, Balanites aegyptiaca, Zizyphus spina-christi, Faidherbia albida and Schinus molle.* Farmers use these trees for the purpose of generating income, development of fodder for dry season feed for livestock and putting beehives around homestead. More over, due to the ever greenness of the trees mentioned, farmers prefer and plant these trees for live fence and shade purpose. The *eucalyptus* tree species grow scattered around the homestead.

4.2.3 Windbreaks

Windbreaks are agroforestry practices in which trees and/or shrubs are planted in widely spaced rows to minimize negative impacts from excessive wind. This practice is seldom to see in the study area. However, farmers mentioned some tree species that can be used for windbreaks for their farmland especially. The common trees and shrubs species that been used for this purpose are: *Acacia etbaica, Acacia tortilis, Zizyphus spina-christi, Balanites aegyptiaca, Schinus molle,Moringa species and Faidherbia. albida.*

4.2.4 Road side plantation
Trees planted on the road side are mostly ornamental trees like *Spatoda nilotica* and *Schinus molle* following the main road in the town of the Woreda. However, these trees are deliberately planted by the agricultural and rural development office of the Woreda. Given the temperature of the study area and the fact that trees totally shade their leaves in the dry season, trees which do not shade their leaves in the dry season are planted on the roadside e.g. *Spatoda nilotica* , *Schinus molle and melia species*. Such trees also have an ornamental purpose in addition to the main purpose of providing shade.

4.2.5 Trees on soil conservation structure
A soil and water conservation activity has been practicing in the area since a long time with the aim of rehabilitating the degraded lands. Tree species used for this purpose are few and exotics and planted as a biological soil conservation structure in some places. The most common tree species are *susbania* and *grass* species.

4.2.6 Crop production
Major crops produced by farmers at Belessa include Tef, sorghum, Chickpea, Shallot and sesame. The trend of production per unit area of these crops is reported by almost all of the respondents to be decreasing. A lack of inputs, such as fertilizer and quality seed, the emergence of invasive weeds, erratic rain fall and degradation of land were mentioned as a prime reason for the observed reduction in crop yield. Degradation on farmland is considered as the main factor for decreasing the area under crop production. Other constraints on crop yield mentioned include natural calamities such as flood and pest outbreaks.

Table 2. Average yield (Kg ha^{-1}) of major crops in Belessa Woreda (SWHISA, 2006)

Crop	**Yield**
Tef	600
Sorghum	1200
Chickpea	800
Shallot	6300
Sesame	400

4.2.7 Animal husbandry
Livestock rearing is also practiced by farmers in the study area; almost all respondents were engaged in the activity. Communal lands and natural vegetations were used as a grazing ground for livestock. A combination of the two and other sources such as fodder bank in

the homestead, acted as a source of livestock feed. Constraints on livestock production mentioned included diseases of various kinds and feed shortage during the dry season.

Table 3. Average number of major livestock's of interviewed households

Livestock type	Average Number
Sheep	3
Got	6
Cow	2
Oxen	1
Donkey	1

4.3 Challenges of Agroforestry practices

Agroforestry was practiced by most of the respondents (81.31%), while the remaining surveyed households had not been involved in tree-planting at least within the past five years. Those households which did not practice tree-planting as part of agriculture mentioned a lack of technical assistance (such as seedling shortage, and lack of preferred species for planting), dead an early stage (seedling establishment), land shortage, pests, open access to resources and the erratic nature of rainfall as reasons discouraging to incorporate the practice of tree-planting.

On the other hand, a majority (*ca* 65%) of the respondents engaged in tree-planting was not satisfied with the species of seedlings provided to them because they are with less survival rate and are not drought résistance. Moreover, land shortage (planting niche availability), combination of components, tree management and the diversity and number of tree seedlings also not attractive. These all are the challenges for the wider adaptation and development of the practices

4.4 Opportunities of agroforestry practices

Agroforestry practices make it possible to achieve multiple objectives, social, economic and environmental, by providing the opportunity to use land by integrating an array of components, such as agricultural crops, trees/shrubs and animals/pasture.

The agroforestry practices observed in the study area provided farmers with items for household consumption and extra produce for the market. It presented an opportunity for farmers to use family labor and less initial investment, thereby easing the requirements on a household to become involved in and to benefit from the practices. For instance, according to the result of this study, some Homegarden were contained: fodder trees, crops, root tubers, vegetables, oil seeds, and fruit trees. In addition feedstuffs, and the much-needed shade for domestic animals, are derived from the agroforestry practices in the area.

It is obvious that Belessa is with much degraded lands and rehabilitation of these lands is imperative. Therefore various techniques are urgently required. In this regard agroforestry takes important part in Belessa Woreda by mitigating soil erosion, soil fertility decline, forest resources loss, pasture degradation and river degradation due to imbalance in the flow regime and sedimentation (Young, 1989).

Tree planting practice, crop production and livestock production in the study area is also noted encouraging on the face of varied obstacles. The combination of these components will provide starting place for further dissemination and wider adaptation. The low fertility rate of the soil, land degradation, availability of feed, land shortage and other factors mentioned above are opportunities for further development of the existing and new agroforestry practices in the study area to mitigate the natural resource problem and its subsequent serious repercussion by the use of agroforestry practices.

5. Conclusion and Recommendation

Agroforestry practices, as seen in the study area, were struggling to become established and to meet the expectations of households in particular. The practices have the potential to address for the further dissemination and mitigate the natural resource problems and its repercussions. Therefore, this study suggests the following recommendations:

- There is a need for further investigation of the potentials and bottlenecks in agroforestry practices and in the cultivation of individual components (i.e. trees/shrubs, agricultural crops and animals/pasture), and for the planning of follow-up activities based on the findings of such investigations, so as to be able to reap multiple benefits from the practices.
- Improvement of the combination of the tree, crop and livestock combination is required for the betterment of the management at household level
- The tree diversity with Adaptation and screening of MPT species and scientific management method should be encouraged
- The existing practices should be backed up with the technical support and demonstration of the model agroforestry practices in the area.

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V) Agricultural Mechanization and Food Science

On-Farm Verification of Improved Donkey Drawn Carts

Dagninet Amare, Abu Tefera & Fentahun Tesafa
Bahir Dar Agricultural Mechanization Research Center
P.O.box 133, Bahir Dar, Ethiopia

Abstract
Metallic wheeled and pneumatic tired animal drawn carts modified by Bahir Dar Agricultural Mechanization Research Center were evaluated under farmer management condition. Medium sized and strong donkeys that are house fed and/or grazing were used for the test purpose With estimated cost of 1005 ETB and load capacity of 2-4qts under gravel, farm and slightly sloppy fields for a distance 5-10kms, the pneumatic wheel donkey drawn cart is preferred than the metallic wheel type. It is estimated to generate additional income of about 2400 ETB annually. The cart is also found advantageous over the use of a single packed donkey and locally used cart on different soil types and seasons of operation. It is also comparatively advantageous over personal carriage and donkeys back transport, which can manage to carry not more than 7-10kgs and 25kgs, respectively, for the specified distance in the locality. It is thus recommended to popularize this cart but with some modifications on the paddle, support frame, length and width of beams, axle and longitudinal planks.

Introduction

Donkeys are most widely used as pack animals in different parts of the country. They provide pack services, carrying different commodities weighing 60–100 kg up to a distance of 15-20 km for duration of 4–5 hours. Observations undertaken along the main roads to and from Addis Ababa revealed that the use of donkeys is directly related to the distance covered. On the Gojjam and Dessie roads goods are transported by donkeys than by people while on the Ambo Road more people carry goods than donkeys (Feseha et al. 2008). In Amhara Region, especially in the rural areas, in-land travel involves transport of goods and is mainly done by pack animals, or humans using head and/or back carrying. Though donkeys are used for transporting of loads, they are rarely used for carting in the region (Geta, 2008). Lack of appropriate sized cart, along with other problems made donkeys little used in carting.

There are, however, some localities, especially in the rift-valley parts of the country, which are using donkeys for driving small carts. Locally made, metallic wheeled donkey drawn carts have been utilized in these areas for long. Melkassa (Nazerat) based Agricultural Mechanization Research system (AIRIC) has tested these models under dirt track field conditions and developed improved designs. These improved cart models were brought to Amhara region and distributed in East Gojjam areas through the extension package. But farmers have pointed out different design problems on these carts. Based on such comments and test results, further improvement has been made by Bahir Dar Agricultural Mechanization Research Center (BAMRC) on these models for making them suited for local conditions. Comparative test was conducted on this modified cart models on flat areas of the region, on gravel and farm roads, and they have been found performing best compared to the AIRIC models (Wolelaw, 2006). These improved models, however, were not demonstrated for farmers and their performance was not measured under farmer's management condition. Thus, this improved design, with pneumatic and steel wheels, was given to farmers to verify performances and suitability under the specific local condition and create awareness among farmers and important data has been taken.

Material and Methods

Demonstrations were held in Metema and Enemay woredas. Twelve modified carts, out of which six are pneumatic and the rest metal wheeled, were produced and one pair (one cart from each) was given to neighboring farmers to comparatively evaluate their advantage. The carts were tried on dry and wet conditions in flat and farm roads. The carrying capacity and distance covered in the demonstration was considered after a service of one and half year. Donkeys that are house fed/grazed were used for the demonstration. Group discussions were held to gather opinion of beneficiaries.

Result and Discussion

Local transport

In the demonstration areas people use personal carriage and packed donkey to transport their small loads. Local made donkey drawn cart, named *karu*, which is produced in Sudan, is also used in Metema area. As farmers disclosed, a person can carry a weight of 7-10 kgs while a donkey is capable of transporting up to 25 kgs for a distance of 5-10kms. Karu cart, whose platform or loading unit is lowered from the pulling beams, has a similar carrying capacity to that of the modified pneumatic cart which, however, depends on donkey's physical condition and the status and compaction of the road.

Figure1. Karu cart as used for different purposes

According to farmers saying, the cost of transporting goods (to specified distance) by pack donkey is about 4 ETB per trip, while Karu carts, whose a purchasing price was about 2600 ETB, and which is heavy, require monthly maintenance cost of about 75ETB (users in Metema) demands more payment for longer distances. Whether rented or used by the owner, however, a Karu cart earns similar amount as to that of the pneumatic type improved donkey drawn cart.

Steel wheeled carts

Though the steel wheel cart is assumed to be of paramount importance to farmers under conditions of gravel and farm roads, its performance was seen to be highly un-satisfactory. The heaviness of the wheels made it difficult to be easily drawn by the animals. It also gets deep to the ground where ever there is crack and unable to pass any obstacle under the prevailing conditions.

Figure 2. Steel wheeled donkey drawn cart

The wheel was not strongly fixed to the axle, createing undulating movement in farm road conditions. It also has high rolling resistance as it is seen heavier to move. Breakage and detachment of some parts has been observed frequent requiring frequent maintenance increasing overall usage costs. Moreover, its movement creates strain and discomfort to the donkey. Due to its greater maintenance cost, higher discomfort for the donkey and difficulty to be easily drawn in different field conditions, farmers has shown little interest in using this cart and was left out immediately. Thus it bears no acceptance under the current status.

Pneumatic wheel

Figure3. show the lower part of the pneumatic wheeled donkey drawn cart. The purchasing price of this cart was1005ETB.Used for transportation in town and trips on marketing days, held once in a week; a pneumatic tire cart earns about 200 Birr per month. After a year and half service, the cart was found having a carrying capacity of 2-4qts for a distance of 5-10kms. Medium and strong donkeys that are house fed and/or grazing were used for the trial.

Figure3. Pneumatic wheeled donkey drawn cart

Table1. Partial budget analyses of different transport systems

1. Partial budget of pneumatic tired verses packed donkey transport

Additional costs	Additional benefits
Dp =90 ETB	GP=2400 ETB
Mp= 27ETB	
Lp=720 ETB	
Reduced returns	**Reduced costs**
Pk=192 ETB	-
(A)Additional costs and reduced returns=1029.00	(B) Additional benefits and reduced costs=2400.00

Net benefit=B-A=2400-1029=1371.00

2. Partial budget of pneumatic verses local karu cart

Additional costs	Additional benefits
Dp =90 ETB	Gp=2400 ETB
Mp=27 ETB	
Lp=720 ETB	
Reduced returns	**Reduced costs**
Gk=2400ETB	Dk=234 ETB
	Mk=900 ETB
	Lk=720 ETB
(A) Additional costs and reduced returns= 3237.00	(B) Additional benefits and reduced costs=4254.00

Net benefit=B-A=4254.00-3237.00=1017.00

It is found preferable even to locally used cart, Karu, as its weight is relatively simple. It is comfortable for the transportation of fruits, vegetables and packed soft drinks along with the normal transport of sacked loads. Low purchasing price along with less maintenance requirement makes it more preferable than the locally used ones. However, some users especially those at Metema suggested that the platform should be lowered in similar manner to that of the Karu type, It was also observed that since the wheels used were small in size, they were easily obstructed by small stones, tree roots, and simple rugged surfaces. Besides their short and narrow beams create sliding of load to the back of the cart and create discomfort to the animals. The cart also lacks supporting side boards creating load instability and problem to tighten the load. Moreover the pad was not sufficient to avoid strain on the animals. The average economic benefit received from pneumatic wheeled cart is higher than that of Karu and the most locally used packed donkey transport. Thus with intended modifications, pneumatic donkey carts can serve good for rural load transport.

Conclusion and Recommendation

Regardless of the relative advantage, it is important to consider the suggestions made and introduce modifications to fully and widely utilize the implement. Hence

- Change the size of the pneumatic wheel to larger one (like 7.5*1.6 inches) to avoid surface obstruction and increasing load capacity
- The width of the cart at the front, which was 36cm during the test, should be increased to 50cm.
- Construct the frame of the bed 30cm far from the rear side of the two beams
- The length of pulling beam should be about 3meters ; 1meter at the back and 2meters in front from the center of the shaft
- Padding material should be smooth to avoid strain on animals
- The bracket should be positioned in such a way that it reduces pull back or hanging of the donkey, especially at inclined roads, and decreases vertical load on the animal
- Popularization and demonstration should be continued after improvement

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On Farm Evaluation and Demonstration of Different Models of Hay Presses

Abu Teffera[1], Solomon Tekeste[1] and Yihalem Denekew[2]
[1]Bahir Dar Agricultural Mechanization Research Center, P.O. Box 133, Bahir Dar
[2]Andassa Livestock Research Center, P.O. Box 27, Bahir Dar

Abstract
Hay is the oldest and most important conserved fodder. The main aim of haymaking is to store feed for later on-farm use. Traditional haymaking practice in Ethiopia has many problems; delayed or early harvesting, improper handling systems during harvesting, transportation, and storage stages are identified as main causes of feed loss. This project is therefore intended to evaluate and demonstrate manual hay presses so as to assist users in haymaking and baling practice. Two hay presses models; vertical and horizontal hay press, were manufactured in the center and after preliminary test was carried out, practical on field test was carried out at two trail sites. Besides, discussions were made with farmers and their opinions were recorded. The test result has shown that, the average pressing rate, bale density, and baling time of vertical hay press was 45.20kg hr^{-1}, 86.5kg m^{-3} and 14min per piece. Likewise similar parameters of the horizontal type were 36.9kg hr^{-1}, 72.27 kg m^{-3} and 18 min per piece respectively. It was observed that most of the respondent farmers preferred the vertical type press due to its lower energy requirement and better out put.

Introduction

Agriculture is the basis of Ethiopia's economy. The contribution of livestock and livestock products to this sector is significantly high, accounting for 40%, excluding the value of draft power, fuel, manure, and transportation (Winrock International, 1992). According to the livestock census of CSA (CSA, 2001), Amhara region has about 9.12 million cattle, 3.82 million sheep, 2.96 million goats, 1.67 million equines and 11.95 million poultry and constituting about 35 percent of the national livestock population.

Grazing lands are the main source of livelihood to many farmers and pastoralists providing year-round feed supporting livestock. As green plants availability is seasonally in most areas, the provision of feed for deficit seasons has always been a major concern in many livestock production systems.

Hay is the most important conserved fodder used for this purpose. However, it may require extra care during harvest, transport, storage, and use. Hay can be prepared at household level using simple machines and techniques. Many small-scale farmers in the region make hay and store crop residues to carry livestock through periods of feed shortage. Residues, straws and Stover of the main field crop are used as animals feed. Traditionally the hay harvested by sickle is spread or left on the ground for 2-3 days to sun dry and once dried the hay is collected and stacked in loose heaps raised off the ground on a platform of stone to avoid soil contact and spoilage. Hay is transported from farm area to the storing place manually and to the market place with carts. Carts to be used for this purpose will temporarily be modified by extending frames to increase their base area and allow transport of a greater load of bulky material.

The main aim of haymaking is to store feed for later on-farm use, and hence it should be easy to transport and store. Particularly, baled hay assist to feed animals with little or no wastage. Pressing of hay helps to conserve it's nutrients for long time and simplifies the transport, storage and preparation of feed rations. Hay can be pressed in to bales of 200-300 kg m^{-3} density when its moisture content is between 18-30% and in to briquettes of up to 700 kg m^{-3} densities when the moisture content is between 10-12% (Bosoi, O.V, 1991).

Studies indicate that, small-scale dairy holders store hay and straw in bales. The average weight of a bale from natural pasture and crop residues is 15-20 and 8-15 kg, respectively. The price of a bale also varies depending on the season and the distance between the production area and the major livestock/demand/market areas. (Suttie. 2000). Haymaking is traditional in most parts of Ethiopia. Especially, in the Amhara region there is no wide practice of making or storing hay and straw in bale. Rather most framers and small-scale dairy holders store hay traditionally by making heap. The price of hay depends on the seasons. A cart of hay/straw costs up to 180 Birr during dry seasons and up to 260 Birr in summer at Bahir Dar town markets. In other hand, animal drawn cart can carried 400-2000kg at speed of 3-5 km/h for distance of 20 km. (Lawrence, 1993).

Under existing practice forage is usually available during the rainy season while it is in short supply during the dry seasons. Therefore, off-season requirements set up by preserving wet-season herbage and residues of crops. However, the conventional method of haymaking has some drawbacks, such as feed loss, maintain low nutrient content, not convenient in transporting and storing. These drawbacks confirm that farmer's lacks knowledge about forage conservation, improvement of low quality feed and using of proper technology for haymaking and storing residue. Therefore, hay making techniques and equipment should be major area of concern.

In other hand, because of in-accessibility of modern breeding service and favorable market condition (on selling of fatten ox, milk and milk products), most of the farmers in the region are engaged in livestock raring activities as a source of additional income. As currently conducted studies indicate, today, strong village level milk marketing units that are owned by farmers milk marketing groups/co-operatives are established, all are successful and are operating profitably (Rangnekar and Thorpe, *2002).* Therefore, in order to be more competent in the market, farmers should know proper method of animal feed preparation techniques and available equipment for haymaking.

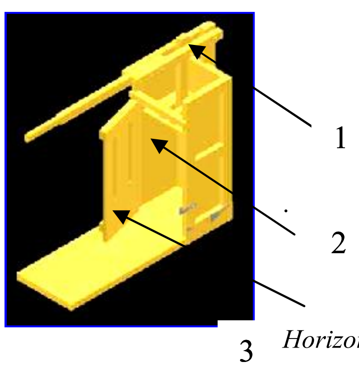
There are different types of haymaking machines in the market, out of which mechanical presser are the most important one. These machines have three level of operation: human powered (manual), animal powered, and mechanical powered. In this particular project attempt has been made to evaluate human powered once. Based on extensive review attempts on different hay press types two models, vertical and horizontal hay presses were selected. Both machines are hand-powered box baler, can be easily constructed from easily available materials. But, these presses are not used in the Region by farmers due to unavailability of presses in the market and poor awareness of farmers on the technologies. Hence, the objectives of this study was to verify the performance of improved hay presses under farmers' local conditions and increase farmers and extension/development workers awareness on the advantages of the technologies. It was also intended to render recommendations on the merits & demerits of the technologies.

Materials and Methods

Description of Hay Presses

Vertical hay press

The vertical hay press (Figure 1) parts are manufactured from hard wood (eucalyptuses tree) and sheet metals. It consists of wooden frame box that is laminated from the inside with 0.8mm sheet metal. It has wooden bottom floor and wooden plunger with arms laminated by 3mm sheet metal. The overall dimension of the machine (LXWXH) in centimeter is 154X54X145. Its weight is 88kg and its manufacturing cost was about 626 ETB.



Vertical hay press main parts

1. plunger with arms
2. receiving and compressing chamber
3. Bottom floor

Figure 1 Vertical hay press

Horizontal hay press

The Horizontal hay press (Figure 2) is a 230X75X140 cm (LXWXH) dimensioned press whose body is made from hardwood (eucalyptuses tree). Parts other than the main body were made from available angle iron, round bar, galvanized pipe, and U-channeled cross section metals. Its empty weight is 156 kg and manufacturing cost was about 1973 ETB.

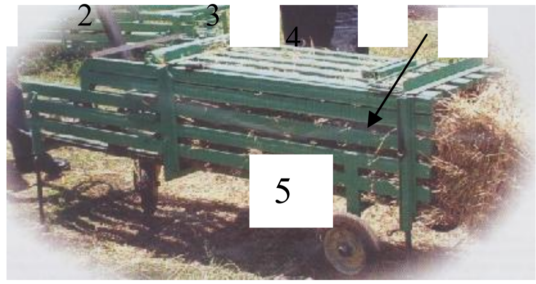


Figure 2 Horizontal hay presses

Horizontal hay press main parts

1. Plunger with arm
2. Receiving chamber
3. Compression chamber
4. Locking fork
5. Wheel
6. Anchor

Evaluation Procedure

Horizontal and vertical hay presses were the two-selected mechanical model, for the study. Based on existing prototype and internet sources both models were modified and manufactured at Bahar Dar Agricultural Mechanization Research Center and preliminary test was carried out for checking proper functionality of the presses in the center.

Then after through discussion was carried out with respective Woreda Agriculture and Rural Development Office experts and development agents and participant farmers were selected from East Gojjam Zone, Dejjen Woreda and West Gojjam Zone, Bahir Dar Zuria Woreda. Experience on preparation of animal feed, awareness about the improved technology, and potential for forage production were considered as the criteria for selection of farmers.

In each selected test site, both hay presses with full accessories were delivered for participants. Selected farmers were trained on operation and handling of improved hay presses. Demonstration was carried out in the presence of selected farmers and some other from the surrounding areas. Participants were encouraged to evaluate and comment on the performance of improved hay presses.

Both hay presses were tested and evaluated for their capacity. Testes were conducted in three replications, with a total of nine observations using single operator. The age and the weight of operator at Andassa test site was 22 years and 50 kg, respectively. Data was collected by using the same operators to operate both machines using natural pasture hay (grass) as test material. Human and cart caring capacity were determined by taking three replication with a total of nine observations for each. Required area, /volume of baled and un-baled hay were determined.

Baling time was measured by stopwatch and defined as the total time required from start of preparation of tightening rope, bale formation, till the end of double tight of the pressed square bale. All bales were wrapped using plastic rope twine spacing. The length, width, and height of all bales were measured to the nearest 1 cm precision to allow calculation of bale area and density. Each bale was weighed to the nearest 0.5 kg precision with 50 kg capacity spring balance. Three samples were used for moisture content determination in which samples were oven dried at 105ºC for 24 h.

Hay presses described theoretically and practically for the farmers, first in each sites, provided theoretical explanation of the use and benefit of the machines for an average of 20 farmers, and secondly practical demonstration was done. Finally, in all trail site discussion was held among farmers, development agents, and Woreda expert on merit and demerit of hay presses. All participants forwarded their opinion regarding the presses performance and other things they consider to be improved. Information was collected and recorded on required improvements, effectiveness, and suitability of the supplied hay presses. The analysis of the data was done by SPSS statistical package using ANOVA and paired samples test.

Results and Discussion

The two improved models of manual operated hay presses were evaluated with respect to their technical performance and farmers view. The technical performance result obtained from Andassa kebele trial site is shown on Table 1. It is the summary of performance parameters of the machines.

As shown on table 1 the differences were seen between presses regarding baling time, bale output, and density. The vertical hay press shows better performance on baling time, output, and density. The statistical analysis on table2 shows that, the mean difference between the presses regarding density and baling out put is highly significant.

In the vertical hay press the operator can use his/her body weight to press the hay. Therefore, this condition assists to reduce energy and facilitate easiness of operation. The horizontal one requires more energy than the vertical because of its pressing pad unit which slides over round bars produces high frictional force reducing operator’s efficiency and speed.

Table1: Performance data of hay presses obtained at 10% moisture content of hay using single operator

No	Baler type											
	Vertical press						Horizontal press					
	Baling time (min.)	Bale weight (kg)	Bale Volume (m^3)	Density (kg/m^3)	Output (kg./h)	Bale Area (m^2)	Baling time (min.)	Bale weight (kg)	Bale Volume (m^3)	Density (kg/m^3)	Output (kg./h)	Bale Area (m^2)
1	16.00	10.00	0.11	89.29	37.50	0.32	19.00	10.60	0.16	67.09	33.47	0.45
2	20.00	11.00	0.12	89.43	33.00	0.35	20.00	11.00	0.15	72.85	33.00	0.43
3	18.00	9.40	0.11	87.04	31.33	0.31	17.00	10.40	0.14	74.29	36.71	0.40
4	10.00	9.00	0.11	83.33	54.00	0.31	17.00	10.80	0.16	68.35	38.12	0.45
5	12.00	10.80	0.11	96.43	54.00	0.32	17.00	11.20	0.15	77.24	39.53	0.42
6	11.00	10.00	0.12	81.30	54.55	0.35	19.00	11.00	0.14	78.57	34.74	0.40
7	15.00	10.80	0.12	87.80	43.20	0.35	18.00	11.20	0.14	80.00	37.33	0.40
8	15.00	9.80	0.12	82.35	39.20	0.34	15.00	10.00	0.17	60.61	40.00	0.47
9	10.00	10.00	0.12	81.30	60.00	0.35	15.00	10.00	0.14	71.43	40.00	0.40
Over all mean	14.11	10.09	0.12	86.47	45.20	0.33	17.44	10.69	0.15	72.27	36.99	0.42

Table 3 shows the mean performance parameters of carts loading capacity and area required during transportation and store of the baled and un-baled hay. The mean loading capacity of animal drawn cart, with un-baled hay and baled hay made by horizontal and vertical hay presses were 119.20, 181.60 and 192.40 kg, respectively. This indicates that averages loading capacity of animal drawn cart has an advantage to transport grater mass of baled hay than the un-baled hay. The average area required for a single cart loading hay is 3.70m^2, 1.69 m^2 and 1.33m^2 for traditional, horizontal and vertical hay presses, respectively. Therefore, pressed hay has an advantage over the traditional using less area for grater mass of hay (Table 3). The reason is that compressed hay gets more weight and requires less area than unbaled hay. It also gives convenient loading condition, more preferred by cart owners. Furthermore, it was clearly observed and farmers also indicated that hay loss by dropping on the track during transporting un-baled hay for longer distance with animal drawn carts is high level of concern for owners. This loss is usually aggravated by wind during windy days.

Table 2: Statistical analysis result of vertical and horizontal hay presses on baling output (C) and density (D) using paired samples t-test.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VHPD	86.4744	9	4.97872	1.65957
	HHPD	72.2700	9	6.19900	2.06633
Pair 2	VHPC	45.1978	9	10.61749	3.53916
	HHPC	36.9889	9	2.72525	.90842

Paired Samples Test

	Paired differences					t	df	Sig.
	Mean	Std. deviation	Std. Error Mean	95% Confidence Interval of the Difference				(2-tailed)
				Lower	Upper			
Pair 1	*VHPD - HHPD	6.57074	2.19025	9.15373	19.25516	6.485	8	.000
Pair 2	*VHPC - HHPC	9.53809	3.17936	.87727	15.54051	2.582	8	.033

*VHPD- vertical hay press density HHPD - horizontal hay press density
*VHPC- vertical hay press capacity HHPC - horizontal hay press capacity

The observation taken at Bahir Dar Zuria Woreda shows that the market price of a bundle hay that weight up to 10 kg costs up to 15 birr and for a single cart that weight up to 150 kg cost up to 260 Birr during summer season. Therefore, even though there is no practice of selling the baled hay, farmer can sell single baled hay with the same weight at the price of 25Birr. From a single cart that can carry an average of 18pcs a total of 459Birr can be obtain. This indicates that baling hay beyond conserving of the nutritional value of the feed and connivance transporting the long way to the market with out losses, has benefit of generating about 190ETB additional income over the traditional system.

Generally due to the provided training and demonstration of the mechanical presses, farmers developed knowledge about the importance of baling of hay. They said that using these machines will help them to easily calculate annually feed requirement for their animals. Determining the rate of feeding per animal, proper storing of the feed, easy transportation by human labor and animal drawn carts and conservation of nutritional value of the feed were the main advantages farmers indicated when introduced with the baling machines. Finally, most of the participant farmers gave their view that the vertical press is better than the horizontal one due to its better out put rate, less power requirement, lower cost and reduced overall weight. On the other hand, when easiness of extracting the baled hay out of the chamber and enabling conditions for longer working period are considered, farmers asserted that the horizontal one is more preferable to the vertical one. Among farmers evaluation parameters given above some of them were supported by figures and found acceptable as indicated on the test results (Table 1).

Table 3; Hay weight to be carried and Space required during transporting and storage by Animal drawn cart

No	Baled with Vertical press		Baled with Horizontal press		Un-baled	
	Hay Weight and Area					
	Bale weight (kg)	Bale Area (m^2)	Bale weight (kg)	Bale Area (m^2)	Hay weight (kg)	Hay Area (m^2)
1	180.00	1.28	190.80	1.80	116.60	3.64
2	198.00	1.40	198.00	1.72	127.00	3.96
3	169.20	1.24	187.20	1.60	133.20	4.16
4	162.00	1.24	194.40	1.80	111.30	3.47
5	194.40	1.28	201.60	1.68	112.32	3.50
6	180.00	1.40	198.00	1.60	112.96	3.52
7	194.40	1.40	201.60	1.60	114.50	3.57
8	176.40	1.36	180.00	1.88	120.00	3.74
9	180.00	1.40	180.00	1.60	123.50	3.85
Avg.	181.60	1.33	192.40	1.69	119.20	3.70

The other thing observed during testing time was that the pressing arms of the vertical hay press were broken and the chambers detached while in operation. This happened after extended pressing work. Based on this breakdown, the research team has concluded that the joints and the arm of this model should be highly strengthened. Participant farmers also gave their opinion that the machine requires in-farm transport mechanism which will facilitate mobility of the device. They also emphasized that minimizing the selling price and reducing machines overall weight are some of the issues that need to be addressed as soon as possible.

Conclusion and Recommendation

The vertical and horizontal hay presses can be manufactured by small workshops. The total cost for manufacturing theses presses will be acceptable by farmers particularly for those who are partially or fully engaged on animal fattening activities. In addition, farmers can be benefited by selling baled hay at higher price than the traditional market way, and by giving renting service to balers they can obtain additional income. Moreover, the technologies have very low maintenance cost, they are simple in construction, and operation. Therefore, they can have higher rate of returns.

But, even though both hay presses were able to make baled hay, farmer's comments and technical test result show that the vertical hay press has better performance with regard to the bale out put, cost, and weight and energy requirement. So, for better livestock productivities in the region, particularly for animal handling and fattening activities, haymaking technologies or balers should be introduced at a relatively larger scale. These machine not only enhance feed preparation processes, but also improve the income generation potential of Small-scale dairy holders. Therefore, the hay presses, especially the vertical hay press model is recommended for further on-farm promotion.

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On Farm Evaluation and Verification of Maize-Sorghum Thresher

Dagninet Amare, Fentahun Tesafa, Abu Tefera, Solomon Tekeste, G/selassie Sahlie
Bahir Dar Agricultural Mechanization Research Center
P.O.box 133, Bahir Dar, Ethiopia

Abstract
Kombolcha modified motorized maize-sorghum thresher was evaluated to verify its technical performance, efficiency and economic feasibility relative to conventional threshing methods and manual maize Sheller under farmers condition. The study revealed that motorized thresher with output capacity of 41qts/hr and 12.5qts/hr of maize and sorghum respectively is economical than conventional threshing methods. Trampling needs much time and animal power and beating by sticks and rubbing hands requiring more force and degrading quality are relatively less advantageous. The cylindrical maize Sheller seems uneconomical compared with motorized thresher, given its cost and service life is significantly important to farmers. Despite of this to enable thresh varying comb sizes of maize modifications should be introduced to fully and widely utilize the technology. It is more preferable in areas that are remote to transport motorized thresher. Generally it is important to demonstrate and motivate farmers union and other capable individuals to invest in motorized thresher and provide service to farmers for maize and sorghum threshing. Besides, it is crucial to popularize manual cylindrical maize Sheller to the smallholder and females in large since in those off-farming seasons farmers and their families are less busy.

Key words: *motorized maize –sorghum thresher, cylindrical maize sheller, threshing capacity, economic feasibility*

Introduction

It is apparent that the Ethiopian economy is dominated by agriculture. It accounts for over 50 per cent of GDP, 90 per cent of the export earnings, and 88 per cent of the labor force. Food supply to the urban areas and supply of raw materials to the manufacturing sector are all dependent upon agriculture (FAO, 1995**).**

Crop production is the major activity in the overall agricultural sector. However, this sector is enshrined in several problems including the pre-harvest and post-harvest activities. Thou significant efforts are made to improve the pre-harvest activities, the post-harvest part have been given less attention. Post-harvest losses include the rotting of produce and damage &loss during threshing, storage, packaging and transportation.. The average post- harvest losses of food crops such as *Teff, Sorghum*, *Wheat* and *Maize* are 12-9%, 14.8%, 13.6% and 10.9% respectively (Shimelis Admassu). Among these components of post-harvest activities, threshing is one of the major factors that incur huge loss in cereal production. Threshing of crops in Ethiopia is done by time old traditional practices. It is either done manually or by using animals. By animals, a ground is smeared using cow dung or irrigating it with water and left to dry. Then the crop to be threshed is laid on the smeared ground upon which several animals tread on. This works for maize and sorghum too. But due to the hardness of these crops for threshing, stick biting is usually accompanied. These threshing methods incur significant loss to the productivity. Besides, along with cracking and damaging of kernels, long stay of crops unthreshed due to lack of treading animals' aggravates productivity loss. So introducing better threshing methods that reduce loss to the productivity of the smallholder is paramount importance.

Recognizing these, Kombolcha research center had modified and evaluated Bako developed maize Sheller (Abay, Geta; 1996). This technology was evaluated with farmers its technical performance, efficiency and economic feasibility and identify possible ways of disseminating the technology.

Material and Methods

Demonstration sites were purposively selected based on scale of production. Farmers training center was used to demonstrate sorghum threshing. Both conventional Maize shelling systems, manual cylindrical and motorized threshers were displayed in the demonstration. Information's about animal trampling were taken from Farmers, since it was not possible to conduct trampling test. Farmers were participated on the process of threshing and maize shelling. Manual cylindrical Sheller and stone-rubbing were conducted with different sexs.Semi-structured questionnaire was used to collect farmers' opinion during the process. For motorized thresher of maize, grain from grain and comb outlet as well as sieve over flow was measured. Three separate trials were done and 3 samples from each trial were taken in 10 seconds time length. Weight of threshed and unthreshed grain from sieve over flow, comb and grain out-let is measured to estimate threshing efficieny. Grain samples from each maize separate trial were taken and weight of broken grain measured to estimate thresher breakage. Three varieties of sorghum in different moisture levels were used for the evaluation activity. Three samples from each two of the varieties and one sample from the other variety were taken. Due to out put amount the samples were taken in 45 seconds time prolonged than the time length of maize sampling. Grain from grain out-let, chaff outlet and plain sieve were taken and considered accordingly. Total grain output was weighed to estimate sample similarity in both of the demonstrations. Moreover FAO test procedures were done to ensure machine efficiency.

Result and Discussion

As local practice maize and sorghum threshing in the small holder is done by animal trampling, beating by stick and stone rub. The capacity and associated efficiency of conventional and motorized thresher is presented as follows.

Conventional methods

Animal trampling

It is the treading of animals over the crop. It requires on average 15 oxen for 7hrs and 5 people to thresh a size of 20qts of sorghum while a minimum of 5oxenand 11 people for 2hrs are required to thresh a size of 21qts of maize. A total of 5 and 11 persons are required for 9hrs to direct oxen, sort the comb and thresh the unthreshed sorghum and maize respectively. Trampling speeds up threshing operation, but it reduces the quality of seed obtained since it is mixed with soil along with harming the hoof of animals. While sorghum is mainly trampled in the areas covered, maize is threshed in other methods alternatively.

Beating by stick (“dulla”)

This operation done with apiece of stick and plastic sacks which is available in any area .It requires more labor than others and damages seeds. Using the plastic sack (madaberia) to avoid spread of seeds, a total of 12 persons and five (5) sacks are used to thresh 21qts of maize in 9 hrs time length .The used sacks are out of use after this operation . In this operation males are mostly the actors, as it requires more force. Eventhou it consumes more labor it is faster than others methods except motorized.

Stone-rub

The stone can be (any stone) collected from the area given which has groves. It doesn’t crush and spread maize seed. More force is required to thresh maize of larger comb size. Stone-rub occasionally rubs the hands of the individuals in the operation. Threshing of 21qts of maize using stone-rub requires 6 persons for 9hrs,with minimum cost, it is preferable than the other traditional methods. During the test the average capacity was 38 kg/hr.

Table1. Data for comparison of cylindrical manual maize Sheller and stone rubbing (each 30 minutes)

Type of thresher	Crop Variety	Quantity threshed in each sex category (kg)							Average Output Kg/hr
		F1	F2	F3	M1	M2	M3	M4	
Cylindrical manual	BH660	14	10	17	15	18	16	12	29.14
	BH540	-	-	-	-	16	15	-	31.00
	Local	-	13	-		15	19	-	31.32
Stone-rub	BH660	26	19	-	-	20	25	-	45.00
	BH540	18	20	-	-	19	14	-	35.50
	Local	13	21	-	-	15	19	-	34.00

*M-male, F-female

Cylindrical manual maize Sheller

This thresher was demonstrated as an alternative. A person using manual cylindrical maize Sheller can produce 30.4kg of maize in 1hr.So it requires roughly 69 persons to shell a size of 21qts of maize in 1hrs time length. The thresher has an estimated service life of 5yrs and cost of 12birr. Cylindrical thresher creates work burden on the farmers to select comb of maize that fits to the size of the technology, as the height of the internal parts doesn't thresh maize of thicker comb. The smoothness of the Sheller body impedes easy maneuverings. It also rubs the hands of persons when using for a longer period; which requires use of additional materials that prevent rubbing. More over it exposes for tiresome to operate for longer period, than traditional methods including stone-rub. This is so because farmers cannot use their full energy in the case of cylindrical one. Despite the cylindrical manual maize Sheller does not crush and spread maize, how ever due to some manufacturing problems and low promotion, it was not accepted by farmers and was lessly used.

Figure1. Cylindrical manual Maize Sheller

Figure2. Motorized maize-sorghum thresher

Motorized maize-sorghum thresher

Motorized thresher with 11 persons for shelling maize (2 on the side of grain outlet, 1 on the side of comb outlet and 8 to feed the machine) has an out put capacity of 41qts/hr of maize on average. While the output capacity of the thresher for sorghum is 12.5qts/hr. The threshing efficiency for maize is 98.3% with breakage of 4.99% and excellent cleaning efficiency. For threshing sorghum, it requires 10 persons (i.e. 1 person in the side of grain outlet, 1 on the chaff outlet and 8 persons to feed the machine) on average to thresh sorghum with threshing and cleaning efficiency of 93.51% and 88.18% and no significant breakage. During operation the machine operator being permanent on both cases, the fuel requirement of the thresher is 3.125lit/hr and 1.473lit/hr for maize and sorghum respectively. The loss in spread that comes from the plain sieve and chaff/comb outlet is not considered as a loss since farmers easily collect it. Besides breakage is not such considered as loss.

Table 2. Data for motorized sorghum thresher (each sample is taken in 45 seconds time)

Location	Crop	Variety	Trials	Out put(kg)			Grain with husk (kg)	Cleaning efficiency %	Capacity Kg/hr
				Grain	Chaff	sieve over flow			
Jilie-Timuga	Sorghum	Abshir	1	11.6	0.5	0.5	0.8	82.76	928
			2	14.3	1.3	0.5	0.8	87.50	1144
			3	13	1.7	1	0.8	87.70	1040
		Serina	1	17	1.8	0.6	1	90.59	1360
			2	21	2.2	0.6	0.8	93.33	1680
			3	18	1.6	0.3	0.8	92.31	1440
		Gobye	1	12.8	1.6	1.2	0.6	83.05	1024
Average value								88.17	1230

Table 3.Data for motorized maize threshing (each trial is taken in 10 seconds time)

Location	Crop	Variety	Trials	Out put(kg)			Wt. of threshed & unthreshed grain from comb outlet (after hand threshing) (kg)
				Grain	comb	Sieve Over flow	
Bure	Maize	BH660	1	7	0.095	0.0297	3
			2	7.7	0.114	0.0189	3.3
			3	11	0.091	-	4
		BH540	1	12.7	0.097	-	4
			2	10	0.095	-	3.3
			3	12	0.357	-	4
		Local	1	11	0.421	0.344	5
			2	14	0.448	0.330	4
			3	13	0.219	0.306	5

Motorized thresher, with estimated service life of 10yrs and cost of 50700ETB, is better compared to the traditional methods. Neverthless; it requires more labor for feeding and guard at the inlet (hopper opening) to protect the spread out of crop to the operator. During the test with the farmers they give comment that" the inlet opening better to be circular and the guard should be on this side so that can protects spread of the seed and blow on the feeders". The open space along the horizontal of the inlet opening the threshed & un threshed crops in addition the dust like material and creates serious problem on the threshing operation. In order to utilize with full capacity of the machine, it requires more feeding and decrease the spreading out of the seeds at the inlet opening, otherwise it consumes similar amount of fuel with less threshing output(capacity).

Table 4.Data of samples in maize breakage for motorized thresher

Variety	Sample	Wt. of total sample in kg	Wt. of broken grain in kg	Wt. of clean grain in kg	Average wt. of sample in kg	Average wt. of broken in kg	Average wt. of clean grain in kg	Breakage in %
BH660	1	0.190	0.015	0.155	0.184	0.013	0.162	3.76
	2	0.200	0.011	0.183				
	3	0.161	0.013	0.148				
BH540	1	0.250	0.016	0.235	0.260	0.0170	0.230	3.47
	2	0.280	0.0191	0.246				
	3	0.250	0.0164	0.209				
Local	1	0.200	0.0281	0.146	0.197	0.0243	0.143	7.74%
	2	0.190	0.0231	0.131				
	3	0.200	0.0217	0.153				
Average maize breakage								4.99%

Table 5.Test result of the maize sorghum thresher (FAO test procedure)

Parameters	Value in each sample			
Sample measurements	Sample-1	Sample-2	Sample-3	Average
Crop/Varity	Maize			
a. Time of sampling run (sec)	10	10	10	10
b. Weight of threshed grain at main grain out let per unit time (kg)	8.60	11.6	12.7	10.96
c. Weight of threshed grain at all others grain out let per unit time (kg)	0.32	0.28	0.69	0.43
j. Weight of un threshed grain at all others out let per unit time (kg)	0.10	0.18	0.36	0.21
Sample results				
1. Total grain output (A = b + c + d) (kg)	9.02	12.06	13.75	11.79
2. Percentage of un-threshed grain (N = j\A x 100) (%)	1.1	1.5	2.6	1.73
3. Threshing efficiency (100 - N) (%)	98.9	98.5	97.4	98.26
9. Out put capacity (W = b+c) (kg/hr)	**3211**	**4277**	**4820**	**4102**

Result Summary of maize

1. Percentage of un-threshed grain = 1.73%
2. Threshing efficiency = 98.30%
3. Out put capacity = 41quintal/hr

The economic data is summarized as follows.

Comparative advantage of motorized thresher over local and manual for maize threshing

The comparative advantage in terms of partial budget is done for all traditional methods and cylindrical manual thresher in comparison to motorized thresher for threshing a size of 21qts of maize and 20 qts of sorghum; which based at the capacity of trampling. Working days per year for motorized thresher is assumed 90 days per year and 6hrs per day. To analyze the cost advantage of the thresher we used the straight line method for calculating the depreciation cost and cost of the machine per hour.

Partial budget of motorized maize Sheller over stone-rub for maize

Additional costs	**Additional benefits**
Depreciation = 4.39 ET.Birr	##
Maintenance = 4.39 ET.Birr	(quality degradation)
Fuel = 9.78 ET.Birr	
Operator = 3.47 ET.Birr	
Labor = 8.58 ET.Birr	
Reduced returns	**Reduced costs**
## (breakage)	**Labor=83.03** ET.Birr

(A)Additional costs and reduced returns=38.73ETB

(B) Additional benefits and reduced costs=83.03 ET.Birr

Net benefit=B-A=83.03-38.73=**44.3 ETB**

Partial budget of motorized over trampling

Additional costs	**Additional benefits**
Dep. = 4.39 ETB	##
Maint. = 4.39	(quality degradation)
Fuel = 9.78	
Motor. = 3.47	
Labor = 8.58	
Reduced returns	**Reduced costs**
## (breakage)	oxen rent= 30.00
	Labor = 148.50

(A)Additional costs and reduced returns=38.73ETB

(B) Additional benefits and reduced costs=178.50

Net benefit=B-A=178.50-38.73= **139.77ETB**

Partial budget of motorized maize Sheller over stick beating

Additional costs	**Additional benefits**
Dep. = 4.39 ETB	##

Maint. = 4.39 (quality degradation, breakage)
Fuel = 9.78
Motor. = 3.47
Labor = 8.58

Reduced returns **Reduced costs**
(breakage) Cost= 25
Labor=162

(A)Additional costs and reduced returns=38.73ETB (B) Additional benefits and reduced costs=187

Net benefit=B-A=187-38.73= **148.27ETB**

Partial budget of motorized maize Sheller over cylindrical manual Sheller

Additional costs **Additional benefits**
Dep. = 4.39 ETB ##
Maint. = 4.39 (selection of comb size)
Fuel = 9.78
Motor. = 3.47
Labor = 8.58

Reduced returns **Reduced costs**
(breakage) Cost= 2.40
Labor=123

(A)Additional costs and reduced returns=38.73ETB (B) Additional benefits and reduced costs=125.40

Net benefit=B-A=125.40-38.73= **86.67ETB**

Partial budget of motorized maize sorghum thresher over trampling for sorghum

Additional costs **Additional benefits**
Dep. = 13.71ETB ##
Maint. = 13.71 (quality degradation)
Fuel = 14.16
Motor. = 3.47
Labor = 24

Reduced returns **Reduced costs**
(breakage, threshing inefficiency) oxen rent=315
Labor = 67.5

(A)Additional costs and reduced returns= 69.05ETB (B) Additional benefits and reduced costs= 382.5

Net benefit=B-A= 382.5-69.05= **313.45ETB**

The symbols (##) under the reduced returns and additional benefits shows the presence of items that should be included. While it is possible to estimate breakage loss of the thresher, it is impossible to get loss in quality degradation, breakage and selection of comb size when using traditional methods and manual Sheller. As a result reduced returns of the *machine (breakage) & additional benefits of the machine are not considered since, more or less, they are insignificant under small holder conditions and immeasurable respectively.*

For the crop maize the advantage of motorized thresher seems insignificant, in monetary terms, compared to stone-rub. Even then, the hardness of the work with stone-rub, easy tiresome of individuals along with discomfort in rubbing hands makes motorized thresher preferable than stone-rub.Similarly,motorized thresher is preferred than animal trampling due to the economic benefit and shortage of animals ,also damage to kernels and hoof of animals.

Stick beating usually requires more labor to thresh and people get tired easily.Hence, it is not practical to thresh the specified amount of maize within the time limit. Thus with the prevailing economic benefit and reduction of breakage loss, motorized thresher is preferable than stick beating. Manual cylindrical thresher shows economic deficiency relative to motorized thresher. Hence, motorized maize thresher is preferred than manual cylindrical maize Sheller due to the economic gains, time wastage in selection of comb size as well as difficulty of easy maneuverings. For crop sorghum, motorized thresher is more advantages than animal trampling. Generally, with modifications to be introduced, motorized thresher bears crucial for maize and sorghum threshing in the region.

Conclusion and Recommendation

Among all threshing systems, Farmers preferred motorized maize-sorghum thresher. The highest cost in terms of maize-sorghum threshing is labor for feeding. Thus it is essential to reduce this cost. Also, the thresher is not available on individual basis under the smallholder and is uneconomical. So it should be given to farmers union or investor like individuals to fetch full advantage of the machine. Moreover means's be searched to enable the manual cylindrical Sheller for different comb sizes and improvements for easiness of maneuvering so that farmers in remote areas could use it. Moreover the following modifications should be implemented

- Better feeding mechanism be searched out for motorized thresher
- Inlet be circular like to enable hold fed crop
- Blowing should be modified in such a way that it avoids spreading and blow of dust on feeders
- Modify manual cylindrical Sheller to enable shell different comb sizes of maize
- Popularization should be done on motorized thresher and manual cylindrical thresher

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Performance Testing of Solar Wax Melters

Gebre-Selassie Sahlie
Bahir Dar Agricultural Mechanization and Food Science Research Center
Tell 0582200631, Fax 0582266315, P.O.Box 133.

Abstract
Solar wax melter is a glass-covered box which uses the heat of the sun to melt bees wax for the purpose of separating it from honey and other materials. On the bases of its simplicity in operation, low-cost, and effectiveness, it is a useful device appropriate for all beekeeping management systems. For generating first hand information on the usefulness of the device, two melter models were tested; one is imported from abroad while the other was made at Bahir Dar Agricultural Mechanization Center. Test was conducted at the center (on station) and at Dangila town (on farm). According to the result, the imported model can melt two kilograms of crud wax in 3:05 hours time and deliver about 780-gram pure wax at an average temperature of 64.85 C^o. Similarly, the fabricated model can melt 4 kilograms of crud wax in 5: 40 hour time and deliver about 1.35 kg pure wax from it. On both models the tusk was handled by one-person at on-and-off working condition. On the other hand, when traditional melting method was investigated, it was observed that, by melting 22.75 kilograms of crud wax within 2:02 hours time, it delivered 11.5 kilogram of pure wax at a temperature of 87.65 ^OC. But the wax obtained by this method was not as attractive for bees as obtained from other models. Cost-Benefit ratio analysis was also used to compare the economical benefits of each melting method. Based on the overall test results solar wax melter with translucent plastic cover was found better than other melting methods in out put even if its benefit is a little less than the fabricated one. It is, therefore, recommended to introduce this technology.

Introduction
Wax is one of the products of bee keeping process. Its use is diverse; used in the manufacture of cosmetics, candles, medicines, floor polish, and leather waterproof. It is also important for making foundation sheet for improved hives. Ethiopia is 1^{st} in Africa and 10^{th} in world in production of wax. The country has more than 10 millions of honeybee colonies with estimated annual production potential of 24000-ton honey and 3000 metric tons wax. Out of the total wax production, the country exports 9%, this is about 270 metric tons annually. Even with this marginal amount the country is considered one of the 12 major exporters of wax products obtaining 360-480 million ETB annually (HBRC study paper 2002).

In the case of Amhara region, estimates show that there are around 610,830 bee colonies with an estimated annual production potential of 3054.15 tons of honey and about 763.54 tons of wax (SOS, 1993).

The quality of bees wax is to be judged from its color and purity. Light colored wax has the highest value. This can only be obtained by careful melting procedures using improved technologies (Beekeeping in the tropics, 1997). There were different attempts world wide to develop and introduce small-scale solar wax melters. In our country, some NGOs as Small Dairy Development Project (SDDP) and Selam Vocational Training Center have tried to import this technology to introduce for users. However, much has not being done so far and technologies are not yet tested and distributed to the end users widely.

Solar wax melters are useful, low-cost, and effective tools appropriate for all beekeeping management systems. A wax melter allows the beekeeper to begin the process of rendering the wax, thereby facilitating wax moth control. Furthermore, the solar wax melter can economically handle small quantities of wax encouraging the saving of beeswax. It is also handy for removing beeswax from excluders. The melter also produces high quality product and eliminates the need for sometimes-hazardous job of extracting wax in the home. Therefore, there is a need to assess and test existing small scale wax melters that could be easily utilized and introduced for beekeepers of the region. This project is therefore conducted for the purpose of evaluating the performance of available solar wax melters and develops necessary information regarding their use at small-scale level.

Materials and Methods

Two solar wax extractor models, one obtained from Amhara Region Bureau of Agriculture (imported type) (Figure1) and the other adopted from internet and fabricated in the center (Figure2), were used with two replications. The models were first tested at the center to observe their performance and determine their optimum holding capacity. Detail specification of tested materials is shown on table 1.

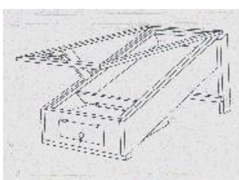

Figure1. Imported model wax Milter

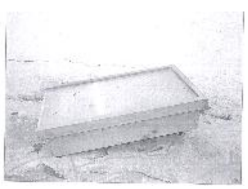

Figure2. Photographic view of fabricated model wax Milter

Table1. Some technical information of tested solar wax Milters

	Solar wax melter models	Overall dimension	Weight (kg)	Production cost (Brr.Eth.)
1	Imported model	75cm x40cm x 15cm	12	185.00
2	Fabricated model	72cm x 60.96cm x 52.70cm	25	251.00

Bees wax is traditionally melted by mixing the wax with hot water in iron pot and then by squeezing the hot water and wax mixture with two persons. It is usually processed in 'Tej' houses as well as in established bee and bee product marketing Associations. When the wax is melted in this manner locally, its purity and quality for export market and for improved hive purpose is not consider. Wax normally melts at temperatures between 63 ^{0}C and 65 ^{0}C while milting water reaches temperature of 70^{0}C - 80^{0}C readily, resulting in overheating of the wax. Over heated or burnt wax is worthless. Besides, wax that has melted in iron or zinc pots looses its smell and color.

Pre-heating of the insides of solar milters was observed necessary before wax is admitted to milting box and each model was pre-heated for about 15 minutes before any test is conducted. The amount of wax loaded to each melter was limited by their floor area, keeping equal depth for each (10 cm depth/thickness layer of the wax in the pan). Based on this observation and their volumetric size, two kilogram of wax for imported one and four kilogram for the fabricated one is optimum amount and used throughout the test runs.

Labor used for these melters was one person at on- and-off working condition. After sufficient preliminary tests were done in the center, the technologies were tested on-farm at Dangila and BahirDar town with users (Bee Product and Market Associations Centers). Participants were first trained on how to use the solar melters. Participants also put their suggestions regarding the melters based on their purity, time, labor, simplicity and out put per day. Personal observations, participant comments and suggestions were also collected and included in the report. In addition, data from local melting method on the respective associations has been taken.

The temperature inside the milters before the wax is added and after the wax is completely melted was measured by portable digital thermometer. Knowing that bees would like to land on the wax which has attractive smell and acceptable wax quality than that which has lower quality, the attractiveness of the wax was tested by observing bee's reaction towards the product. Values of accessories material used for each melting method were estimated from current price study, service life estimated and depreciation or service cost calculated. Lastly, cost-benefit analysis has been carried out using benefit-cost ratio method by considering all involved costs, material, accessories, and labor costs.

Results and Discussions

After complete melting is carried out, the inside temperature in the melters was 33.15 ^{o}C for imported model, 28.25 ^{o}C for fabricated model, and 95.0 ^{o}C for local melting methods. This clearly shows that the temperature in traditional milting system is so high to cause some quality and material loss in this system.

Table 2 On-farm test result using the three wax extracting methods

No.	Tested parameters	Treatments tested		
		Imported wax melter	Fabricated wax melter	Traditional melting method
1	Crude wax used for the test (kg)	2	4	22.75
2	Milting time (hr)	3.08	5.67	2.17
3	Pure wax extracted (%)	39%	34%	50%
4	Impure wax after extraction (%)	36%	59%	14%
5	Amount of volatile (%)	25%	7%	36%
6	Temperature of the melted wax (^{o}C)	64.85	64.00	87.60

According to the test result (table 2), the imported model can melt two kilograms of crud wax in 3:05 hours time averagely and has given about 780 gm pure wax, which is 39% of the total with an average temperature of 64.85 ^{O}C. While the fabricated model can melt four kilo- grams of crud wax in 5: 40 hour time and delivered about 1.35 kg (34%) pure wax. One person was required at on-and-off working condition on both models.

In the case of traditional melting method, it was observed that when melting an average of 22.75 kg of crude wax, 2:10 hours were required and 11.5 kilo-grams (almost 50%) has been recovered as pure wax. However, three laborers were needed with continuous and un-interrupted follow up until the melting is finished. The wage paid for the laborers in the traditional system was two birr for a kilogram of pure wax extracted in the form of contractual payment.

As observed during traditional wax milting procedures, the crude wax was added into the milting barrel filled with hot water which is pre-heated for about 42.5 minutes. The water temperature rose to an average value of 95 ^{o}C and lowered to 87.65 ^{o}C after the wax is added. This process takes about 2:10 hours. The wax stays on the fire until the workers complete squeezing the melted wax. Squeezing takes about fifty minutes, on the average, to complete the given amount of wax. This has shown that local melting method consumes much fuel wood, about 1.25 average man loads, costing eight Ethiopian Birr.

The wax melted in this method has no attraction for honeybees as compared to that of the wax milted by solar melters. It was observed that quite few bees landed on this wax while many bees have landed on the solar milted wax. The color of traditionally melted wax was brown and its smell was that of burnet candle.

One big and eight small plastic bowls, plastic jog for fetching the molten wax, one half barrel, bucket for holding water, around five 'fertilizer bags' and fuel wood are important accessories used during local melting methods. Besides, three persons, one for pouring the molten wax on to the bag and the other two for squeezing it, were required throughout the squeezing time. The estimated service year of the materials (barrel) and accessories is given in the table below (Table3). Estimated service life of the solar melter is also indicated on the table.

According to the data shown in the table above, the imported model has shown 15% more efficiency than the fabricated one. This difference was due to the nature of the glazing used in the melters. The imported model is covered with non-crystalline polystyrene plastic glass, which has excellent transparency and greater refractive index (1.59) than soda lime/common glasses glazing. However, the fabricated one was covered with common glass, which has lower transparency and refractive index (1.51) than the imported one.

Table3 Estimated service life of the materials and accessories

Materials and accessories	Cost (Br)	Total service delivery through out the life	Depreciation per service delivery or service cost (Br)
Imported wax melter	185.00	300 (10yr & 30 services/ yr)	0.62
Fabricated wax melter	251.00	150 (5yr & 30 services/yr)	1.67
Barrel	120.00	5 service only	24.00
Big plastic bowl	60.00	20 service	3.00
Medium plastic bowl (# 8)	200.00	20 service	10.00
Plastic jog	6.00	6 service	1.00
Bucket	30.00	90 service	0.33
Bag (fertilizer) # 6	12.00	3 service	4.00

Remark: - *Solar wax melters use only a plastic jog as an accessory.*

Table 4 Benefit-cost ratio for each melting method (based on unit base)

Types of melters	1 Unit cost	2 Benefit per unit	3 Benefit-cost ratio 2÷1	4 Net benefit (2) - (1)
Imported wax melter	14.58	42.00	2.88:1	27.42
Fabricated wax melter	13.56	42.00	3.10:1	28.44
Traditional wax melting method	16.49	40.00	2.43:1	23.51

Table 4 shows the cost-benefit comparison of the three melting methods. The result indicates that fabricated wax melter has the greatest B-C ratio. And based on this decision-making rule, this method has been chosen as the most preferred of the three melting methods. In the same table, the present value of the net benefits of each of the three melters is also shown. Applying the present value decision rule would result in the choice of fabricated wax melter and imported wax melting method would be ranked second. Local melting method will be the list. However, in the case of solar wax melters and their efficiency one can choose the imported one because this melter is more efficient than the fabricated one as discussed previously. The difference in benefit is due to the holding capacity only. If the capacity of the imported melter was equal as the fabricated one and were made in the center it would be much beneficial than fabricated one.

Farmers' comments and suggestions

Participant beekeepers forwarded their comments and suggestions regarding wax-melting methods. They said that solar wax melters are preferred for many of their qualities; are safe for working, no accident or hazed possibility, melt quality wax, require little accessories and little attention. They also commented that, as they do not require skilled manpower, these technologies are more effective in house hold level if they are available at reduced price. However, as farmers commented, these melters are not time effective as they melt less amount per day relative to local method.

Likewise, regarding local melting method, the place where wax extraction is carried out is on open-stoves (three stone stove). In such stoves the fire burns in all direction, consuming much fuel wood, becoming difficult, if not impossible, to control the temperature ranges as precisely as needed. As the wax will cool down immediately, becoming harder for squeezing, the crude material stays on fire until the wax is believed to be completely extracted. Farmers are aware that this makes the work tedious, and due to the flame burning during fetching the molten wax and while stirring, this system is more dangerous. The fire may also flame up if molten wax pours in to it accidentally. Furthermore, workers who melt the wax using local method know nothing about wax quality and the amount of temperature it needs. Beekeepers and wax processors do not know the importance and value of quality wax in the current market and important quality parameters other than separating debris.

Conclusion and recommendation

The study indicated that pure wax attracts honeybees and has higher values. This pure wax can only be obtained by improved technologies from which the solar wax melter is the one. It enables to melt little amount of wax in less cost and labor at household level especially for modern hives (foundation sheet). Besides quality wax can easily compete in global market and can earn more benefit than large amount of worthless product. Other social benefit as lowering of health hazardous, reduced deforestation, and labor hour saving will have enormous impact on individual and social well being. On the other hand, the wax extracted from traditional melting method is brown in color and is less attractive for bees. For such reason users, especially those who are aware of wax quality parameters did not support the local melting method. Therefore, it can be recommended that:

1. The imported wax melter should be available in the market or, by assessing non-crystalline polystyrene plastic glass in the market, should be produce in the center and demonstrate to the users with optimum melting capacity.

2. Training in selecting, handling and processing of good quality wax should be provide to beekeepers in collaborating with Bureau of Agriculture and Rural Development and other concerned organizations.

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Testing and Evaluation of Animal Drawn & Wheeled Hand Hoe Weeders

Worku Biweta and Asmamaw Endeblhatu
Bahir Dar Agricultural Mechanization and Food Science Research Center P.O.Box 133

Abstract

Weed is the major problem in small holder crop production system. If it is not controlled at the right time, it can significantly reduce crop yield. It also create additional work load on farmers. Under the traditional farming systems as much as 30% of the total labour employed in food crop production is used for weeding. In the case of Amhara region during June to august land preparation and weeding are taking place at the same time which make labor the limiting factor for crop production. To alleviate problems related to weed and weed control and drudgeries in traditional weeding systems, two kinds of mechanical weeders (wheeled hand hoe and triangular tool bar animal drawn weeder) were prepared and evaluated compared to conventional methods of weeding. The test result has shown that triangular tool bar animal drawn weeder has better performance than others. Its labor requirement was 10 person-hr ha^{-1}, while its weeding efficiency was 78% and saving in labor and weeding time was about 83% compared to conventional weeding system. Wheeled hand hoe, on the other hand, requires 30 man-hrs ha^{-1}, with a weeding efficiency of 75% and labor and operation time saving of 71%. Therefore, to get best control of weeding, triangular tool bar animal drawn weeder with a combination of manual weeding enhance weed control and reduces labor requirement. But for small holder farmers where draft animas are not available during peak weeding times, wheeled hand hoe gives best result.

Introduction

A weed is a plant grown un-wonted. Weed compete the crop for light, water, and other nutrients which are important for plant growth. When availability of these essential elements is limited, as it always is, competition occurs and plant growth suffers resulting in reduction of crop yield.

Weeds are constant problem in agriculture, if not controlled at the right time, significantly reduce crop yield and impair crop production. All crops are affected by weeds to some extent, but how serious this effect could be depends on the species and the circumstances under consideration. The institute of Agricultural research (IAR) reported that delayed weeding of maize reduces production by 44%.Average crop loss due to weeds is estimated to be about 25%, but can be as high as 50%-80% with some food crops (Lavabre,1991).

Report of the Institute of Agricultural research (IAR) also shows that when weeds are not removed from the cropped land at proper time, farmers will loss nearly 30% of their potential yield (Regional weed survey report 1997). Therefore the main objective of weed control is minimizing production losses due to weed effect. Furthermore, most of the mechanical weed control methods will improve the soil moisture status by reducing evaporation and enhancing infiltration.

In the Amhara region weeding is primarily done by hand pulling, but some times it can be assisted by hand hoes. This system involves scraping the soil to cut the roots of weeds just below the soil surface and shaking the soil off the roots to prevent weed re-growth. Under such traditional weeding systems, as much as 30 percent of the total labour employed in food crop production is used for weeding. (Practical field guide for control of weed,1996).This can cause labour bottlenecks specially during Jun-August when land preparation and weeding are taking place simultaneously.

Farmers use hand weeding and ox-weed (*shilshalo*) techniques with family labour. Planting maize behind the plows in parallel rows at least 40 cm apart and cultivating with traditional *maresha*, usually called inter-row cultivation, or *shilshalo,* is used by farmers to weed, to thin maize and to loosen the soil for better moisture retention. *Shilshalo* usually has to be assisted with some hand weeding or hoeing to remove the weeds which are left untouched. The first weeding should take place about two weeks after emergence and subsequent weeding or *Shilshalo* should be done when the maize is at knee height. (Practical field guide for control of weed, 1996)

The labor burden of weeding can be reduced through mechanical weeding. Mechanical methods of weed controls are simple and easily understood by farmers. The tools and implements for mechanical weed control are mostly manual operated or animal drawn. However, in order to use of mechanical cultivation methods, the crop must be planted in rows that are spaced wide enough for the animal tools and farmers to pass through, without damaging the crop.

Weeding with animal traction is much faster than hand weeding, and it is less tedious as well. Animal power makes the timely weeding of all fields possible, with benefits of increasing labor productivity and crop yield. Animal drawn weeding techniques are more cost effective than herbicides and are more likely to be amenable to small holder farmers. But whatever method is used, weeding should eradicate weeds within crop rows at an early stage and significantly reduce weed density (Starkey et.al., 1994).

Animal powered weeding can be carried out using whatever animal is most appropriate to the environments and culture of the people. Mules and horses are better established in weeding roles through they tend to be less suited to delicate crops and soils. A pre-requisite for animal based systems is the presence of proper care and training of the animals (Lavabre, 1991). Hence the objective of this study was to prepare mechanical weeding implements (Triangular tool bar weeder & wheel hand hoe) and test their suitability for maize cultivation under local conditions.

Materials and Methods

Two types of weeders (triangular toolbar animal drawn weeder and wheeled hand hoe) were designed and fabricated at Bahir Dar Agricultural Mechanization Research Center. The wheeled hand hoe was developed at Punjab Agricultural University and its design obtained from Central Institute of Agricultural Engineering (Bhopal, India). But triangular tool bar weeder was developed in the centre

Wheeled Hand Hoe

Wheeled hand hoe (Figure1.) is manually operated implement suitable for weeding and inter-culture. The handle is manufactured from ½" Galvanized iron pipe and it's height is adjustable according the operator size. The wheel and the frame were fabricated from 12 mm diameter deformed bar and 40x3 mm flat iron respectively. Duck foot type sweep weeder body, which is preferred for general weeding purpose, was selected and produced from 3 mm sheet metal. Depending to the soil condition one or two persons will be required to operate the weeder.

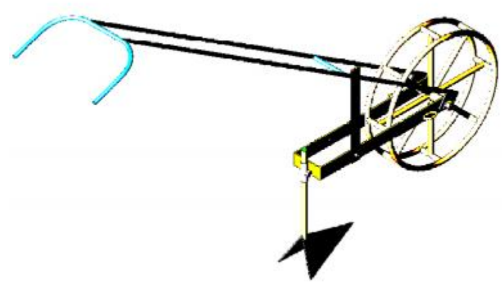

Figure-1 wheeled hand hoe weeder

Triangular Toolbar Animal Drawn Weeder

Triangular tool bar animal drawn weeder (Figure 2.), equipped with facilities for row-to-row spacing adjustment, is used as weeder and an inter-culture implement. The frame was manufactured from 30x30x3 mm angle iron to which three sweeps were attached by bolt and nut. The height of the shank, which is adjustable, is between 180mm-200mm. The duck foot sweep is designed to cut the soil beneath weeds with a superficial roots system or to cut through the roots of weeds deep inside. Taking this into consideration, the angle of attack, which is approximately 15^0, is ideal to lift and separate the weeds from the soil. Approach angle of 30^0-50^0 were selected. (Brian and Sims, 2000)

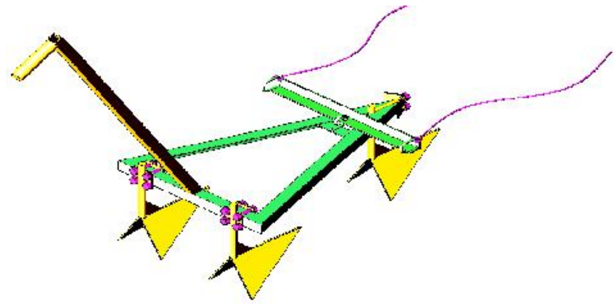

Figure- 2 Triangular tool bar animal drawn weeder

Test procedure

The test was conducted on maize farm planted in rows and a mule harnessed using breast band, was used as a source of power for the animal drawn weeder. The mule was trained on pulling the weeder for a few days prior to actual testing. The time taken to complete a particular operation was measured using a stop watch. Data was collected on representative field samples and field capacity, labor requirement, and weeding efficiency were then calculated and the mean value of at list three measurements reported. Important parameters were determined as follows;

- Weeding efficiency - is quantitatively expressed as the ratio of number of weeds present after weeding operation or passes to that before. Samples of weeds within and between the maize were taken using a 1 m^2 quadrant sampler and weed collected was dried and weighed. The frame is dropped on the un-weeded and weeded land randomly. Replicated samples are taken, oven dried at 130^0c for 18 hours, and weighed. Weeding efficiency is thus calculated by

$$\eta_{weed} = \frac{(W_p - W_e)}{(W_p)} \times 100$$

Where:

η_{weed} = weed efficiency,

W_p = Weight of oven dry weed per unit area before weeding

W_e = Weight of dry up-rooted weed after weeding

- Working speed - is calculated from the time taken to weed a distance of 25m
- Theoretical field capacity (F_{ct})- is calculated from mean values of working speed as

$$F_{ct} = W x V$$

Where:

W= working width (m),

V= working speed (m se^{-1})

- Soil moisture content – was measured by gravimetric method in which soil samples were taken, weighed immediately in the field, and then oven dried at 105 ^{0}c for 48 hours. Percentage soil moisture content (dry bases) was determined from;

$$M_s = \frac{(W_{twet} - W_{tdr})}{(W_{tdr})} \times 100$$

Where:

M_s - Soil moisture
W_{twet} - wt of wet sample
W_{tdr} - wt of dry sample

Results and discussions

The test result (Table1) has shown that the hand hoe weeding method gives better weed control result. However, it is a slow process, which is labor- intensive compared to the other mechanical methods. It is hard and tedious work. As labor requirement is about 232 person hr ha^{-}1, total area coverage per person per day is limited. It can, however, be useful for areas where labor is available during the season and wages are low.

However weeding with pair of oxen using traditional plough at weeding tine is much faster and saves labour and time by about 79% compared with this hand hoe method (table 1). If weeding is performed at early stage, about two weeks after emergence, the plough throws enough soil on the crop rows which will burry and suppress small weeds without harming the crop. Weeding efficiency is 81% (table 2). However, this system too has some series short comings. During weeding or cultivating using a pair of oxen, one of them will probably pass on the free space between rows of plant while the other will ride on planted rows, causing breakage on germinated crop. Besides, cultivating depth, which is about 12cm, is greater than the required depth.

The test result also shows that it was easier to weed with single animal than two. Weeding with one mule by triangular toolbar weeder is much faster (table 1) and, of course, less tiring. Labour requirement was observed to be 10 person h ha^{-1} and saves labour and operation time by 83% compared to hand hoe. On the other hand, it was observed that weeding with of wheeled hand hoe was cumbersome when the implant was to be push by one person, especially when the soil moisture content was low. To simplify this problem, two framers were used to work at a time, one person pushing the implement while the other pulls it by a rope. In such conditions, labor requirement was 30 person h ha^{-1} and still saves labor and operation time by about 71% compared to hand hoe system. Field observation has also shown that cultivation should be performed when weeds are not more than 15 cm tall and the soil is not too wet.

Table 1 Average working performance of different weeders

Implement	Working width (cm)a	Working speed (m s-1) *
Hand hoe	80	0.0148
Wheeled hand hoe weeder	15	0.625±0.12
Triangular toolbar weeder	40	0.714±0.06
Traditional Maresha	20	0.583±0.035

*= Mean ±standard deviation of three measurements

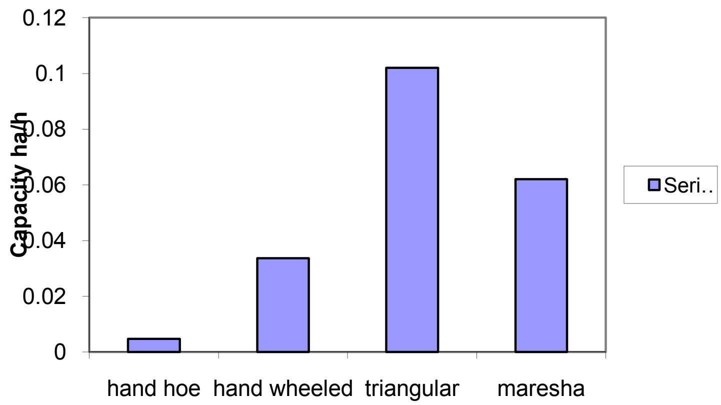

Figure 3, Working capacity of weeders

Table 2 Weeding efficiency of treatment weeders

Implement	Average Weeding efficiency %
Hand hoe	91
Wheel hand hoe	75
Triangular toolbar	78
Traditional maresha	81

Conclusion and Recommendation

Using triangular toolbar weeder drawn by a single mule, with a combination of manual weeding enhance weed control, reduce labour requirement and can suppress the effect of weeds on crop yeald. During high output, triangular animal drawn weeder can help in the timeliness of operation and saving time. For small farmers where draft animals are not available wheel hand hoe with a combination of manual weeding gives best control of weeds. The weeders can be made and maintained in the small workshop.

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The papers should be organized in the following manner:

a) **Title:** The title should be concise but informative. Not more than 13 words.
b) **Author(s)** name(s), and the name(s) and address(s) of the center/institution(s) where the work was carried out should follow the title.
c) **Abstract.** The abstract should be condensed to a maximum of 200 words and should be intelligible by it self. It should have objectives, methodologies, results, and a conclusion in a single paragraph.
d) **Introduction.** This section of the manuscript should indicate the explanation or fundamental hypothesis on why the study or the research was conducted. Gaps found in previous related literatures and objectives should also be stated.
e) **Material and methods.** Brief description of the environment, materials used, procedures followed, experimental design and statistical analysis applied are briefly explained here. Year of accomplishment should also be indicated. This has to enable others to repeat one's experiment.
f) **Results and discussion**. ***Result***-is the core of the paper. Simply and clearly stated presentation of what is found with the investigation as related what is stated in the introduction part. It includes un repetitive presentation of representative data.
g) ***Discussion***- should explain what the result means and its practical significance and implication for future study. Discusses whether it agrees or disagrees with previously published work. Based on this conclusions are stated with evidence and recommendations can be given for follow up.
h) **Acknowledgments**. Acknowledgments, if any, may be given immediately following results and discussion section very briefly.
i) **References**. Only publications cited in the text should be given in the references. All literatures cited should be closely relevant to the author's work. Exhaustive list should be avoided, not more than 10 except under special condition. References should be arranged in alphabetical and chronological order (from older to recent). Checking the accuracy of references is the responsibility of authors. In the text, references should be presented in the author-year style. E.g. (Tan, 1978) or Tan (1978) ; (Lim and Aziz,1979) or Lim and Aziz (1979). When there are three or more authors (Tan *et a*l.,1979) Tan *et al*., (1979) .

References should be listed according to the following format. *Note*: names of Ethiopian authors are written fully.

Journal Article

Mabbayad, M.O. and Moody,K. (1985). Improving butachlor selectivity and weed control in wet -seeded rice. *Journal of Plant Protection in the Tropics* 2(2): 117-124.

Beyene Chichaibellu, Coppock, C.E. and McDowell R.E.(1977). Laboratory evaluation and estimation of nutritive values of some Ethiopia feedstuffs. *J. Assoc. Adv. Agric. Sci Africa* 4(2):9-23.

Book

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

Edited works (Chapter in a book or paper in a proceedings)

Loegering, William Q. (1984). Title of the chapter/paper . P. 165-192. *In* William R. Bushnell and Alan P. Roelfs (eds.) title of the book/the proceedings Academic Press, Orlando, Florida.

Un Published reports

Huxley, P.A.(1986) Rationalizing research on hedgerow intercropping: an overview. ICRAF Working Paper 40. Nairobi: ICRAF. P66-75

Personal communications are not included in a reference list. They are simply listed in the text as: (Anthony Youdeowei, Pers.comm.) or simply as (personal communication).

2. The format

The manuscript has to be typed on one side only, double spaced on A4 sized paper and margins of 25, 30, 35 and 25 mm on top, bottom, left and right margins respectively. The font type has to be *times new roman* through out. The font size of the text has to be 12 unless an otherwise specified below. Scientific names have to be written following standard binomial nomenclature.

Except under special recommendation, the manuscript should not be more than 3500 words excluding illustrations, or totally, a maximum of 5-7 pages.

The title of the manuscript has to be bold and centered, only the first letter written in upper case except under special condition. Author(s) name(s) and the institution to which they are affiliated should be written centered with font size of 10. Main Headings (introduction, materials and methods etc) should be left justified and bolded starting with capital letter. Sub-headings are typed alike the main headings but they are italicized and are not bolded. Figures and illustrations should be in a form suitable for edition and reproduction. They have to be black and white and with high contrast.

Tables should be numbered consecutively as Table 1, Table 2, etc., in the order in which they are first cited in the text. Each table, with its heading, should be typed on a separate sheet. A table should be self explanatory and concise. Table-footnotes should be marked with superscript * (asterisk) and the foot note has to be italicized with font size of 10.

Authors are advised not repeat information in the text presented in the tables or in charts or graphs. Submission of unmanageable and oversized tables may lead to rejection.

All measurements must be reported SI units or metric system. Negative exponentials, like Kg ha^{-1} are recommended in stead of writing as Kg/ha. Point has to be used for decimal as 10.5 to say ten point five. Every three digits have to separated by space as 10 556. Abbreviations or short hand forms have to be first fully spelt out before they are used in abbreviated/shorthand form in the rest part of the text. The ISO designation for Ethiopian currency is ETB and this has to be used whenever the currency is expressed. Gregorian calendar should be used for dates, months and years.

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Two hard copies of manuscript should be submitted to the respective directorates or secretaries of the respective editorial committees not latter than 45 days after the papers are presented on the conference. The range includes time required for postal transfer. Soft copy should be submitted with in the same time on diskette or as attachment to e- mail

4. Correspondence

Where a paper has joint authors, one author must accept responsibility for all correspondence.

The Editorial committee or the institute shall take no responsibility for the loss of the manuscripts in the process of mailing. The authors are advised to retain copies of their submission.

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The editorial committee includes forestry, soils and water management and agricultural mechanization research directorates. The committee is accountable to the director general of the institute in order to maintain uniformity in the publication of proceedings and to monitor the overall activities of the annual conference and its regular implementation. The final decision on the papers presented is made by the respective editorial committee taking into consideration the inputs from the participants during the annual conference. Accepted papers will be further evaluated and commented by senior reviewers and sent back to the authors for corrections. The final editorial work will be done by members of the respective editorial committee which will be made ready for printing.

List of participants

No	Name	Address	E-mail
1	Abebech Abera	Adet ARC	afr.2007@yahoo.com
2	Abraham Demekristos	Adet ARC	abr2030@yahoo.com
3	Abu Teffera	B/Dar Mechanization	abuteffera@yahoo.com
4	Anteneh Abewa	Adet ARC	antenehabewa@yahoo.com
5	Asmamaw Endeblhatu	B/Dar Mechanization	e_asmamaw@yahoo.com
6	Asmare wubet	Sirinka ARC	asmareaw03@yahoo.com
7	Behonegn Akalu	Gonder ARC	behonegnakalu@yahoo.com
8	Belay Tseganeh	ARARI	belay_tsega@yahoo.com.
9	Berihun Dulale	Adet ARC	geegz2007@yahoo.com
10	Berihun Tefera	Sirinka ARC	berihunadugna@yahoo.com
11	Beyene Belay	Sirinka ARC	beyene.belay@ yahoo.com
12	Birru Yitaferu (Dr.)	Adet ARC	birru_yitaferu2002@yahoo.com
13	Chalachew Abebe	Adet ARC	chalachewbb@yahoo.com
14	Demlie G.sillassie	Sekota ARC	demdgs2005@yahoo.com
15	Ertiban wondifraw	Gondar ARC	ertiban15@yahoo.com
16	G.selassie Sahlie	B/Dar Mechanization	gsahlie@yahoo.com
17	Geta Kidanematiam	B/Dar Mechanization	getakiddan@Yahoo.com
18	Hanibul lemma	Gondor ARC	haniballemma@yahoo.com
19	Ismael Indris	Sekota ARC	emashcool@yahoo.com
20	Kibruyesfa Sisay	Gondar ARC	kibru122@Yahoo.com
21	Menale Wondie	Adet ARC	menalewondie@yahoo.com
22	Menelik Getaneh	Adet ARC	menelikgetaneh@yahoo.com
23	Sisay Demeku	Sirinka ARC	sdemeku@yahoo.com
24	Solomon Tekeste	BAMRC	soltektana@yahoo.com
25	Tadele Amare	Adet ARC	tadele17b@yahoo.com
26	Tatek Dejene	Gondar ARC	tdejenie@yahoo.com
27	Tesfaye Feyisa	Adet ARC	tesfaberhan98@yahoo.com
28	Teshome Tesema (Dr.)	ARARI	teshome_tesema@yahoo.Com
29	Wolalaw Endalew	B/Dar Mechanization	en_wolelaw@yahoo.com
30	Worku Biweta	B/Dar Mechanization	workubiweta@yahoo.com
31	Yihenew G.selassie (Dr.)	ARARI	yihenewgs@yahoo.com
32	Yirga Alemu	Gonder ARC	yirgale@yahoo.com
33	Yonas Girma	Debrebirhan ARC	yonasent@yahoo.com
34	Zewdu Ayalew	B/Dar Mechanization	zewduoyalew@yahoo.com