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ETHIOPIAN ENVIRONMNET AND FOREST RESEARCH INSTITUTE

Forest and Environment Research: Technologies and Information

Edited by:

Mehari Alebachew
Getachew Desalegn
Wubalem Tadesse
Agena Anjulo
Fassil Kebede

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PROCEEDINGS OF THE 1ST TECHNOLOGY DESSIMINATION WORKSHOP

26th - 27th November 2015

Tokuma Hotel, Adama, Ethiopia

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PREFACE

Forests are sources of different products and services that may be used to improve the well-being of population. Moreover, it contributes to the development of the national economy through wood and non-timber forest products supply, also contributes to various sectors of the national economy such as energy, agriculture, food, industry, health,environment andtourism. In general, the socio-economic contribution of forestry at national scale can be seen from various angles such as employment generation,earning of foreign curreny and import subsititions.However, forests in Ethiopia are shirnk from time to time due to reckless cutting of trees and shrubs for fuelwood, charcoal, construction wood, lumber and agricultural land expansion. Moreover, due to deforestation, there is acute shortage of fuelwood, charcoal, construction wood, timber and non-wood forest products. Currently, the seemingly combined objective of restoring vegetation cover and production of fuel wood is a key environmental issue. Besides, restoration of degraded forest lands and woodlands can be paving as other potential opportunity in the future for firewood production.

For the last decaded, forestry research is becoming a key area to alleviate the problems of deforestation and supplement the shortage of supply of forest products from natural and plantation forests, in part due to timber-harvesting restrictions imposed over a few valuable indigenous species Forestry Research contributes to achieve several objects to provide high value commercial timber and fuelwood, to rehabilitate the degraded lands, for agroforestry purposes, provide non-timber forest products and sustainably manage our natural forests and the monoculture plantations established. Forestry research is conducted at federal, regional, and higher learning institutions and they play significant role on conducting and providing appropriate, up-to-date and applicable technologies and information on several forestry related desciplines.

Thus, Forestry Research Process under Ethiopian Institute of Agricultural Research (EIAR) has done several research activities in the past to select, promote and disseminate multipurpose and fast growing tree species for rehabilitation of degraded lands to alleviate fuelwood shortage and to combat soil fertility depletion in the country. The Ethiopian Environment and Forest Research Institute (EEFRI) were established with the mission to conduct research on forest development, management, conservation and utilization and thereby generate and disseminate technologies, information and knowledge.

The objective of this national workshop was to present completed forestry research over the last tenyears. Therefore, this proceeding has a total of 35scientific papers in different disciplines, plantation and agroforestry, forest resources utilization, ecosystem management, environmental pollution control and management and forest protection aspect. The research technologies may be utilized in a number of forestry and environment related development, utilization, management, conservation, enterprises and education sectors.

We strongly recommend all the stakeholders to read the different articles of different technologies and information obtained in recent years and applies a number of forestry and environmnet related research, development and utilization activities as appropriate.

Finally, I would like to forward my grateful to the workshop organizing committee of the institute for the successful organization of the workshop and compiltation of the proceedings. My great pleasure and special thanks to all the organization that sponsored the workshop and publication of this proceeding.

Thank you

Wubalem Tadesse (PhD)
Director General
Ethiopian Environment and Forest Research Institute

ACKNOWLEDGEMENTS

WELCOME SPEECH

Mehari Alebachew

Coordinator workshop organizing committee, EEFRI

Dear Dr WubalemTadesse Director General, EEFRI

Dear Dr Agena Anjulo Deputy Director General, EEFRI

Dear parlament representatives, ladies and gentle men

First of all I would like to say well come to the 1st Ethiopian Environment and Forest Technology dissemination workshop which will be conducted at Tokuma Hotel, Adama from 26th - 27th November 2015 in the name of EEFRI workshop organizing committee and my self. I wish a happy and pleasant stay for all of you.

The aim of this workshop is to disseminate and popularized knowledge, information and technologies which are generated by EEFRI for the last two to four years and popularize it to the major stakeholders. Primarily, the EEFRI workshop organizing committee was prepared a format for receiving abstract distribute to the authors. In the meantime we received a total of 68 abstracts in different environment and forestry themes: plantation and agro-forestry, natural forest management, forest protection and forest product utilization and environmental pollution control and management. Then the abstracts were critically reviewed by senior and prominent researchers and scientist under our institute. Moreover, the committee was critically evaluated and screened the abstracts based on the findings and nobility of the information. A total 68 abstracts (33 forn oral presentations, for 15 poster presentation and 10 for abstracts published in the form of book of abstarcts) were screened by the committee. And these findings will be presented in this workshop and summerized abstarcts were published in the form of book of abstracts for the workshop participants.

- Dear Dr WubalemTadesse DG, EEFRI
- Dear Dr AgenaAnjulo DDG, EEFRI
- Dear parlament representatives, ladies and gentle men

In addition to disseminate of our research finding for the stakeholders in these two days workshop we expect also inputs from our stakeholders who enable us to strengthen our future research edavours and outsourcingkey researchable issues for our future new research proposal formulation and implementation phase. The researchable agendas which might be aligned with contributing to accomplish the GTP2 and attaining climate resilience green economy strategy of the country.

In addition, in the name of workshop organization committee and myself I would like to thank all the reviewers for our abstracts, the sponsoring organization for this particular workshop particularly.

- Food and Agriculture Organization (FAO), Regional Office in Addis Ababa for covering accommodation for our workshop particpants including us

- REDD+ secretariat for covering refreshment, lunch and conference room cost for the workshop

- Institutional Strengthening Program for Forest Sector Development, Ministry of Environment, Forest and Climate Change for covering perdium, stationery and transportation cost for workshop particpants and publishing banner for EEFRI

- I would like also thank all administrative and supportive staffs and EEFRI core process and supportive staff directors and Ministry of Environment, Forest and Climate change supportive staff for your facilitation and encouragement to materialize our workshop

Once again, I wish having a happy and pleasant stay in Adama, Ethiopia. Finally, kindly request all the chairpersons and oral presenters to be serious with time management to accomplish our target with these two days.

OPENING SPEECH

Wubalem Tadesse

Director General, EEFRI

Distinguished honorable parliament representatives ladies and gentle men,

It gives me a great pleasure and honor to be with you this morning and officially open the **1ˢᵗTechnology Dessimination workshop of Ethiopian Environmnet and Forest Research Institute.** In this venture**,** I would like to say welcome all of you and express my sincere appreciation for your availing and spending precious time to participate in this important workshop.Your presence is a sign of your commitment and dedication towards increasing awareness about environment and forest related problems such as forest degradation, land degradation, water, air and soil pollution and climate change mitigation and adaptation. Now a day it is already known that our world faced major water resources degradation due to point and non point sources pollution, water hyanith and forest resource degradation. Hence, to with stand this problem Ethiopia established institutional based organization such as EEFRI mandated to coordinate and conduct environment and forest research and thereby generate and disseminate technologies, information, and knowledge to end users.

As it is already known, over the last four decades, the forestry research system has been organized under different institutional structures and carried out several research activities in the area of industrial plantation, agro-forestry, natural forests, ecosystems management, forest protection, forest resources utilization and environment management issues. Within this research activities, various technologies, information and knowledge were generated that need to be disseminated and popularized to the stakeholders. Hence, the main objectives of this workshop to popularize and disseminate various technologies, information, and knowledge those were generated in the past. It encourages me to see a wide range of sectors, local governmentalauthorities, development partners, non - governmental organizations. This wide range representation will enable this workshop to comeup with realistic, viable and operational programmes for effective Environmental Management, poverty reduction as well as establishing climate resilient green economy in our country.

Distinguished honorable parliament representative's ladies and gentle men, let me take this opportunity to praise the organizers of this workshop and thank the collaborator of EEFRI for the realization of this workshop such as MEFCC, FAO and REDD+ for their financial support. Your continued support is a reflection of your commitment towards better environmental and forest management for the current and future generations.

Distinguished honorable parliament representative's ladies, gentle men and participants with these remarks I extend a warm welcome to you all and wish you fruitful deliberations for the two days stay in Adama. I have the pleasure to declare the 1ˢᵗ technology dissemination workshop organized by EEFRI, officially opened. I wish you fruitful deliberations for the coming the two days of the workshop.

I thank you all for your kind attention.

Wubalem Tadesse (PhD)

DG, Ethiopian Environmnet and Forest Research Institute

PLANTATION AND AGROFORESTRY

EARLY GROWTH PERFORMANCE OF *JUNIPERUS PROCERA* HOCHST. EX ENDL IN DEGRADED LANDS OF NORTH SHOA

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Abstract

Juniperusprocera Hochst. Ex Endl has both economical and ecological importance in afforestation and reforestation programs. A community based *J.procera* plantation was conducted in North Shoa zone, Baso Ena Worana woreda, in 2011 with the objectives of evaluating the growth performance of *J. procera*. Two villages in Wayu Peasant Association, Telasa and Muter, were purposely selected to carry out the trial with the participation of thirty one farmers. Two hundred *J.procera* seedlings were distributed to each farmer and planted at 1.5 m spacing in 40 cm by 40 cm dug pits. Survival and height of seedlings were assessed at six months and three years after its establishment. The result of the assessment revealed that the mean survival percent of the two sites was 61% and average heights were 17.30 cm and 101 cm within six months and three years after planting respectively. But there was no significant variation ($P < 0.3$) between the sites and among the sample plots (farmers). The result of this study showed that degraded lands in North Shoa could be rehabilitated with the promotion of *J.procera* best performing populations under farmers' management practices. Furthermore, promotion of community-based afforestation and reforestation activities of degraded lands of the country using indigenous tree species such as *J. procera* is inevitable both to restore the species and to get economic benefit out of it.

Key words: degraded land, *Juniperus* procera Hochst. ex Endl, plantation rehabilitation

Introduction

Now a days, Ethiopia's precious indigenous trees are endangered due to sever land degradation in most parts of the country. The dominant anthropogenic causes of land degradation in the country are poor farming practices, population pressure, overgrazing, soil erosion, deforestation, salinity and alkalinity problems, and a utilization of livestock manure and/or crop residue for fuel as energy source for the poor rural households (Cesen, 1986; World Bank 1984; Hawando , undated).

1

Despite the extreme shrinkage of *Juniperus procerea* Hochst. Ex Endl populations in their natural ranges, establishment of plantation forestry using this tree species is hardly done due to its slow growing nature, prevalence of seed dormancy, susceptibility of juniperus trees to fire and uncertainty of future land ownership (Yirdaw, 2003; Teketay, 1993; FAO, 1958). Besides, recent afforestation programmes did not include these valuable indigenous tree species for the reason that they are climax tree species and/or has low growth rate Legese (2002) quoted in Tesfaye and Diriba (2009). The problem of successful juniperus plantation establishment in this country is also attributed to extensive forest clearing for crop cultivation, over-grazing and exploitation of forests for fuelwood, charcoal and construction materials without making an effort to opt for afforestation and/or reforestations programs in a site.

Previously, Forestry Research Center (FRC) has established juniperus seed sources and conducted performance evaluation trial of different juniperus populations collected from different parts of the country. But only few significant efforts made to use it as commercial plantation development. Nevertheless, its economic and ecological importance made *Juniperusprocera*Hochst. Ex Endl very interesting to restore (Tigabu et al., 2007) and establish as a plantation. Though it has a value to produce fine timber with a heavy, durable and termite resistant wood, the natural and plantation of *Juniperusprocera*Hochst. Ex Endl is under heavy encroachment (Negash et al., 2012). Nevertheless, to overcome the problem of genetic erosion and ensure natural regeneration of juniper trees, it is indispensable to reforest/afforest the degraded areas via community based afforestation programs. According to Herzog (1998) Juniper seedlings can survive with a rainfall as little as 150 mm per year, but they don't survive a "drought" season lasting longer than 2-3 weeks that implies the lack of natural regeneration potential of juniperus via seeds. According to our observation in this trial site the natural stands of Juniperus have been restoring due to reforestation activity in the site. In line with this, Pohjonen and Pukkala (1990) emphasized that Ethiopian plantations will be replaced ultimately by native tree species through succession in the long run.

In this paper, we present a pilot study that has been conducted by EIAR/FRC in collaboration with Univastidad de Madrid to evaluate its performance of *Juniperusprocera*Hochst. ex Endl tree species planted in two sites in Wayu PA.

Material and Methods

Description of the study sites

The study was conducted in North Shoa zone, Basona Warana woreda, Wayu ena Angent Mewugia Peasant association (PA) specifically in Xelasa and Muxer sub-site (Fig 1). These sites are located in lower areas of Wayu PA. The areas are characterized by rugged topography covered by stunted and scattered juniperus trees. They are neighbored by Oromia and Afar National Regional States.
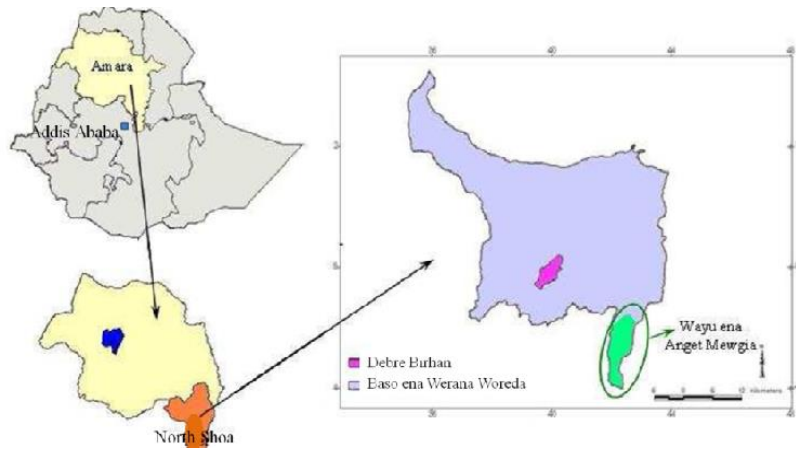
Figure1: Study site

Assessment

Six months after the establishment of the trial, early growth assessment was conducted using 25 randomly selected plots of farmers' lands in 2012. On each farmer's land, 100 m^2 were laid and a survival count, root collar diameter and height of planted seedlings were taken and registered on data collection form. A minimum of three plots were considered for each households. The plot numbers per households varies with the size of the land covered by eucalyptus plantations.On top of that both a survey was conducted on the role of *Eucalyptusglobulus* Labill woodlot on the livelihood of selected farmers using Focus group discussion and key informant interview in the study area..

Results and Discussion

The result of the assessment revealed that the mean survival percent of the two sites was 61% and average heights were 17.30 cm and 101 cm within six months and three years after planting respectively. But there was no significant variation ($p < 0.3$) between the sites and among the sample plots (farmers) (Table 1). Nonetheless, this study indicated that survival of farmer managed juniperus (60 %) at *Telasa/ Muter* is greater than an experimental plot at, i.e., less than 50 %, *Senga Beret* area (Mifta et al., 2012). Similarly, the mean height (1.98 m) of juniperus (*Telasa*) under farmers' management is close to that of Shakiso population (2.27 m) (Girma et al., 2012) 4 years after planting *Kulumsa* exp plot.

Although there was severe drought and frost season in 2010, the seedlings at both sites were healthy and vigorous (Figure 1). If there is continuous follow up & care for the seedlings, there would have been better performance under farmers' management.

Figure 2: photo of *Juniperus procera* seedling in Muxer or/and Talasa

Table 1: Mean ±Se of survival percentage of *Juniperusprocera*Hochst. Ex Endl seedling planted one year after in the study sites (n=31)

site	No of farmers	Survival (%) (6 months)	Height (cm) (6 months)	Height (cm) (year 4)
Telasa	14	63.00 ± 2.9	30	198
Muter	17	59.18 ± 3.2	28	101
Total/mean	31	60.90 ± 2.2	26	150

Conclusion and Recommendations

The result of this study showed that degraded lands in North Shoa could be rehabilitated with the promotion of *Juniperusprocera*Hochst. Ex Endl best performing populations using farmers' management practices. It worth mentioning that a success of community managed Juniperus planting and management practices at the *Muter* and *Telasa* outweighs that of conventional research method reported from similar location (Miftah et al., 2013). The preliminary result of this activity is one step forward to save our endangered indigenous tree secrecies on top of its importance to rehabilitate a degraded land and contribute to longterm household income. This achievement was one of the successes that were attained in late 1990s' as a result of the proposed rehabilitation project in collaboration with Technical university of Madrid in the study site. Empowering farmers with provision of seedling stock and technical knowledge were some of the important resources of the project implemented by Forestry research center in collaboration with Technical university of Madrid at Baso Ena Warana in the last decade. Reports (Wubalem et al., 2010) indicate that farmers' tree preference vary in the study area with their top priority being e. globulus due to fast growth and well known silviculture. Nevertheless, the farmers did not refrain from incorporating Juniperus in their parklands due to its economic importance and to reduce risk of tree survival. Of course, such a practice needs follow up and awareness creation for the community and encouraging them via provision of improved germplasm and technical advises. Furthermore, promotion of community-based afforestation and reforestation activities of

degraded lands of the country using indigenous tree species such as *Juniperus procera*Hochst. ex Endl is inevitable both to restore the species and to get economic benefit out of it. Despite the challenging nature of the study site, community driven afforestation and reforestation programmes using indigenous tree species in, indeed, encouraging. This should be backed up with provision of selected and research proven provenances that adapt to the local area. Kolobo, Chilimo and Wofwash provenances can adapt to the North shoa based on recent reports by forestry research center (FRC, 2010 unpublished report). Thus, it is recommendable to involve the local community in Wayu kebele and its surroundings to participate in Juniperus and other indigenous tree species plantation that could adapt to the sites. The role of local extension and research centers including forestry research in providing germplasm and advice is important to enhance such community based tree planting activity.

Last not the least is reworking this participatory action research on more sites and more households is very important to make a difference in boosting the degraded landscape and improving community livelihood in current changing climate. Data on community perception in reforestation using indigenous tree species, biophysical data and tree growth parameters (nursery to field) including community management practice are very important to document detail of the preliminary result in the study area.

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COMMUNITY ESTABLISHED EUCALYPT PLANTATIONS IN ETHIOPIA FOR DEGRADED LAND RESTORATION AND INCOME GENERATION

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Abstract

This study was designed to evaluate the role of *Eucalyptusglobulus* Labill planting through community participation in rehabilitating degraded lands and to assess the impact of eucalypt plantation on community livelihood using cost benefit ratio in North Shoa zone. In this paper we presented the performance of community based on-farm *E.globulus* tree planting that was commenced in 2011 in Wayu Kebeleusing 1.5 m by 1.5 m spacing. The planting was done on degraded plots of land of 72 farmers. Six months after the establishment of the trial, in 2012, early growth assessment was conducted using 25 randomly selected plots of land. Besides, a survey was conducted to gather data on current role of previously planted *E.globulus* plantations on the livelihood of the rural community. Despite the severe frost problem in 2011, the result revealed that the mean survival percentage was 88 % and; mean height growth was 31 cm at the study area. The study also revealed that there was highly significant variation in seedling survival percent and height among the households' plots six months after planting. This variation might have been due to difference in the level of management among the households and/or due to the specific characteristics of the sampled plot of land that needs further research. Those farmers who possessed eucalypt plantation are making their livelihood from their plantation earning up to 150,000 ETB from less than one ha land of eucalypt plantation. From the present assessment it was concluded that planting eucalypts in such degraded lands is very promising and economical. It is also believed to play a key role in improving the livelihood of the farming community in the study areas.

Key words: Community based, Sustainability, *Eucalyptus globulus,* livelihood

Introduction

Land degradation is the reduction in the capacity of the land to produce benefits from a particular land use under a specified form of land management Blaikie (1989) quoted in Mitiku et al., (2006). Land degradation is one of the biggest problems in Sub-Saharan Africa in general and in Ethiopia in particular caused by natural and/or anthropogenic factors. The main causes of land degradation are complex and attributed to a combination of biophysical, social, economic and political factors (Mitiku, et al., 2006). The main anthropogenic factors that escalate this event are

clearing of trees for agricultural expansion, fuel wood gathering and charcoal making, logging, settlement, urbanization, overgrazing, improper development interventions, etc. Additionally, there are various underlying causes among which population growth, rural poverty and poor policies are key ones.

Consequently, land degradation negatively has affected our environment and human livelihood due to, floods and landslides, drying up of springs and water bodies, siltation, loss of biodiversity, climate change, desertification, soil erosion, depletion of soil nutrient, decline of agricultural productivity. It is one of the major problems that pose a serious threat to a house hold food security.

It was reported that in Ethiopia, about 19,000 ha of hill and montane forest are deforested annually, which accounts for about half of the total annually deforested area in the country (FAO, 1993) that paves a way for land degradation. Similarly, land degradation due to soil erosion has been one of the chronic problems in Ethiopia (Nyssen et al., 2003) quoted in Mitiku et al., (2006). Consequently, it was estimated that about 42 tons ha^{-1} yr^{-1} of soil of arable land of the Ethiopian highland is lost that accounted for average annual crop land productivity decline of 0.21 % (Hurni, 1993), thus brings about lack of sufficient food and/or poverty. To mitigate the impact of land degradation a number of techniques are devised including plantation establishment, adoption of agroforestry practices and soil and water conservation.

Semen Shoa is one of the highly degraded lands of Ethiopian highlands. According to FAO (1984) and Hawando (undated), on two million ha of cultivated land of Ethiopian highlands the soil depth is so reduced that the land is no longer able to support any vegetation cover. Thus, North Shoa is one of the highly degraded areas that has called for every body's attention including the local community to mitigate land degradation impact and to reverse a trend towards land degradation so that farther degradation is controlled and community livelihood is improved. Rehabilitation of degraded land like that of Ethiopian highlands/ North Shoa is important to attain food security, fodder security, minimization of farther environmental degradation and improvement of livelihoods. Community participation is one way to reverse a degradation problem on Ethiopian highlands in general and North Shoa Zone in particular. Thus, community oriented land rehabilitation project has been launched in selected sites of Basona Ena Warana woreda. Hence, this paper presents the performance of *Eucalyptusglobulus* Labill plantation and to assess the livelihood roles of this community-based tree planting the project area, in Wayu kebele.

Material and Methods

Description of the study site

The study was conducted in North Shoa zone, Basona ena Warana, Wayu PA in 2011. *Eucalyptusglobulus* Labill seed was from Forestry research Center collected from Dire site and sawn directly in 8 x 10 cm polythene tubes filled up with a soil mixture of 3:1:1 manure, local and sand in Wayu nursery in 2011 EC. The seedlings stayed in nursery for 4 months. The

seedlings were distributed for purposely selected Wayu kebelefarmers when they reached plantable size and planted at 1.5 m spacing between seedlings.
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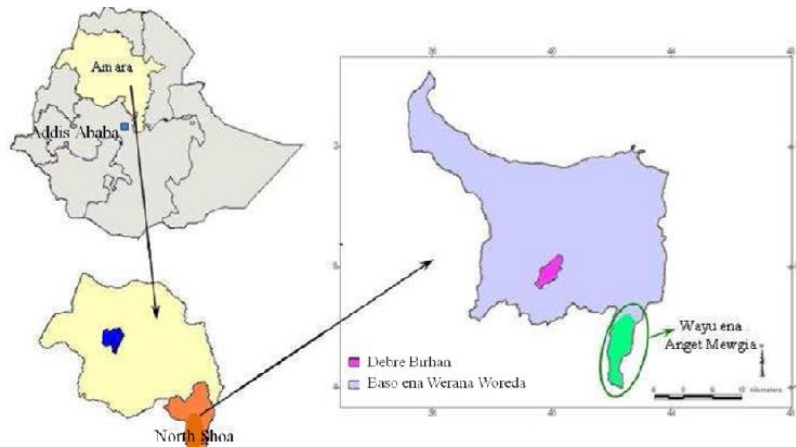
Figure 1: Study site.

Assessment

Early growth of Eucalyptus globulus Labill seedlings

In 2012, six months after the establishment of the trial, early growth assessment was conducted using 25 randomly selected farmers' plots. On each farmer's land, 100 m2 were laid and a survival count, root collar diameter and height of planted seedlings were taken and registered on data collection form. A minimum of three plots were considered for each households. The plot numbers per households varies with the size of the land covered by eucalyptus plantations. On top of that both a survey was conducted on the role of *Eucalyptus globulus* Labill woodlot on the livelihood of selected farmers using Focus group discussion and key informant interview in the study area.

Results and Discussion

The result of this study revealed that though there was sever frost problems in Wayu area the mean survival percentage was 88%, height (31cm) and root collar diameter (10mm) in six months after planting (Table 1). The study also revealed that there was highly significant variation (p < *0.0001*) in survival percent and height of the plantation. There is significant variation in seedling height (p < 0.0001) and survival percent (p < 0.0001) but root collar diameter (0.2) in the study sites based on the sample house holds' plot of land. It was also observed that there is difference among the farmers in managing the plantation that has led to variation in the survival of the seedlings after the planting. Some tend their plantation where as some did not five due attention to the tending operations after the establishment.

Table 1: Early growth value (mean ± standard error) of *Eucalyptusglobulus* Labill six month
after planting

Parameters	M ± Se	F-value	P-value
Root collar diameter (cm)	0.1 ± 0.007	1.3 ±	0.2
Height (cm)	31 ± 0.4	5.3	<0.0001
Survival percent	88 ± 0.2	361	<0.0001

In 2007, in Wayu kebele, 40 purposely selected farmers were provided with *E. globulus* seedling to plant in their plot of land (wubalem, et al., 2010). This had a paramount importance to rehabilitate the natural landscape of the degraded surroundings and to generate income from the established small scale eucalyptus plantation. There is a clear difference on the feature of the land before and after the intervention (Figure 1).

Figure 2*: P*hotos before and after intervention at wayu (2007 and 2012).
Despite the degradation of Wayu physical environment, this report revealed that the communities livelihood was improved and their land was rehabilitated with community strong willingness and researchers commitment to assist these resources degradation affected people of the study area.

Figure 3: Eucalyptus role in improving community livelihood (case of Wayu kebele)

The result of the survey revealed that the sampled households who had planted Eucalypt on small plot of land (~1.4 ha) has earned on average 150,000 ETB in five years, first rotation, eucalypt plantation (Figure 2). Eucalyptus plantations have the potential of improving household welfare (Holden et al., 2003) & ecological restoration of degraded lands (Zhou et al., 2001). Similarly, Jagar and Pender (2003) emphasized that farmers' rate of return from eucalyptus is more than 20%. Study conducted in Ethiopia indicates that average rate of return to land from *E. globulus* woodlot is 1.5 times greater than the sole wheat cropping (Selamyehun, 2004). Kaleb and Wubalem (2010) also reported that income from eucalypt product sale in Anget Mewugia Kebele by far surpasses income from other income sources including sale from crop and livestock. Some of the farmers sold standing eucalypt plantation and others assorted into poles and logs for construction purpose. One of our farmers mentioned that he had earned cash that he had/will never ever earn in his life time. According to the respondents, the livelihood of such farmers has been improving due to eucalypt plantation. Such farmers are attaining food self-sufficiency through using *Eucalyptusglobulus* plantation grown on a small plot of land. This money is huge money to be used to construct house, feed the family, buy agricultural inputs, send their children to school, run some petty trade like shop, and even deposit some money in bank.

Moreover, there is a great benefit in restoring *Juniperusprocera* natural stands and grass growth that was revealed by the study and concurred with the perception of local community in the project area.

Conclusion and Recommendations

The study indicated that in Anget Mewugia farmers' managed *E. globulus* growth performance in very promising despite the high degradation intensity that has affected the landscape over century. The farmers who have participated in small scale eucalypt woodlot development have been earning thousands of birr. This is a supplement to various wood products that the farmers are getting from eucalypt. Small holder farmers are extracting poles, fuel, and construction wood for furniture/farm implement making, etc. It is possible to conclude that in such degraded areas like North shoa there is an opportunity to get best out of planting eucalypt and other well adapted indigenous tree species that could rehabilitate the sites, boost site productivity and generate livelihood benefits. All this leads towards alleviating poverty and attain food self-sufficiency and mitigate climate change.

Based on this preliminary result, we would like to recommend expansion of eucalyptus planting in space and time with the participation of more farming community back up by an impact assessment on landscape and livelihood of the community. Documenting farmers' experience in eucalypt management and other learned lessons is very important to be promoted to other areas where eucalyptus planting is slow-moving and/or not practiced with smallholder farmers.
Detail opportunity cost of smallholder farmers' eucalyptus planting in comparison with other livelihood strategy per unit area is the other potential research idea for Anget Mewugia kebele and similar eucalypt growing areas. Assessing a change in any livelihood condition of eucalypt growers and non-growers is an important future direction for Anget Mewugia kebele..

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CHARACTERIZATION OF TRADITIONAL AGROFORESTRY PRACTICES AND SOCIOECONOMIC FACTORS AFFECTING THEIR ADOPTION IN DIFFERENT AGROECOLOGICIES OF SOUTHERN TIGRAY, ETHIOPIA

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Abstract

This study was carried out in 2013/14 in southern zone of Tigray with the aim of identifying and characterizing traditional agro forestry practices in the region. It was conducted to understand the existing knowledge of farm households on the management of trees under different practices in separated agro ecologies. Surveys were conductedonsystematically and randomly selected147 farm households at three agro ecologies of the study area. The finding indicated that overwhelming number of farmers (46.3 %) in the study area carry out home garden agroforestry practice (AFP). The second largely exercised agroforestry practice by (25.9 %) of the households' wasfarm live fence with trees; whereas the list practiced one account for (15 %) farmers was parkland agroforestry. Most dominant domesticated and wild fruit tree species observedin the home garden agroforestry were *Caricapapaya, Malusdomestica, Persea americana and Mangifera indica, Ziziphusspina-christi, Balanites aegyptiaca*. Additionally, other cash crops like *Coffee arabica and Catha edulis were also available*. From the total respondents 68% own thesefruit trees intheir home gardens. The research identified dominant tree componentsin the agri-silviculture agroforestry system. The first most dominantcomponents encompass fruit tree + cereal crops + *Ziziphus spina-christi+ Balanites aegyptiaca* and/or Acacia species. The second components were dominated by cash crops like *Coffee arabica*/*Catha edulies*+ fruit trees + *Cordiaafricana + Balanitesaegyptiaca and/or acacia species as a boundary and live fence*while the third components were irrigated fruit trees + vegetables within a boundary of *Sesbaniasesban* and other acacia species. Most farmers (90.16 %) residing on the highlands pointed out shortage of farmlands as the main constraint and hindering factor for agroforestry practicing. About 34.44 % of farmers use leaves of*Cordiaafricana*, *Balanitesaegyptiaca,* pods of *Acacia*species and crop residue as the main source of animal fodder. The socio-economic survey indicated that most of the sample households (86.4 %) recognize the importance of multipurpose trees for soil fertility enhancement, controlling run off, micro climate amelioration, environmental protection and dry season animal fodder. Hence, consideration of the way to improve their knowledge on traditional farming system would intensify their potentials to control their environmental and climate related problems. To conclude, presence of different tree - crop components and higher number of trees on farmlands shows that the agri-horti-silviculture agro forestry system is more resilient to the vagaries of the harsh climate with multiple advantage as well as diversified products from a piece of land. This, in turn, is insurance in times of annual crop failure and enhances the livelihood of farmers.

Keywords: Agro forestry, Indigenous Knowledge, Home garden, Fruit Trees, Cash Crops

Introduction

Severe land degradation affects the livelihood of many farmers in the highlands and lowlands of Tigray, northern Ethiopia. Agro forestry is a kind of land use system that has been practiced since long in many parts of the world. Agroforestry is a dynamic, ecologically based natural resource management system that, through the integration of trees/woody perennials in farm and rangelands, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (ICRAF, 2006). This land use system has good potential for enhancing farm income diversification and rehabilitating degraded lands. In addition, agroforestry has the potential to reduce poverty and can efficiently be used in poverty reduction strategies of the tropical East African countries (Basambaet al*.,* 2016).

As a land use system that combines the three main components i.e. food crop, livestock and forest products, preferably on the same piece of land on a sustained yield basis, agro forestry offers potential for enhancing farm production and household farm income. At the same time, it reduces the conflicts between arable farming, livestock keeping, and forestry interests, especially in the high-potential areas that are facing intense population pressure (Dhakalet al., 2012). A variety of agroforestry technologies is finding enormous application in the East and Central African region (Basambaet al., 2016). Based on agro-ecological diversity, different localities in Ethiopia undertake different agroforestry systems and practices. These contribute considerably to the improvements of household economy and food security (Thapa and Weber, 1994).

In Ethiopia, there are location specific agroforestry practices such as home garden, parkland and cash crop based alley cropping agroforestry practice, and woodlots at the edge of crop fields. Furthermore, there are also fruit tree based agroforestry practices (Badege Bishaw and Abdu Abduilkadir, 2003). In the dry lands of Northern Ethiopia, there are number of indigenous agroforestry systems involving agrisilvicultural, silvo-pastoral and agro-silvo-pastoral systems which have trees, shrubs, agricultural crops (mainly cereals), and livestock as components in a mixed pattern (Kindeya Gebrhiwet, 2004).

Southern Tigray is characterized by high population pressure and its consequence of scarcity of arable and grazing land and also high moisture stress area. High pressure on land is progressively narrowing farmers' agro economic decisions and forcing part of them to encroach and cultivate previously unused marginal or pastoral grazing lowland areas. In response to this pressure, efforts have been made by the farmers for introducing high value tree based farming systems. Even if agro forestry is contributing a lot for the farmers' livelihood and environmental protection by reducing soil erosion and mitigating climate change, no research is conducted which acknowledges the income diversification role of agro forestry practices in the area.

Limited agro forestry research and development efforts have been undertaken by different institutions to address the aforementioned challenges. For instance, screening research carried out by (Abebe et al., 2001; Kindu et al., 2006): agroforestry technology evaluation by (Abebe and Diriba, 2003; Abebe et al., 2004) and traditional agroforestry practices by Tesfaye, 2005; Berhane and Agajie, 2006; Berhane et al., 2008; and few others. However, all of the efforts had

inadequate agro ecological coverage, address specific problems, and lack interdisciplinary research approach and lack adequate participation of stakeholders.

Therefore, this research is intended to investigate the socioeconomic factors that affect agro forestry practices, and farm income diversification role of this land use system in Southern Tigray, Ethiopia.

Material and Methods

Descriptions of the study area

The study was carried out in three woreda's of Southern Tigray Ethiopia. The study area lies between Latitude $39^o10'$E to 40° $02'$ $34.08''$ E and Longitude $12^o53'$ $29.76''$N to 12° $15'$ $2.88''$N.The minimum mean annual temperature of the study area is 12^oC at offal and Endamohni woredas and 18^oC at raya azebo woreda.While the mean annual rainfall ranges between 350mm at the low land of Raya Azebo and 1000mm at the highland and mid land of Endamohoni and Ofla woreda's. The major Agricultural activity in the area is mixed farming system. The dominant food crops grown in the study areas are maize, sorghum, wheat, Teff, pea, barley and cheek pea. While high value tree crops such as *Mangifera indica, Percea americana, Papaya crack, Psidium guajava (Guava)* in the lowland and *Malus domestica* (Apple) in the highlands of Endamohoni and offal woreda's are produced in large quantities. Major livestock reared in the zone are cattle, sheep, goats and equines such as donkey, horse, mule and camel.
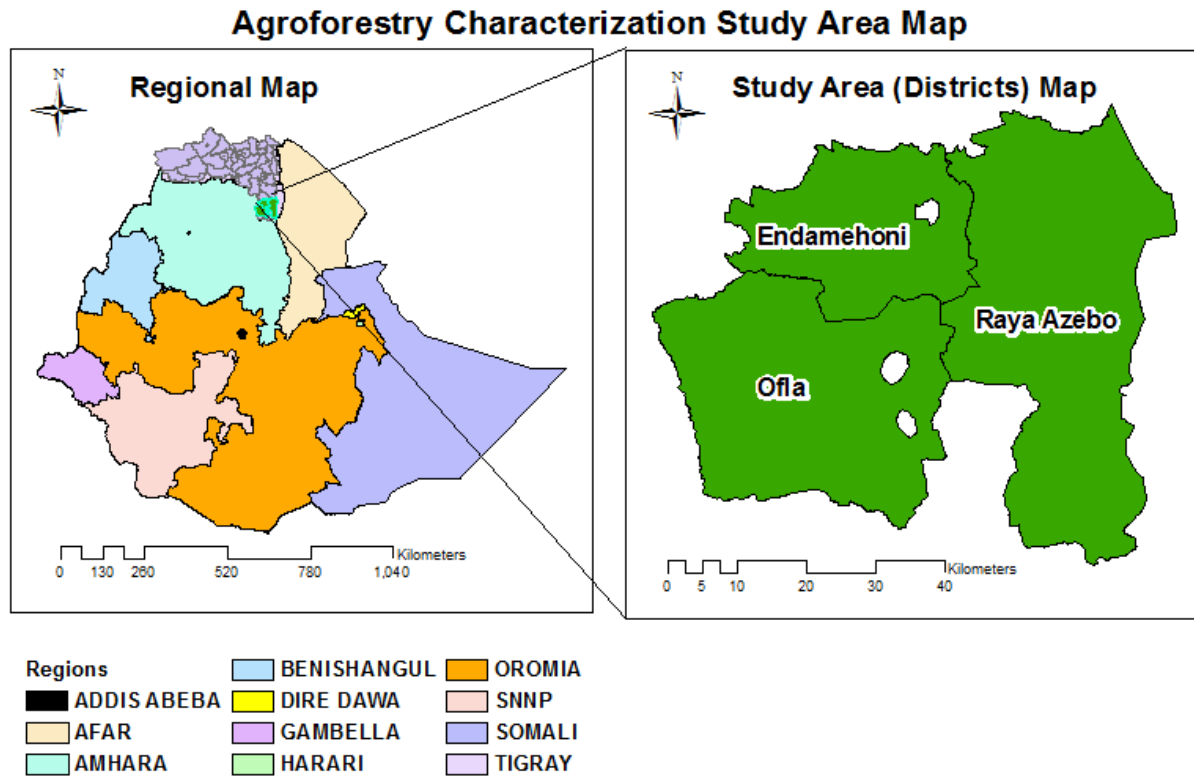
Figure 1: Study area map

Methods

Indigenous agroforestry practices in the low, mid and highlands of southern Tigray were studied according to the following approaches. Secondary information was collected from reports, maps, censuses, thesis and other publications to have an overall picture of the agro ecologies. The specific sites for the study were identified in collaboration with a multidisciplinary research team, local people and administrative bodies.

Reconnaissance and diagnostic surveys were undertaken. A total of 147 farm households were selected systematically from the three agro ecologies of the study area. The households were selected randomly from the long listed farmers of the three districts of southern Tigray zone.

Informal surveys were conducted to gather qualitative information about traditional agro forestry practices and other related activities. Checklists were developed for the informal survey activities. Major issues that were included in the checklist were niches for the practices, species composition, species arrangement and management, components in the different practices (livestock, crop, vegetation, soils), benefits (social, economic, cultural, and environmental), laws and bylaws associated to the practices, resources management and conservation systems, collective actions, complementarities between/among practices, innovations,

changes/modifications of the components in the practices over time, opportunities and constraints. A formal survey was carried out using structured questionnaire to quantify and verify the informal survey findings. The formal survey involved direct field observation of the traditional agroforestry practices, discussions with individual and group interviews, and key-informant interviews, resource mapping, preference ranking and other participatory rural appraisal techniques.

Model selection

Logit regression analysis was carried out to analyse the factors influencing the adoption of agroforestry practices in the study area based on the prepared questionnaire. The questionnaire was designed to find out views concerning factors influencing the adoption of agro-forestry among smallholder farmersTherefore, a logit model as described by Gujarati (1995) wasused in this study to determine the relationship between traditional agro forestry and factors affecting the practicing in the study area.

Data analysis

 Data were entered to spread sheets and analysed using SPSS version 20 and Stata 12 software for various parametric and non-parametric tests. The data were also analyzed using descriptive statistics that include frequency distributions, means and percentages. Chi-square ($\chi2$) was used to test the presence of associations in the variables obtained. Student t-test was used to verify the presence of significant differences between respondents' gender, proportion of those aware of agro forestry practices and those who are not aware. The logit model by Gujarati (1995) was used to analyze the agro forestry adopters and non-adopters.

Results and Discussion

The results of this study are presented in two sections; the first section covers the results on characterizations and identification of traditional agro forestry practices within the three different agro ecologies of southern Tigray. While the second results cover the socioeconomic characteristics and factors that determine the adoption of agro forestry practices.

Characterization of agro forestry practices (AFP) in southern Tigray, Ethiopia

The major agro forestry practices involved in the study area were homeGardena followed by live fence AFP(Figure 2 and Table 1).Homestead AFP had higher value with significant difference (p < 0.05) between highland and midland agro ecology than that of the lowland in the study area. This indicates that homestead AFP is preferred to that of the other agro forestry practices on study area by the respondent farmers.
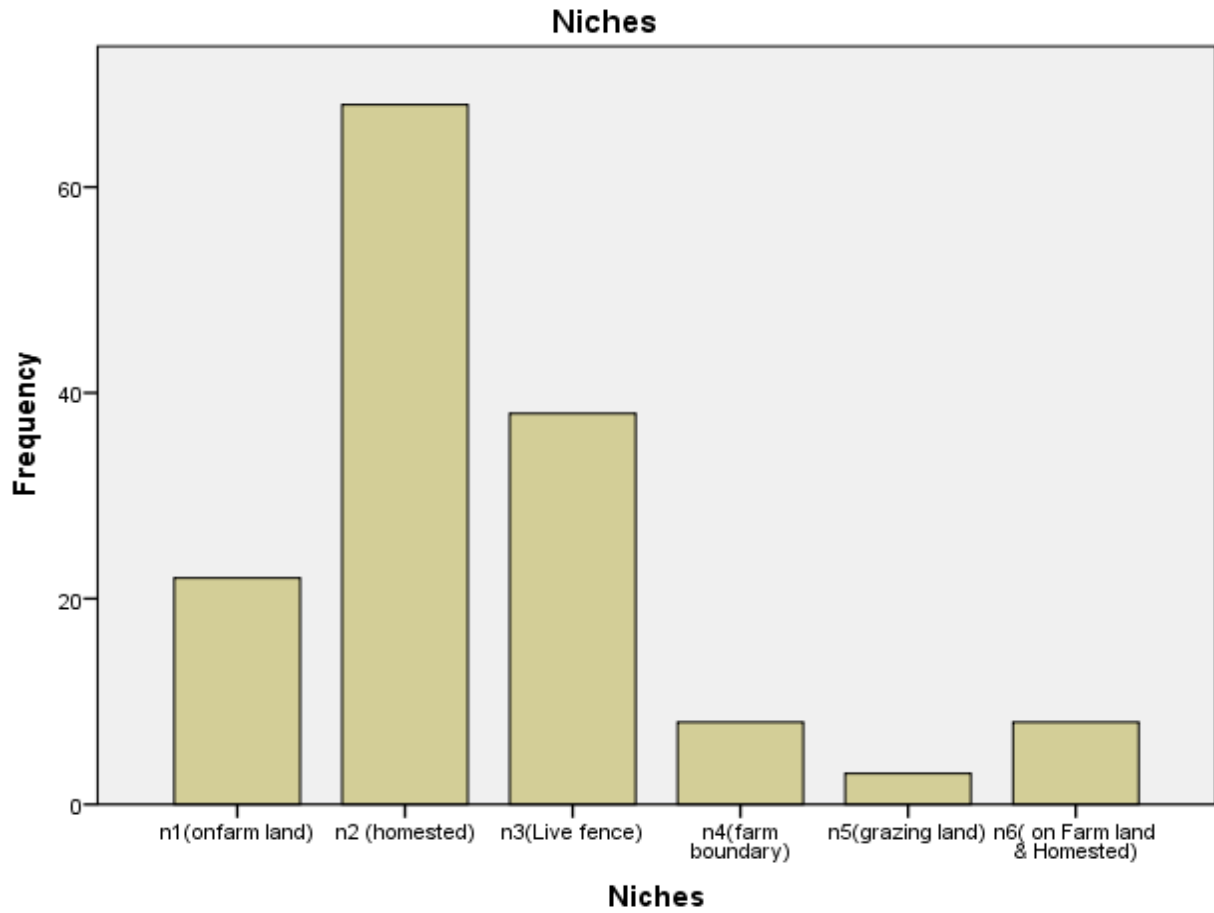
Figure 2: Characterization of niches of agroforestry practices by frequency in southern Tigray
n6 is inappropriate to combine (farm land + homestead), these are distinct practices.

Table 2:Agro ecology and agro forestry practices niches

Agro ecology* Niches		Niches						Total
		on farm land	homestead	Live fence	farm boundary	grazing land	on Farm land & Homestead	
Agro ecology	highland (> 2300)	5[a]	27[a]	11[a]	1[a]	3[a]	1[a]	48
	Midland (1500-2300)	6[a]	29[a]	17[a]	4[a]	0[a]	3[a]	59
	low land (<1500)	11[a]	12[b]	10[a, b]	3[a, b]	0[a, b]	4[a, b]	40
	Total	**22**	**68**	**38**	**8**	**3**	**8**	**147**

Each superscript letter denotes a subset of Niches categories whose column proportions do not differ significantly from each other at the 0.05 level.

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19.793[a]	10	**0.031**
N of Valid Cases	147		

- **Home gardens AFP**: 46.3% of the total respondent practiced home garden agroforestry. Home gardens are characterized by high species diversity and usually 3-4 vertical canopy strata using MPTs, fruit trees, vegetables, root crops, and tuber crops.

Description of agroforestry practices and the common wild fruit trees found in Southern Tigray

- *Ziziphus spina-christi, Balanites aegyptiaca,Tamarindus indica, Carissa edulis, Cordia africana, Diospyro smespiliformis, Dovyalis abyssinica, Vernonia amygdalina* Del., *Ficus sur, Ficus vasta, Xmenia americana, Syzygium guineense, Grewia ferruginea, Grewia villosa, Mimusops kummel, Rhus natalensis, Opuntia ficus-indica, Prunus persica*

- **Living fences:**constitute 25.9%lines of trees or shrubs planted in close spacing's on farm boundaries or on the borders of agricultural fields. Tree species used as live fences are *Acacia tortilis, A. seyal, A. sieberiana, A. etbaica, A., abyssinica*, *Ziziphus spina-christi, Balanites aegyptiaca, Opuntia ficus-indica* (L.) Mill.

- **Scattered trees in croplands (Parkland AFP):** 15% Common tree species are *Acacia tortilis, Acacia abyssinica, Cordia africana*, *Ziziphus spina-christi*, *Balanites aegyptiaca.*The crops grown in association with Parkland AFP are, Teff, sorghum, maize, wheat, barley and pulses such as chick pea, bean, lentil and.

- **Trees on rangelands – silvopastoral systems**: The trees are, *Acacia seyal, A. tortilis, A. sieberiana, A. abyssinica, A. etbaica, A. bussei, Balanitesaegyptiaca, Ziziphusspina-christi.*

- **Boundary trees for soil conservation**: Trees are planted for soil conservation works (grass strips, bunds, risers and terraces) for stabilizing the structure and making productive use of the land they occupy. E.g. *Balanites aegyptiaca, Ziziphus spina-christi Eucalyptus camaldulensis*, *E. globulus*, *Grevillea robusta*and *Acacia* species.

- **Woodlots:** Woodlots are established on underutilized or degraded lands for the purpose of supplying fuel wood or fodder with trees such as *Eucalyptus camaldulensis*, *E. globulus*, *Grevillea robusta*, *Faidherbia albida, and Acacia* species.

Agroecology difference and Agroforestry system (AFS) in southern Tigray

From the sampled households of the study area, Agro-silvo-pastoral system (ASPS) was significantly differentat (p < 0.05) than that of Agrisilviculture andSilvopastoral with a low land than that of the high land and mid land agro-ecology in study areatable 1. This indicates that Agro-silvo-pastoral system was betterpracticed by the respondent farmers than that of other types of agroforestrysystem in the lowland areas. The major agroforestry systems practiced in the study area wereagrisilviculture 59.18 % followed by agrosilvopasture 28.57% and silvopastoral 12.25% systems (table 2, 3 and 4) and shows agrisilviculture type of agroforestry system was more adopted by the respondent farmers.

Agrisilviculture was dominantly practiced by the midland and highland farmers and it was least practiced by the lowland farmerswhile the Silvopastoral system was more practiced by the midland farmers followed by the lowland farmers. Whereas agrosilvopasture wasmuch more practiced by the lowland farmers followed by the midland and highland farmers respectively. This is expected practice as the lowland farmers have more animal population than the midland and highland farmers.

Table 3: Agroecology difference and Agroforestry system (AFS) in southern Tigray

		Agroforestry system			Total
		Agrisilviculture	Silvopastoral	Agrosilvopasture	
Agroecology	high land(>2300)	35^a	4^a	9^a	48
	Midland (1500-2300)	36^a	8^a	15^a	59
	low land (<1500)	16^a	6$^{a,\,b}$	18^b	40
Total		**87**	**18**	**42**	**147**

Each superscript letter denotes a subset of AFsystem categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.585^a	4	0.032
N of Valid Cases	147		

Table 4: Frequency of Agroforestry system (AFS) and Agroecology difference in southern Tigray

agroforestry system * Agroecology		Agroforestry System			Total
		Agrisilviculture (59.18)	Silvopastoral (12.25%)	Agrosilvopasture(28.57%)	
Agroecology	high land(>2300)	35	4	9	48
	Midland (1500-2300)	36	8	15	59
	low land (<1500)	16	6	18	40
Total		**87**	**18**	**42**	**147**

Table 5: Agroecology and agroforestry systems with their frequency distribution

Agro ecology * AF system Cross tabulation					
		Agroforestry system			
Agroecology* Agroforestry system		**Agrisilviculture**	**Silvopastoral**	**Agrosilvopasture**	**Total**
Agro ecology					
high land(>2300)	Count	35^a	4^a	9^a	48
	% within Agroecology	72.9%	8.3%	18.8%	100.0%
	% within AFS	40.2%	22.2%	21.4%	32.7%
Midland (1500-2300)	Count	36^a	8^a	15^a	59
	% within Agroecology	61.0%	13.6%	25.4%	100.0%
	% within AFS	41.4%	44.4%	35.7%	40.1%
low land (<1500)	Count	16^a	6$^{a, b}$	18^b	40
	% within Agroecology	40.0%	15.0%	45.0%	100.0%
	% within AFS	18.4%	33.3%	42.9%	27.2%
Total	Count	87	18	42	147
	% within Agroecology	59.2%	12.2%	28.6%	100.0%
	% within AFS	100.0%	100.0%	100.0%	100.0%
	% of Total	59.2%	12.2%	28.6%	100.0%

Each superscript letter denotes a subset of AF system categories whose column proportions do not differ significantly from each other at the .05 level.

Overall there were five agroforestry practices identified in the study areas. These are on farm, home garden, live fence, farm boundary, grazing land and agroforestry practices. In the highlands, all the practices were found while in the lowland and midland the grazing land were lacking. Among the identified practices, homestead agroforestry is highly practiced across all agroecologies followed by live fence in the highland and midland and on farm agroforestry practice in the lowland. The reason why home garden practice was dominant practice is that farmers can diversify their income and minimize risk of crop failure. In addition, the farmers allocate the small parcel of land for practicing home garden agroforestry to minimize the shortage of land they face.
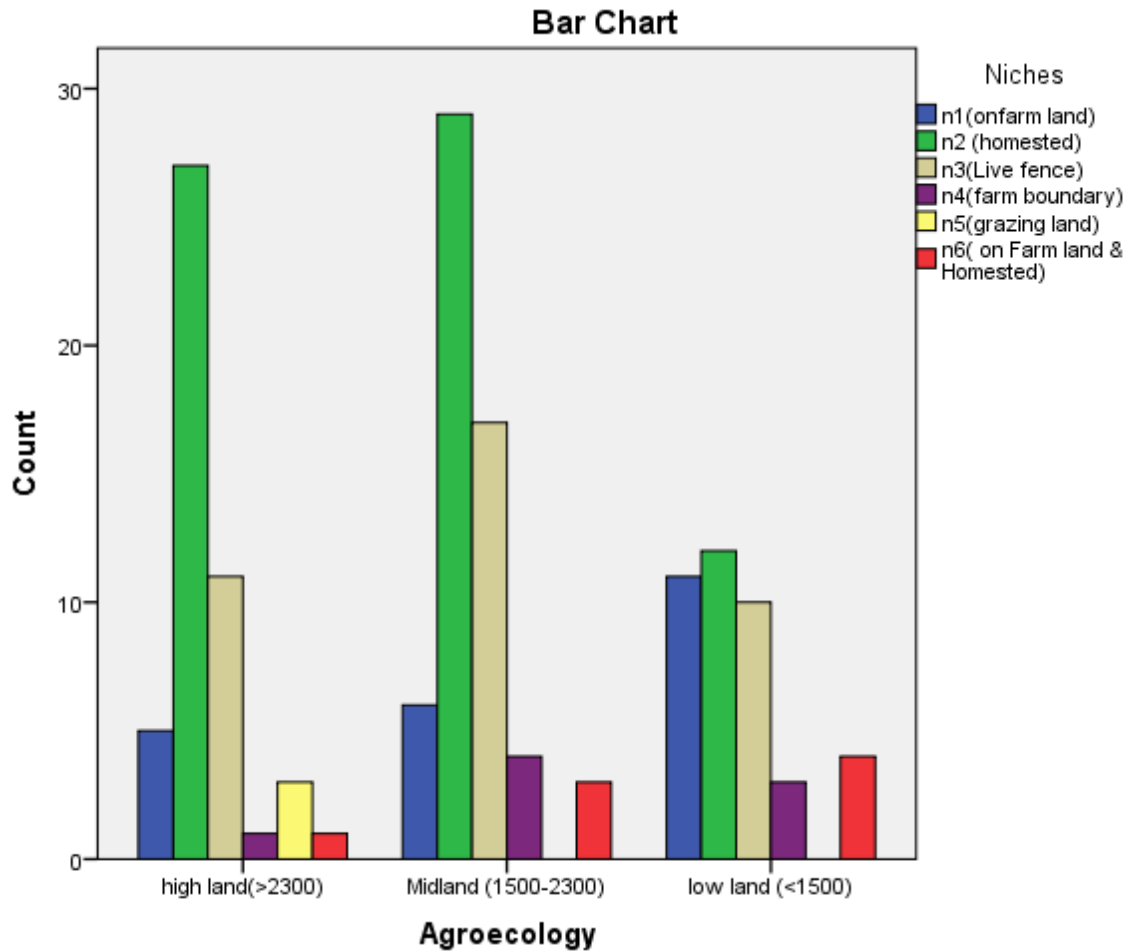
Figure 3: Count of Agro forestry practices at different Agro ecology
This part presents the major findings of the study with analyses and interpretation using both descriptive and econometric results.

Descriptive analysis

Descriptive statistics was run to observe the distribution of the independent variables. The factors socio-economic and institutional characteristics of the respondents such as age, gender, family size, level of education, land holding, farming experience, livestock holding etc of agro forestry users and non- users were analysed. The descriptive analysis employed the tools such as mean, standard deviation, percentage, and frequency distribution. In addition, t-test and chi-square statistics were employed with respect to some explanatory variables.

Household characteristics

Age of the household head: Age is one of the demographic characteristics that is useful to describe households and provide indication about the age structure of the sample and the population as a whole.The age of the sampled household heads had a range from 20 to 71 years.

The average age of the sampled household heads was 43.56 years with standard deviation of 10.392. As indicated in Table 1, agroforestry user farmers had an average age of 43.62 years and standard deviation of 10.387, while non-users had an average age of 43.20 years and standard deviation of 10.685, respectively.

An independent-sample t-test was conducted to test if there is significant difference in the mean age of agroforestry users and non- users. The result of t-test showed that there **was not** statistically significant mean age difference between agroforestry users and non-users (t= 0.165, P= 0.870).

Table 6: Descriptive Statistics of age of the household heads

Variable	Users (N = 127)		Non-users (N =20)		Total(N = 147)		T-value	P-value
	Mean	SD	Mean	SD	Mean	SD		
Age	43.62	10.387	43.20	10.685	43.56	10.392	0.165	0.870

Family Size of the household head: Family size in this study is considered as the number of individuals who resides in the household. Most of the time, large family size was assumed as an indicator of labor availability in the family to use integrated agroforestry practice. The average family size of the sample farm households was 5.80 with minimum of 1 and maximum of 10 persons. Agro forestry users had an average family size of 5.65 with standard deviation of 1.949 while non-users had 6.70 with standard deviation of 1.658.

An independent sample t-test showed that the mean difference in family sizes of the agro forestry users and non-users was statistically significant (t = 2.273, P= 0.024).

Variable	Users (N = 127)		Non-users (N =20)		Total (N = 147)		T-value	P-value
	Mean	SD	Mean	SD	Mean	SD		
Family size	5.65	1.949	6.70	1.658	5.8	1.949	2.273	0.024[*]

Table 7: Descriptive Statistics of family size of the household heads
*Significant at 5% level

Sex of the household heads: Sample households were composed of both male and female household heads. From the total **147** sample household heads, about **73.5 %** of them were male and the remaining **26.5 %** were female. The proportion of male-headed households was **87 %** for agroforestry users and **13 %** for non-users. The result revealed that the percent of male headed households of agroforestry users were higher than that of female headed households. In order to see the association between gender and adoption, chi-square test was conducted and showed insignificant relationship between male-headed and female-headed households with respect to traditional agroforestry using.

Educational status of sample household heads: Education is very important for the farmers to understand and interpret the agricultural information coming to them from any direction. A better educated farmer can easily understand and interpret the information transferred to them by

development agents and any other bodies. Of the total 147 respondents, 46.3 % were illiterate, 20.4 % table to read &write, 21.1 % above grade 4, and 12.2 % of the respondentswere above 5 grade respectively.

Table 8: Descriptive Statistics of educational status of the household heads

Educational Status	Frequency	Percent
Illiterate	68	46.3
Read &write	30	20.4
Grade 4	31	21.1
>5	18	12.2
Total	**147**	**100.0**

Marital statuses of the house hold heads: With regard to marital status, from the total sample respondents31.3% was single while the rest 68.7 % were married households. The proportion of married respondents was much larger than the remaining marriage categories.

Table 9: Distribution of sampled household heads by marital status

Maritalstatus	Frequency	Percent
Single	46	31.3
Married	101	68.7
Total	**147**	**100.0**

Agro ecology of the household heads residence: of the total respondents most were living in mid-altitude agro-ecologies. In contrast, 27.2 % of them were living in lowland areas.

Table 10: Agro ecology of the household heads of the study sites

Agro ecology	Frequency	Percent
high land(>2300)	48	32.7
Midland (1500-2300)	59	40.1
low land (<1500)	40	27.2
Total	**147**	**100.0**

Land holding: Land is the main asset of farmers in the study areas. Land size was thought to be a good proxy indicator of wealth which is important resource for any economic activities in the rural and agricultural sector. Hence, the availability of enough land per household is assumed as a potential for agro forestry using and investment for further economic progress. According to the sample survey data, only **22** farmers own more than 1 ha of land while the rest **125** farmers owns below one hectare.

Table 11: Land holding size of the respondents

Variable		Frequency	Percent
Land holding	<0.5ha	78	53.1
	0.5-1ha	47	32.0
	>1	22	15.0
	Total	147	100.0

Agro forestry adopters and non-adopters with gender
Of the total respondents, 86.40% were adopters. Among the adopters, 74.02% and 25.98% of them were male and female headed households respectively.

Table 12: Agro forestry adopters and non-adopters with gender

Sex	TAFP		Total
	Adopters	**Non adopters**	
Male	94	14	108
Female	33	6	39
Total	127	20	147

LOGIT MODEL ANALYSIS
Table 13: Logit model of the respondents

Variable	Coef.	Odds ratio	St.E	Sig.	Z
Age	-0.003	0.024	0.019	0.892	0.997
Sex	1.142	0.778	2.151	**0.022***	3.132
Marital	0.995	0.779	1.634	0.201	2.705
Family size	0.367	0.148	6.185	**0.013***	1.444
Educational level	0.036	0.246	0.021	0.098	1.037
landholding	-0.214	0.367	0.338	**0.05***	0.808
Constant	**-6.877**	**2.912**	**5.576**	**0.018**	**0.001**

* indicates that significant difference at P<0.05

According to the logit model analysis, among the tested variablessex, family sizeand land holding were significant different to one another at (P<0.5) while marital status, educational level and age were not significant (P>0.5). The variables sex and family size can play a decisive role in the adoption of agroforestry practices. For instancethose households having high family size are willing to adopt as compared to small family size as they can get information from different sources. High family size means high availability of labour and small family size means small availability of labour (Jamala et al.,2013). Moreover, there could be a variation in the adoption of agro forestry practices due to sex. Home garden agroforestry practice could be more liked by the female headed household while other agroforestry practice which can be done with the help of irrigation water could be preferred by the male headed household. And family size which refers to the availability of physical labor is also very important factor that affects agro forestry practice adoption. The adoption of agroforestry enhances the production of cereal crops, incomes of the house hold and provides fire wood and fodder for their livestock's. This finding is in line with the finding of (Akinnifesi et al., 2008) who found a variation in adoption of agro forestry practices due to sex.Similar to this finding Kumar et al.(2012) also found that the adoption of agroforestry increases crop production, income, savings, improves food supply and provides firewood and fodder tree based agroforestry plans offer a tangible opportunity for rural development and enrichment through promoting agro industries and improves local economies by creating means of employment previously unavailable.

However they are not significant in this study, the other factors which could have a significant influence on the adoption of agroforestry practice are marital status, educational level and age of the respondent but in this study they are non-significant.

Table 14: The adoption of agroforestry in relation to sex of the household

Sex	Niches						Total
	on farm land	homestead	Live fence	Farm boundary	grazing land	on Farm land &Homestead	
Male	15	51	29	5	2	6	108
Female	7	17	9	3	1	2	39
Total		**68**	**38**	**8**	**3**	**8**	**147**

Priority Fruit and Fodder Species of North Ethiopia

There are different plant species that are selected by farmers for different purpose (Table 14). For instance, *Opuntia ficus-indica, Ziziphus spina-christi, Balanites aegyptiaca etc* are preferable species as wild edible fruit trees while *Faidherbia albida, Acacia nilotica and Becium grandiflorum* asfodder trees.

Table 15: Species ranking for fruit and fodder in the study area

No	Priority Fruit Species	Priority Fodder Species
1	*Opuntiaficus-indica*	*Faidherbiaalbida*(*Acacia albida*)
2	*Ziziphusspina-christi*	*Acacia nilotica*
3	*Mimusops kummel*	*Ziziphusspina-christi*
4	*Prunuspersica*	*Beciumgrandiflorum*
5	*Balanitesaegyptiaca*	*Acacia seyal*
6	*Ximeniaamericana*	*Grewiabicolor*
7	*Cordiaafricana*	*Balanitesaegyptiaca*

In the study area there were different factors that affect tree planting and retention (Figure 4). The factors include lack of water, shortage of land, lowincome, slow growth and lack of seedlings for fruit trees in their respective order. However, there is good awareness on the importance of agroforestry practices, these factors and other related problems are hindrances for the adoption of agroforestry practice in the study areas.

Figure 4: Factors that affect tree planting by farmers in drylands of south Tigray, North Ethiopia

Conclusion and Recommendations

- Farmers of the study area practice Agro-silvo-pastoral system, Agrisilviculture and Silvopastoral type of agroforestry system
- Home garden, scattered trees on farmland, live fence, farm boundary tree planting and trees on pastureland werethe types of agroforestry practices found in the area.
- Home garden is the dominant agroforestry across all agroecologies.
- There are different fruit and fodder species with potential for integration into agroforestry practices.
- Moisture stress, land holding, low income, slow growth of out planted seedlings and lack of fruit tree seedlings affect the agroforestry practices
- Sex and family size affect agroforestry practices adoption.
- Fruit and fodder trees are recommended to be incorporated with farming on pocket of land such as farm boundary and hedgerow in cropland for nutritional and food security, improved animal production.
- Researches on nutritional value, propagation, and interaction of fruit and fodder tree species with annual crops and economic analysis of the individual agroforesty practices involving fruit and fodder species are most priority areas for drylands of North Ethiopia.

Acknowledgements

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EARLY SURVIVAL AND GROWTH PERFORMANCE OF TREES AND SHRUBS ON DEGRADED MIDLAND OF ETHIOPIA

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Abstract

Astudy was conducted to evaluate the survival and growth performance of trees and shrubs on a severely degraded land of Fotololo, West Shoa, Ethiopia. A total of sixteen treatments (i.e., six exotic species, five indigenous species and five mixed plots of both origins) were arranged in randomized complete block design with three replications. Survival rate, height and root collar diameter were assessedseven times atsix monthsintervals. The survival percentage of all screened species decreased considerably over the first two sampling periods but remained largely constant after 18 months. The lowest survival percentage among indigenous species was recorded by *Albizia gummifera* (4 %) and the highest survival was recorded by *Olea europaea ssp cuspidata* (51 %). Among the exotic species, *Sesbania sesban, Acacia saligna* and *Eucalyptus camaldulensis* showed the highest survival percentage. Similarly, most exotic species flourished and grew more rapidly than the indigenous ones. Thedry biomass of undergrowth (grass and herbs) harvested per m^2 ranged from 448 (under *O. europaea*) to 952 g (under *S. sesban*), with a mean value of 698 g. Our results indicatethat *S. sesban* and *A. saligna*can be chosen as pioneer species to rehabilitate degraded lands at Fotololo and other areas with similar agroecological conditions as these speciesaccomulated high carbon stockover a short periodand allowed the growth of goodundergrowth biomass.

Keywords: degraded land, exotic species, growth performance, indigenous species, survival

Introduction

Land degradation is a serious environmental problem in the central highlands of Ethiopia (Berry, 2003); and its cause is attributed mainly to inappropriate farming practices and unsustainable utilization of naturalresources. The Ethiopian highlands cover 44% of the nation's total landmass, and are generally characterized by the presence of high human and livestock population. Natural forests in the areahave for long been giving enormous benefits to millions of its inhabitants as source of fuel wood, food, healthcare and income. However, theforest lands are said to have dwindled in the past millennia as a result of anthropogenic practices undertaken to address high demands for food and forest products.Additionally, decline in soil fertility (Amare

et al., 2006) together with climate changehaveaggravatedthe rate of deforestation and land degradation in this area.

Severely degraded lands are characterized by low vegetation cover and diversity, nutrient deficient soils, reduced primary productivity, and poor water infiltration and storage capacity (Verma et al., 1999). Rehabilitation of degraded lands using appropriate measures is, therefore, essential to enhance land productivity, sustainable rural livelihoods, economic development, conservation of biodiversity, and other ecological services (Berg and Kellner, 2005). In this regard, trees and shrubs play a fundamental role in rehabilitating degraded lands. Afforestation/reforestation of degraded areas with suitable trees and shrubs does not only provide woody and non-woody products but also improves the soil quality through improving the soil organic matter (SOM), biological N_2 fixation, recycling of nutrients, soil water infiltration and storage capacity, and soil biological properties (Young,1997). However, selecting appropriate tree species is a more complex venture as it requires detail information on plant, soil and hydrological parameters; compatibility of the species with undergrowth vegetation; and others (Franzel et al., 2008).

Planting of trees and shrubs on degraded lands is a common practice in Ethiopia. However, the survival and growth of both indigenous and exotic plant species have notbeen satisfactory, mainly, due to poor species and site matching (Mihretu et al., 2006) as most of these afforestation and reforestation initiatives were not informed by findings from well-designedspecies screening trials.Hence, an experiment was conducted to evaluate the survival and early growth performance of different exotic and indigenous trees and shrubsspecies on severely degraded midland of Fotololo, West Shoa, Ethiopia.

Material and Methods

Description of the study area

The study was conducted at Fotololo site, which is found in the Tokakotaye district, West Shoa, Ethiopia. Geographically, the site is located at 9°11′N and 38°20′E with an elevation of 2100 m.a.s.l.The agroclimatic zone of Tokakotaye is tepid to cool humid plateau (H2-6); and is favourable for the growth of many mid- and high-land plantspecies. The length of growing period of thearea varies from 241 to 300 days.Soils in the study district were predominantly Nitosol followed by Vertisol. Mixed farming is the dominant land use systemin the studied district. Indigenous trees and shrubs diversity around Fotololois relatively low where *Acacia abyssinica* and *Olea europaea ssp cuspidate* are grown sparsely on riverbanks, farm - and grazing-lands. Large scale tree plantations in mountainous areas of the district wereconstrained by poor soil fertility, shallow soil depth, poor water infiltration, as well as problems related to human/livestock interferences. Moreover, poor selection of species hadled tounsuccessful tree plantation in the district (Personal Communication, Office of Agriculture and Rural Development of Tokakutaye district (district OARD), 2010). In the late 1980's, for instance, a reforestation effortwasmade tocover Fotololosite with *Cupressuslusitanica*althoughsuch effort remained largely unsuccessful because of poor site and species matching.

Study site selection procedure

A group discussion was organized with the district-OARD andthe local communityrepresentativesto identify a highly degraded site for the study. The local community representative comprised of elders, key informants and local leaders. During site selection, different variables/indicators such as presence of gullies, soil depth, existed vegetation cover, slope, presence of big stones/rocks, aspect, and the existing land-use type, inhabitants, and otherswere considered.The Fotololo site was chosen following a direct visual assessment onthe ground. Thisis because the sitecontained many big gullies, poor plant cover including grasses and herbs, and shallow soil depth. The slope and aspect of Fotololosite werearound 20 % and facing to thewindward direction, respectively. Few termite mounds were also present on the site. Moreover, the site was abandoned by the local people a decade ago sincethey could not use itforagricultural purposes due to severe land degradation.

Seedling production

Seeds for seedling production were obtained from the Forestry Research Center. They were pre-treatedas needed and sown directly on polythene tubesfilled with mixed substrates of 4 (local soil): 2 (forest soil): 1 (sand). The source of forest soil was the pine plantation. The pine forest soil was chosen to enrich the substrate with an organic matter as well as to foster mycorrhizal association with the plant root.The size of the polythene tube was 15 cm (height)by 8 cm (diameter). Seedlings were raised at Guder Nursery Site where management practicessuch as watering, shading, weeding and hardening were practised. The selected seedlingsfor plantationfulfilled most criteria set for quality nursery plants (i.e., good root-to-shoot ratio, green and healthy leaves, strongand upright stem, and free from any visible disease symptom).

Experimental design and management

The survival and early growth performance of six exotic (*Acacia decurrens, A. saligna, Casuarinaequisetifolia, Gravilearobusta, Eucalyptus camaldulensis, Sesbaniasesban*), five endogenous species (*Albiziagummifera, Cordiaafricana, Millitiaferruginea, Juniperousprocera, Oleaeuropaeassp cuspidate*), and the mixed treatmentsof both origins (*A. decurrens+C. equsetifolia, S. sesban+O. Europaea ssp cuspidate, E. camaldulensis+J. procera, C. equisetifolia+M. ferruginea, S. sesban+C. africana*)were evaluated on the severely degraded site of Fotololo. Since the rate and speed of rehabilitation process are greatly affected by our choiceof species (Parrotta 1992), the above species were selected in consultation with the district-OARD and local community. The availability of seeds had also dictated our species selection.Sixteen treatments werethen laid out in randomized complete block design with three replications. Each plot had the area of 56.25 m^2 and accommodated 25 trees/shrubspeciesat spacing of 1.5m x 1.5m. Seedlingsin mixed plots were planted in alternative pattern where exotic species accounted for 13 of the 25 seedlings. Distances between the experimental plots and the blocks were 3m and 5m, respectively.

All species were planted during the main rainy season of the area. Each planting hole had a depth of about 50 cm. Since most of the top soilin the study site has beenwashed away throughwater erosion, soil brought from Guder town wasmixedduring refilling to facilitate good root growth at

the early stage of tree/shrub establishment.No biting-up operation was done after planting. In order to reduce high plant mortality, seedlings had received wateronce a week (i.e., between mid-January and mid-May). Our water source was the Guder River. Moreover, the experimental site was fenced with barbed wire to abate human and livestock interference.

Data sampling and laboratory analysis

Data on survival, height and root collar diameter were assessedseven times at six months intervals.At each sampling time, the total number of live trees/shrubs was counted per plot to determine survival percentage.The heights of all survived plants were also measured using a graduated stick. The vertical distance between the ground line and the apex of the tree/shrub was considered to be a plant height. Whenever we had multi-stemsplant, we took height measurement from the tallest stem. Root collar diameter was measured 1 cm above the ground using a digital calliper.

The undergrowth vegetation (i.e., grasses and herbs) biomass per $m^2$was assessed using a quadrat method. The quadrat had a 50 cm by 50 cm size. Sampling was taken 42 months after plant establishment (at the end of December) by throwing the quadrat randomly inside the plot ($n = 4$). This sampling method is often statistically valid and provides crucial information about the types and amount (number and weight) of undergrowth vegetation (Reuben, 2010).All undergrowth vegetation within a quadrant was severed at the ground surface using sickle. The respective dry biomass wasdeterminedafter oven drying the harvested fresh biomassat 70 °C for 96 h.

The initial soil characteristics were determined by collecting samples at depths of 0-10 cm, 10-30 cm and 30-50cm using augur. Samplings were taken from nine spots. Soil parameters such as pH (1 : 2.5 water), total N (%), organic C (%), available P (mg kg^{-1} dry soil) and exchangable K (mg kg^{-1} dry soil) were determined at the Soil and Plant Laboratory of Holetta Agricultural Research Centerfollowing the appropriate soil analyses procedures.

Calculations and statistical analyses

Mean survival percentage per plot was calculated as a percentage of total number of survived plantsat the time of sampling divided by 25.At each sampling period, the mean total plant height per plot was computed by dividing the summation of all live plant heights to the number of all measured trees/shrubs.The difference between two consecutive samplings was considered to be the correspondingmeanheight increment over six months. The same procedures were also adopted for the root collar diametermeasurements. The dry biomass (g/m^2) was computed as the summation of dry biomass of four quadrats by assuming there is uniformvegetation growth and distribution within a given plot.

The standard error of the mean (SE)for survival, plant height and root collar diameter was computed to estimate the variability between samplesusing R-Statistical Software (R statistical software, version 3.1.0, 2014) where the lower value of SE indicates more precise estimates of the population mean. Mathematically, SE = $s/\sqrt{n}$; where s=the standard deviation between means, n=the sample size. The coefficient of variations (CV, %) were calculated according

to s/x*100, where s represents the deviation between the treatment means and x is the overall mean value of the treatments.

Results and Discussion

Initial soil characteristics

Improper land use, steep topography and often torrential rainfall at Fotololosite have subsequently led to severe soil erosion and exposed nutrient-poor and unproductive alkaline soil, as indicated by low SOM content, poor N and P contents, andhigh pH (Table1). The soil pH in the experimental site ranged from 7.99 to 8.15; and the values seemed to increase with increasing soil depths.SOM is one of the most important variables used to describe soil fertility as it directly or indirectly influences the soil'sphysical, chemical and biological properties. Total organic C, which accounted for nearly 58 % of SOM, tended to decrease with soil depth. Fertilesoils have an average SOM content of 5 % (Wild, 1996) to indicate that the fertility status of theexperimental site is ratedas poor (i.e., the top 0-10 cm soil depth contained only 1.57 %). Similarly, the total N content in the 0-10, 10-30, and 30-50 cm was 0.06, 0.05 and 0.03 %, respectively (Table 1); and all soil N are rated as very low (Barbar, 1984). However, total Nmeasurement may not serve as a mere indicator of thereadily available N to plant root as majority of total N in the soil are existed in non-readily available state. According to Buruah and Barthakur (1997), nearly 95-99 % of total Nin the soil found in the organic form as compared to inorganic N form (ammonium and nitrates) that accounts only for 1-5 %.

Table 1: Some of the pre-planting soil characteristics at Fotololo

Soil depth (cm)	pH [a] (1:2.5 water)	Total N (%)	Organic Carbon (%)	P Olson (mg kg^{-1} dry soil)	Exch. K (mg kg^{-1} dry soil)
0-10	7.99±0.20	0.06±0.01	0.91±0.10	1.67±0.12	0.89±0.14
10-30	8.05±0.10	0.05±0.01	0.75±0.14	1.60±0.20	0.90±0.21
30-50	8.15±0.09	0.03±0.01	0.51±0.20	1.67±0.23	0.84±0.10

[a]mean ± standard deviation (*n=9*)

The available P, asdetermined by Olson method, ranged from 1.60 to 1.67 mg kg^{-1} dry soil (Table 1) with no trend with soil depth. The very low available P content in these soils can partly be explained by low SOM contentsasSOM is the main source of exchangeable Kin most soils (Buruah and Barthakur, 1997).Available K in the soil extract varied between 8.4 and 9.0 mg kg^{-1} dry soil.Our results showed an irregular distribution of available K with soil depth although available Kis generally influenced by soil pH, the amount and type of clay mineral, cation exchange capacity andK buffering capacity.

Survival percentage

The survival percentage showed greater difference between the screened species where the higher mortality was recordedmostly for indigenous species (Table 2). The overall survival

percentages of eleven tree/shrub species after 6, 12, 18,30 and 42 months were 71, 56, 46 42 and 41%, respectively, to indicate that survival percentages decreased considerably over the first two sampling periods but remained constant after 18 months. Existing evidence (e.g., Mihretu et al., 2006) indicates that the growth and survival of newly planted seedlings could considerably be affected by the environmental stresses in the field such as water shortages and poor soil conditions. Hence, absence of rain during the short rainy season of Tokakutaye district (i.e., between January and February) and poorinherent soil characteristics in the site (Table 1) may have contributed to the observed high mortality during the first year of the tree/shrub establishment. The lowest survival percentage among indigenous species was recorded by *Albizia gummifera* (4 %) while the highest survival was recorded by *Olea europaea ssp cuspidata* (51 %). Among the exotic species, *Sesbania sesban* and *Acacia saligna* had the highest survival percentage (77 % and 71 %, respectively).The lowest survival percentage among exotic origin was recorded by*Acacia decurrens* (20 %). Overall, five species namely *S. sesban, A. saligna, E. camaldulensis, O. europaeasspcuspidata* and *M. ferruginea* showed the highest survival percentages after 42 weeks compared to the overall mean survival percentagedespite the fact that the altitudinal range of Fotololo is best suited for most of the tested species (Bekele-Tesemma, 2007). Mixing slow-growing indigenous species with fast growing exotic species resulted in increased survival percentage and can be taken as an alternative approach to hasten the recovery of degraded lands at Fotololo and elsewhere. However, replacing short-leaved exotic species viz. *Sesbania* by long-term species and compatible should be considered at some stage of the rehabilitation effort.

Table 2: Mean survival percentage of tree/shrub species (%) planted at Fotololo

Species	Time after planting (month)				
	6	**12**	**18**	**30**	**42**
1. *Acacia decurrens*	47±6	35±6	23±7	20±2	20±2
2. *A. saligna*	85±7	77±7	76±0	71±14	71±14
3. *Casuarinaequisetifolia*	60±0	49±7	41±3	41±13	39±10
4. *Gravilearobusta*	74±4	51±9	41±10	41±11	41±11
5. *Eucalyptus camaldulensis*	75±4	57±1	56±5	56±5	56±5
6. *Sesbaniasesban*	87±6	87±8	87±2	80±9	77±8
7. *Albiziagummifera*	69±7	33±5	8±0	4±4	4±4
8. *Cordiaafricana*	77±13	49±7	17±3	12±5	10±4
9. *Millitiaferruginea*	87±8	63±5	59±1	44±12	38±10
10. *Juniperousprocera*	53±15	51±8	46±0	42±9	39±8
11. *Oleaeuropaeassp cuspidate*	64±10	59±3	56±0	51±1	51±1
12. *A. decurrens+C. equsetifolia**	67±7	43±5	43±0	38±9	36±10
13. *S. sesban+O. europaea**	68±2	47±8	47±3	47±2	47±2
14. *E. camaldulensis + J. procera**	52±8	41±3	41±5	41±1	41±1
15. *C. equisetifolia + M. ferruginea**	77±5	56±16	49±1	49±1	49±1
16. *S. sesban + C. africana**	85±3	61±5	48±4	35±7	35±7
Mean±SE[a]	**71±4**	**56±5**	**46±7**	**42±7**	**41±7**
CV (%)	**19.2**	**28.9**	**52.0**	**55.3**	**56.8**

Height and diameter growth

The patterns of height growth are shown in Table 3.After 42 months, the lowest height growth was measured from indigenous species in the range of 0.52m (*A. gummifera)* to 1.20 m (*C. africana*). The lowest root collar diameter growths by *Albiziagummifera, J. procera* and *O. Europaeasspcuspidata*which might be associated with the slow growing nature of the species. In contrast, *A. saligna and S. sesban* attainedthe highest root collar diameter growth while the lowest root collar diameter growth was attained by *Albiziagummifera*. Planting *Acacia species* on degraded lands is a common practice in most part of Ethiopia (Maginnis and Jackson, 2003) as these species believed to improve soil quality and facilitate the growth of undergrowth vegetation that in turn provides protection to the area. Hence, planting *Acacia saligna and*Sesbaniasesban* at the Fotololo site might help to increase not only the carbon stock but also improve soil N through N fixation.

Table 3: Mean height of tree/shrub species and species mixes (m) planted at Fotololo

Species	Time after planting (month)				
	6	12	18	30	42
1. A. decurrens	0.39±0.04	1.20±0.09	1.60±0.09	2.30±0.05	3.2±0.1
2. A. saligna	0.96±0.09	2.27±0.03	3.08±0.19	3.71±0.05	4.9±0.8
3. C. equisetifolia	0.77±0.08	1.64±0.19	1.88±0.46	2.52±0.44	3.5±0.7
4. G. robusta	0.46±0.02	0.98±0.13	1.26±0.03	1.40±0.31	1.9±0.6
5. E. camaldulensis	0.73±0.03	1.12±0.30	1.92±0.35	2.44±0.40	3.4±0.7
6. S. sesban	2.46±0.06	2.95±0.08	3.30±0.24	3.75±0.25	4.2±0.6
7. A. gummifera	0.18±0.01	0.31±0.04	0.39±0.06	0.41±0.16	0.6±0.3
8. C. africana	0.58±0.02	0.70±0.24	0.76±0.09	0.91±0.07	1.2±0.3
9. M. ferruginea	0.40±0.02	0.70±0.09	0.76±0.24	0.87±0.14	1.3±0.2
10. J. procera	0.29±0.01	0.44±0.06	0.54±0.06	0.68±0.08	0.9±0.2
11. O. europaeasspcuspidata	0.35±0.03	0.53±0.04	0.73±0.08	0.77±0.06	1.0±0.1
12. A. decurrens+C. equsetifolia*	0.53±0.11	0.82±0.26	1.17±0.23	0.94±0.39	3.7±0.5
13. S. sesban+O. europaea*	0.43±0.12	0.71±0.22	0.89±0.34	1.01±0.41	1.3±0.4
14. E. camaldulensis + J. procera*	0.35±0.03	0.51±0.09	0.72±0.09	0.89±0.09	1.1±0.3
15. C. equisetifolia + M. ferruginea*	0.51±0.04	0.92±0.03	1.04±0.30	1.18±0.40	1.5±0.5
16. S. sesban + C. africana*	0.54±0.13	0.74±0.20	0.87±0.25	0.99±0.30	1.4±0.4
Mean±SE[a]	**0.69±0.19**	**1.17±0.25**	**1.47±0.30**	**1.78±0.36**	**2.4±0.5**
CV (%)	**91.8**	**70.5**	**67.7**	**67.5**	**63.5**

[a]overall mean excluding mixed species ± standard error
*species whose results are reported in the table

Themean height and root collar diameter incrementsof most screened species reached the maximum after thesecond sampling but decreased over times.Theseresults seemto be in line with Mekonnen et al. (2006) who reported a higher diameter, height and biomass incrementsat early stage (12 months) than late ages (64 months) despite the fact that these two experiments were conducted in different soil types, altitudinal ranges, and experimental managements.The height and root collar diameter growths of indigenous tree/shrub species tended to improve when they were planted with exotic species than planting alone (Table 3 and 4). In this regard, there is increasing evidence (Parotta, 1999) on the merits of mixed-species plantations in rehabilitating degraded lands than the single-species plantations by increasing land cover, producing better biomass, attracting animal seed dispersers as well as improving soil fertility.

Table 4: Mean root collar diameter (mm) and grass biomass harvested under planted tree/shrub species at Fotololo

Species	Time after planting (month)					Grass biomass (g m^{-2})
	6	12	18	30	42	
A. decurrens	4.2±0.2	13.8±0.3	17.2±1.8	20.0±0.6	28±1	746
A. saligna	11.6±1.1	25.8±4.0	43.0±2.4	48.1±3.6	62±3	880
C. equisetifolia	6.4±0.8	17.2±1.3	22.3±4.6	27.5±5.4	42±4	734
G. robusta	5.5±0.8	16.5±0.4	30.5±4.0	19.1±2.9	21±2	795
E. camaldulensis	9.1±2.8	19.5±0.7	33.6±1.8	33.5±3.3	39±5	555
S. sesban	24.9±0.6	29.5±4.8	47.0±3.2	49.9±2.1	58±4	952
A. gummifera	3.5±0.3	10.1±2.2	7.7±2.0	4.0±0.0	7±2	589
C. africana	10.8±0.9	18.9±2.0	23.9±0.3	24.1±3.5	29±3	595
M. ferruginea	5.9±0.6	13.8±0.3	17.0±3.2	18.5±1.1	22±2	771
J. procera	3.7±0.1	7.2±2.4	10.0±1.2	11.7±2.0	16±3	635
O. europaeasspcuspidata	3.5±0.2	10.8±1.6	15.2±1.0	22.6±1.1	27±2	448
A. decurrens+C. equsetifolia	5.1±0.8	13.4±1.4	15.4±2.6	21.7±2.8	43±7	796
S. sesban+O. europaea	4.2±1.1	14.7±3.9	19.1±3.1	25.3±4.5	28±4	925
E. camaldulensis + J. procera	4.3±0.7	7.5±1.4	13.7±1.6	16.7±8.7	20±5	893
C. equisetifolia + M. ferruginea	6.6±0.6	13.4±4.5	17.2±2.6	22.4±1.9	25±3	803
S. sesban + C. africana	12.0±1.2	17.6±1.8	25.1±3.3	28.9±4.2	33±5	821
Mean±SE[a]	**10.1±2.8**	**16.7±2.0**	**24.3±3.9**	**24.4±4.4**	**31±5**	**698±44**
CV (%)	**77.5**	**40.1**	**53.0**	**55.2**	**53.2**	**21.4**

[a]overall mean excluding mixed species ± standard error

 *species whose results are reported in the table

Undergrowth biomass

The dry biomass of grass and herbs in single species plots after 42 months varied between 448 (*O. Europaeasspcuspidata*) and 952 g m^{-2} (*S. sesban*), with a mean value of 698 g m^{-2} (Table 4). The amount and type of undergrowth vegetation (herbs and grasses) may partly provide valuable information about the degree of land reclamation in a given degraded land. This is because they are frequently cited as most useful plants in combating topsoil erosion as they have shallow but

dense and fine root mats (Reuben, 2010). All screened tree/shrub species allowed the growth of undergrowth vegetation although there were differences in density and height growth. These differences might be attributed partly to the growth habits of the tested species as growth habits (branching, canopy shape) known to influence the amount of sunlight radiation reaching to the ground surface. The common broadleaved undergrowth species in the area were *Trifoliumbidens*, *Medicagopolimorpha*, *Guizotiascabra*, and *Scorpurusmuricatus* whereas the dominant undergrowth grass species were *Digitaria abyssinica, Cyanadondactylon, Setariafumila*, and *Rhodes* species. Data on the relative abundance of these broadleaved and grass species indicated that *Rhodes* species dominated the site, followed by *Digitaria*, *Cyanadon* and *Trifolium* species.

The total dry biomass in the mixed plot was mostly higher than the two individual species grown separately (Table 4) to suggest that mixed plots might create better environment for the growth of undergrowth and therebyprovide higher soil protection. Undergrowth vegetation is believed to protect the top-soil from a direct rainfall hit and thereby decreased erosion as rainfall induced erosion on degraded lands can be reduced a hundredfold by maintaining a dense cover of grasses, or herbaceous vegetation (Gray and Sotir, 1996).Research results showed that suitable fast-growing tree species on degraded lands could facilitate the recruitment of a variety of native tree species (Otsamo, 2000). Following the fifth sampling period, regeneration of some woody plant species (e.g., *Acacia abyssinica)* from the seedbank have been observed; but the random pattern of regeneration all over the fenced area suggest that none of the tested species played a specific fostering role.

Conclusion and Recommendations

Our results on survival, height and root collar diameter growths generally indicate that *S. sesban*, *A. saligna, E. camaldulensis, O. Europaea ssp cuspidata* and *M. Ferruginea* are the outstanding performers on degraded land of Fotololo.Growing exotic species in mixture with indigenous tree species improves the survival and early growth performance of the later origin and contributes to hasten restoration of degraded lands. It can be, therefore, concluded that *S. sesban* and *A. saligna*can be chosen as pioneer species to rehabilitate degraded lands at Fotololo and other areas with similar agroecological conditions as these species accumulated high carbon stock over short period and allowed good undergrowth cover.However, integrating appropriate soil conservation measures with these pioneer/promising species is essential to restoredegraded soil and land quickly.

Acknowledgements

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WOODY SPECIES REGENERATION THROUGH EXCLOSURES AND PERCEPTION OF LOCAL COMMUNITY IN DAMOTA AREA, WELAITA ETHIOPIA

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Abstract

Area exclosure is promoted widely in Ethiopia as one re-greening strategy. However, effectiveness of the approach both in terms of encouraging woody species regeneration and the socio-economic conditions around it are not well studied. In this study we assessed regeneration status of woody species in seven year old exclosure area on Damota Mountain in Southern Ethiopia. Perception of the local community towards the area exclosure was also studied. Vegetation inventory was made in 15 quadrats (20 m x 20 m) laid following two transect lines running parallel. A total of 71 households from the surrounding villages were interviewed and group discussions were also conducted. A total of 26 species (19 families), (total density 2864) individuals (DBH $\geq$ 2 cm) per hectare, were recorded. The vast majority of the tree species had height less than 4.5 m and DBH of less than 6 cm. The basal area, Shannon diversity index and evenness in the area exclosure were 15.84 m^2/ha, 2.54 and 0.39, respectively. The tree species, *Maesa lanceolata, Ozoroa insignis, Maytenus arbutifolia, Nuxia congesta, Rhamnus prinoides* and *Rapanea simensis* were structurally the most important species. About 87.3 % of the respondents support further expansion and maintenance of the area exclosure whereas the remaining 12.7 % were against the intervention. All interviewed agree on the improvement of the vegetation cover since the establishment of the exclosure. However, all wanted improved access to the grass in the exclosure area so as to use it in cut-and-carry system. We conclude that social issues need to be handled carefully to make the effort sustainable.

Keywords: Area exclosure, degraded land, diversity, regeneration, socioeconomic

Introduction

Human and livestock intervention and set aside for rehabilitation (Nedessa et al., 2005). In many parts of Ethiopia, degraded lands that almost have lost significant part of their production potential are set aside for rehabilitation. These areas are set aside to foster natural regeneration of native flora through protection of the areas from human and animal interference (Mengistu et al., 2004). Establishing exclosure is also considered advantageous since it is a quick, cheap and moderate method for the rehabilitation of degraded lands (Bishaw and Abdelkadir 2003; Nedessa et al., 2005). Once areas are exclosed, trees and grasses will often regenerate spontaneously and grow without much additional external inputs. Rehabilitation of degraded lands through exclosure has recently received attention in many parts of Ethiopian (Mamo, 2008).

Good examples of successful exclosure in Ethiopia include those undertaken by the Tigray Regional state, exclosures established by Self Help International (SHI) in the drylands of the rift valley of southern Shoa and those established in Humbo woreda, Wolaita (Bishaw and Abdelkadir, 2003).

Despite the fact that exclosures have been claimed instrumental in the re-vegetation and rehabilitation of degraded lands, there is limited area specific knowledge on the diversity, sources of propagules and status of regeneration of the developing flora as well as the actual and potential socio-economic benefits that can be derived from such resource management scheme. Exclosures are claimed to have been established with the consent and involvement of the local communities. Yet research based assessment on the effectiveness of community involvement, perception, attitude and adoption potential and benefits accrued will be essential to generate lessons and guide future similar interventions. The general objective of this study was to assess the rehabilitation and regeneration status of the degraded and deforested area of mountain Damota for facilitating better management and to study the perception of the community regarding the exclosure. Specifically the study aimed at 1) describing species diversity and composition of woody plants in the area exclosure, 2) determining the relative density of cohorts (adult tree, sapling and seedling) of woody species, 3) determining the population structure of selected important tree species, and 4) assessing the perception of local community towards the area exclosure.

Material and Methods

The study area

The study was conducted on exclosure of mountain Damota, in the Wolaita Zone of the Southern Nations Nationalities and Peoples Region (SNNPR). The area is located between 6.4^0 - 6.9^0 latitude and 37.4^0-37.8^0 longitude (Figure 1). The mean annual temperature of Damota area varies from $16\,^0$C to $19.9\,^0$C and the mean annual rainfall is 1375 mm.
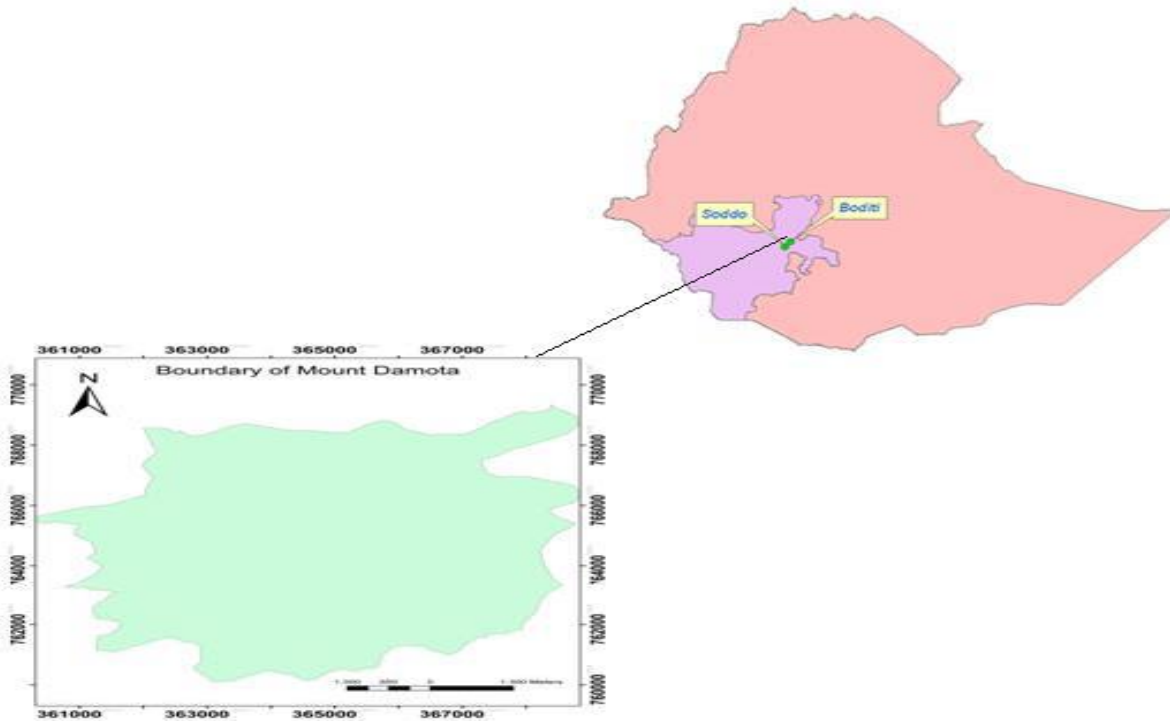.

Figure 5: Map showing Damota exclosure and its location in Ethiopia

The Damota Mountain was formed due to volcanic activity during the Tertiary period, which occurred on the western edge of the Great Rift Valley. Since then it has been exposed to erosion under humid climate and forest cover creating the numerous small valleys cut by the rivers (Gal and Moliner 2006). Mixed farming is practiced in the area involving the production of cereals, root crops, Enset (*Enset ventricosum*) and coffee.In the 1997/8 production year, households with a holding of one hectare and below in the Zone was accounted for 90.4% of the total households (CSA 2008). Different types of livestock are also kept. Pressure on the land due to increasing density of both human and livestock population is high.

Study design

The study was designed in such a way that data could be gathered on vegetation and community's perception towards area exclosure establishment, development and further expansion. Details of vegetation and community perception evaluation surveys were conducted after a preliminary survey. There was no land unoccupied (open area) in which a comparative study of vegetation change due to the area exclosure could be made. Instead, community perception and other socioeconomic survey were used to justify the changes observed..

Woody species abundance, density and diversity

To investigate the impacts of area exclosure on the density and diversity of woody plants, vegetation data was collected by line transects parallel to each other and with a south to north orientation in the exclosure. Two transects were laid and the distance between two consecutive parallel transect lines was 500 m; and transects ended at the end of the exclosed area.

Along the transect lines, sample quadrat measuring 20 m X 20 m (400 m^2) were laid down at 300 m interval from center to center of the plot. Within the main quadrats small plots measuring 5 m X 5m (25 m^2) were used to measure and record saplings and four 1 m X 1 m (4 m^2) were laid at the four corners of the larger plots to record seedlings. The quadrats established were marked using a plastic ribbon and four wooden pegs until the end of the study. Along the two transects, a total of 15 quadrats (seven and eight plots on transect one and two, respectively) were established in the exclosure. The first sample plot was laid randomly (at 40 m from the bottom of the forest, 700 m to the right in to the forest from the side) by a lottery system.

The woody plant species encountered in the plots were identified on spot based on own experience supported by plant knowledge of local elders. In addition, books on useful trees and shrubs of Ethiopia (Kelecha 1980; Hedberg and Edwards 1995 and Bekele-Tesemma 2007) were used throughout the process of identifications. For species that were difficult to identify in the field, herbarium specimens were collected, pressed, dried and transported and identified in the National Herbarium, Addis Ababa University.

Regeneration status and population structure

Regeneration status and population structure of woody species were assessed in the 15 quadrats. In each quadrat, all individuals with 2 cm and above diameter at breast height (dbh) (1.3 m) were measured for their dbh and heights using tree caliper and hypsometer and measuring stick, respectively. Computation of importance value index (IVI), abundance, frequency, basal area, height structure and diameter structure were conducted based on the data on individuals with ≥ 2 cm dbh. Seedlings (defined as individual with a height less than 0.5 m and with two leaves above cotyledon) were counted in 4 subplots (1 m x 1 m) at the corners of each quadrat. Saplings (defined as individual with a height 0.5-3 m) were counted in subplot of 5 m x 5 m in the center of each quadrat. Tree (defined as an individual ≥ 3 m) were measured in each (20 m x 20 m) quadrat.

Socioeconomic survey

To undertake the socioeconomic survey, sample households in close premise to the exclosure were selected. There three Kebeles (Kokate, Dalbowogene and Damotawaja), that surround the forest. Each of the Kebele had three sub-kebeles, and only two of the sub-kebeles which are closest to the forest were included in the study, hence, six of the sub-kebeles were considered. From 1361 of the total of households in the six sub-kebeles, five percent plus of the total households (i.e. 71 households) were sampled systematically in which every 20th household were included in the survey. Then, a formal survey composed of unstructured and structured questionnaires was carried out. In addition to the household survey, discussions with focus groups, namely Elders, kebele leaders, DA's and different groups in the Agriculture office of the three kebeles were conducted..

Data processing and analyses

Species abundance, density and diversity

The sum of all woody species encountered in the quadrats of the exclosure was used to determine the species richness in the study site. Likewise, the abundance of each woody species, defined here as the total number of all individuals of a species in all the quadrats within the exclosure, i.e. individuals/ 6000 m^2 (15 quadrats x 400 m^2) were calculated. Then, the density of each woody species in the exclosure was determined by converting the total number of individuals of the species encountered in all the quadrats to a unit area of one hectare (individuals/ha). The frequency of each woody species was calculated by determining the proportion of quadrats in which that species was encountered. In addition, the basal area of each woody species was calculated.

The total number of species was taken as a measure of richness, whereas the Simpson and Shannon indices were taken as a measure of heterogeneity (Magurran, 1988).

Shannon diversity index, H' $= -\sum_{i=1}^{s} pi \ln pi$ ………………………………...……….. (1)

Where: H'= species diversity index; ln= natural logarithm and Pi=n/N is the proportion of individuals found in the ith species (ranges 0 to 1); n=number of individuals of a given species; and N = total number of individuals found (Begon et al., 2006).

Evenness (Equitability): $J = \dfrac{H'}{H'_{max}} = -\sum P_i \ln(\dfrac{P_i}{\ln S})$ ....(2)

Where: ln= natural logarithm; S= the number of species.

Inverse Simpson's Index, $D = \dfrac{1}{\sum_{i=1}^{s} pi^2}$ …………………………………….………... (3)

Where: S = total number of species in sample (i.e. richness); and Pi= the proportion of individuals found in the ith species (Wilson et al., 1996). Important Value Index (IVI) of a species is used to express the relative dominance of the species in the community (Kent and Coker 1992), and was calculated from the sum of relative dominance, relative density and relative frequency.

Socioeconomic data analysis

The socioeconomic data were fed into SPSS (V. 16.0) for windows and analyzed using descriptive statistics to assess the perception of local community regarding establishment, management, change in vegetation status and further expansion of the exclosure practice in the area.

Results

Woody vegetation restoration

Composition of woody species

A total of 24 species belonging to 19 families were recorded in the area. A total of 2864 individuals (stem per hectare) were recorded (Table 1). Many of the stems were (78.3 %) were saplings and shrubs, 18 % were seedlings and only 3.7 % were trees. The family Myrsinaceae and Rhamnaceae were represented with three species each and Rhamnaceae and Oleaceae with two species each and the rest families with one species in the area exclosure.

The importance value indices revealed that *Maesa lanceolata, Ozoroa insignis, Maytenus arbutifolia, Nuxia congesta, Rhamnus prinoides* and *Rapania simensis* were structurally the most important species and dominated the exclosure. These species represent 58.52 % of the importance value indices in the area whereas the majority (50 %) of the remaining species had an importance value index of less than 10. *Maesa lanceolata* was the biggest tree species comprising 14.95 % of the basal area whereas *Ozoroa insignis, Nuxia congesta*, and *Maesa lanceolata* were the most abundant and frequently distributed species in the exclosure.

The majority (94 %) of the stems has a DBH range between 2 to 6 cm and also 93 % of the stems had a height less than 4.5 m. The mean basal area and height were 1.16 m^2/ha SD and 3.05 + 2.17 m, respectively.

Table 1: Abundance, frequency, basal area (BA) and Importance Value Index (IVI) of woody species in decreasing order of IVI

Species name	Family name	Abundance/ quadrats	Abundance/ ha	Relativ e abu.	BA (m2/ha)	Relativ e BA	Frequ.	Relativ e freq	IVI
Maesa lanceolata	Myrsinaceae	48.00	430.00	15.01	4.75	29.98	8.00	7.84	52.84
Ozoroa insignis	Anacardiaceae	83.00	388.33	13.56	3.25	20.50	11.00	10.78	44.84
Maytenus arbutifolia	Celastraceae	26.00	193.33	6.75	1.81	11.44	10.00	9.80	28.00
Nuxia congesta	Loganiaceae	54.00	340.00	11.87	0.12	0.73	10.00	9.80	22.40
Rhamnus prinoides	Myrsinaceae	39.00	140.00	4.89	1.02	6.45	6.00	5.88	17.22
Rapanea simensis	Myrsinaceae	30.00	325.00	11.35	0.27	1.68	4.00	3.92	16.95
Oliniar ochetiana	Oliniaceae	21.00	96.60	3.37	1.33	8.39	5.00	4.90	16.67
Brucea antidysenterica	Simaroubaceae	23.00	113.33	3.96	1.09	6.85	4.00	3.92	14.73
Syzygium guineense	Myrtaceae	22.00	211.67	7.39	0.04	0.24	5.00	4.90	12.53
Ilex mitis	Aquifoliaceae	7.00	85.00	2.97	0.79	4.98	4.00	3.92	11.87
Myrsine africana	Myrsinaceae	24.00	215.00	7.51	0.04	0.22	3.00	2.94	10.67
Protea gauged	Proteaceae	11.00	68.33	2.39	0.94	5.90	2.00	1.96	10.25
Pavetta gardeniifolia	Rhamnaceae	27.00	70.00	2.44	0.05	0.32	7.00	6.86	9.63
Olea europaea ssp cuspidata	Oleaceae	5.00	8.33	0.29	0.27	1.72	5.00	4.90	6.91
Bersama abyssinica	Melianthaceae	9.00	65.00	2.27	0.01	0.09	3.00	2.94	5.30
Apodytes dimidiata	Icaccinaceae	11.00	18.33	0.64	0.02	0.15	4.00	3.92	4.71
Gouania longispicata	Rhamnaceae	8.00	13.33	0.47	0.02	0.11	4.00	3.92	4.49
Echinops longifolius	Asteraceae	5.00	33.33	1.16	0.01	0.04	1.00	0.98	2.19
Galineria coffeoides	Rubiaceae	2.00	33.33	1.16	0.00	0.01	1.00	0.98	2.16
Flacourtia indica	Flacourtiaceae	3.00	5.00	0.17	0.01	0.08	1.00	0.98	1.23
Pittosporum viridiflorum	Pittosporaceae	2.00	4.00	0.14	0.01	0.05	1.00	0.98	1.17
Olea welwitschii	Oleaceae	2.00	3.33	0.12	0.01	0.05	1.00	0.98	1.14
Clausena anisata	Rutaceae	1.00	1.67	0.06	0.00	0.02	1.00	0.98	1.05
Acacia sp.	Fabaceae	1.00	1.67	0.06	0.00	0.01	1.00	0.98	1.05
			2863	100	15.84	100	102	100	300

Diversity of woody species

The diversity indices, i.e. Shannon and the inverse Simpson index of diversity for woody species in the exclosurewere 2.54 and 1.39, respectively, while the species evenness was0.39.

Density and frequency of wood species

A total of 2864 individuals of woody species were encountered per hectare in the area. Most frequently distributed woody species in different life forms (tree, sapling and seedling) in the study area was *Ozora insignis*, with a frequency of 11 in the quadrats. The other most frequently populated species in the studied exclosure were *Nuxia congesta* and *Maytenus arbutifolia*, followed by *Maesa lanceolata*.
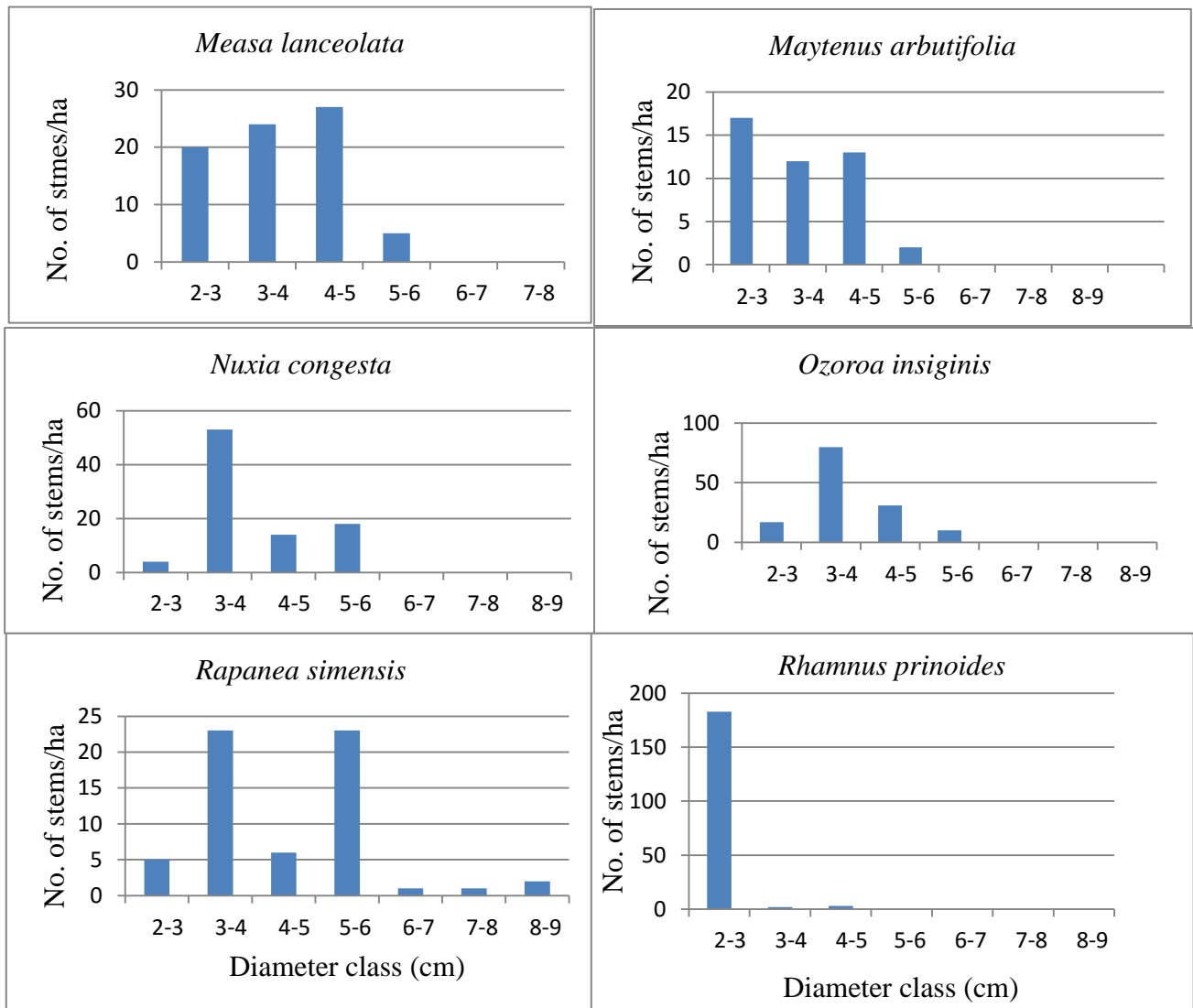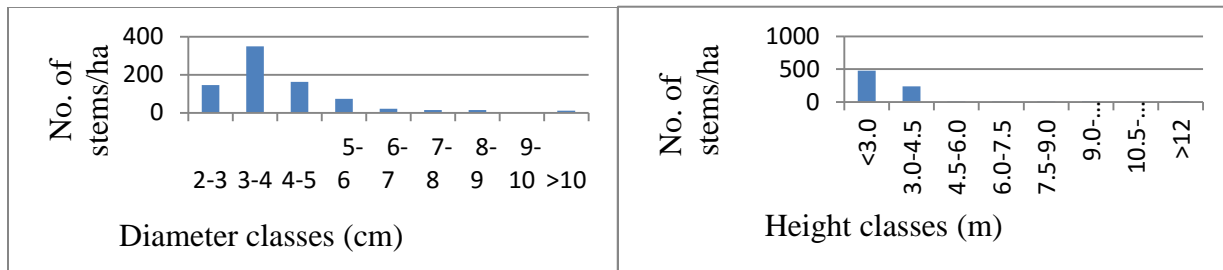
Figure 6: Basal area (m^2/ha) distribution of all woody species, diameter class (cm): (Left) and frequency distribution of height classes (m) for woody species, (Right).

Diameter structures of the six woody species which showed highest IVIs, namely *Maesa lanceolata, Ozoroa insignis, Maytenus arbutifolia, Nuxia congesta, Rapanea simensis*, and *Rapanea prinoides* were constructed (Figure 3). All six species were represented by individuals in all size classes (dbh> 2cm), and written in an alphabetical order.

Figure 7: Diameter structure of six woody species with high IVI at Damota exclosure area

Woody species with height < 2 m constitute 23.3 % of the total individuals recorded, whereas those with >2 m were 76.7 % in the exclosure.

Socio-economic study

In the study area male accounted about 90.1 % of the respondents and female 9.9 %. From the total household 46.5 % were illiterate, 26.8 % elementary and the rest 15.5 % were high school. The livelihood of 93 % of the community were based on farming and the rest 7 % were living both on farm and off farm but there was no respondent that depends on off-farm activities alone.

The mean farm size of the household in the study area was 0.5 ha of land; in disaggregate, 32.4 % own 0.25 ha, 49.3 % own 0.5 ha, 1.4 % own 0.75 ha and 16.9 % own one ha

Perception of farmers on land degradation and towards Area Exclosure

All (100 %)of the respondents indicated that deforestation of vegetation cover at mountain Damota was due to human population increment, open access and overgrazing caused by high livestock pressure from the community. The respondents specified that the community used to collect and sell fuelwood, grass, local medicines; 'Dambursa' grass, and local medicines from plant roots, 'Gesho' (*Rhamnus prinoides*), and bamboo (*Oxytenanthera abyssinica*) for long period of time. Currently, 100 % of the community members agree that there is a dramatic increase in vegetation coverage in the area exclosure.

However, they expressed concerns over shrubs and climbers which closed the area that harbor dangerous wild animals, which are harming their animals and even humans. Harvesting of grass

for livestock feed and sale was the primary benefit that local people used to get from the area but the existing restriction in accessing such resources was a grave concern of the community.

Some of the farmers did not seem to be clear about the eventual benefits of the exclosure, especially with respect to access to woody vegetation, grass and local medicines; they were eagerly awaiting permission. Because of the lack of access right and lack of fodder and grazing area for their animals, communities' interest to participate in the management was low. About 59.2 % were in fear of displacement from the exclosed area, and this was seriously affecting the managements. A few of the community members (10 %) have negative feeling to the exclosure though they were getting several indirect benefits from the exclosure such as reduction of flood hazards to their farmlands at the downhill areas as the rest of the community.

During the establishment of the exclosure, about 40.8 % had agreed on its establishment while the majority (59.2 %) had been in fear of displacement from the area. The majorities were worrying about the future grazing area, shortage of fodder and fuelwood and had negative feelings to the exclosure. But at the moment, the perception of 90 % of the total household has changed positively.

Respondents in the study area regard the exclosure as beneficiary to the community and the environment. About 87.3 % of the total respondents have the willingness to see the area exclosure further expanded but the rest 12.7 % were still refusing the exclosure due the shortage of grazing area and source of fodder and fuelwood. Only 45.1 % of the respondents got training regarding the aim and advantages of area exclosure and the majority (55 %) did not get training.

Benefits from area exclosure

All of the interviewed farmers agreed that animal fodder and vegetation has increased after area exclosure establishment. They were not using fodder from the area. The forage supply as cut- and -carry system from the exclosure site was not allowed. Before the establishment of the exclosure, community members were using fodder from the study area but after the establishment of the exclosure about 11.3% are using crop residue and buying fodder from other places, and 88.7% are using other sources of fodder like Enset, fodder from their own farmland and crop residues.

Discussion

Vegetation status

Even if baseline data for the study area was not present at the time of establishment, the results from this study clearly confirm the importance of area exclosure in vegetation restoration on degraded areas. Such degraded lands that have been set-aside as exclosures can rehabilitate fast to restore lost or reduced biodiversity in an area (Yami, 2006; Hailu et al., 2006; Mamo, 2008). Area exclosure is also attractive in that artificial afforestation requires economy and additional resources but a vegetation restoration program based on natural processes of vegetation recovery such as area exclosure is a cheaper alternative (Dalmaco, 1987). The establishment of exclosures assists to improve the overall ecological conditions of degraded areas so that they can provide

better products and services for the people (Mengistu et al., 2004). From the results of this study, there was a good regeneration status of vegetation on the area. The lesser proportion of seedlings (18 %) compared to the very high proportion of saplings/shrubs (78 %) could indicate the exhaustion of the seed bank and the existence of strong competition for resources on any emerging seedlings from the already established saplings. In fact, the low seedling population could also be due to the change in vegetation succession from more open condition pioneer type of species during the early succession to a more shade tolerant late succession types.

Shannon diversity index obtained for the exclosure of the study area indicated a good collection of species. This could be an indication for the importance of exclosure for the restoration of plant genetic resources. Such high diversity can indicate for increased ecosystem processes as species interactions among the species in the given community increases with diversity (Mamo 2008). The simplest measure of the character of a community that takes into account both the abundance (or biomass) patterns and the species richness is Simpson's diversity index (Begon et al. 2006). The Simpson index indicated that the area was diverse and showed that there was interaction of species on the area. Furthermore, the evenness of the species was good since external interference of animals and human beings was controlled (Lusigi, 1984; Ormerod 1978, Lamprey, 1983). On the contrary, forces such as permanent grazing can affect the species diversity and structural diversity of woody plants (Mengistu 2002). In addition, the availability of a ready market, from within and outside the district, for charcoal, firewood, building materials, livestock, and labor could increase the pressure on vegetation resources.

Socioeconomic study

Often failures in conservation emanate from the failures to fully participate local community and win their interest and commitment to contribute towards success. This was what was observed in this study. The majorities of the interviewed households were not aware of the objectives and advantages of area exclosure and thus face difficulty in appreciating the intervention. Despite the lack of awareness at the beginning, the majority of the respondents support the conservation and management of area exclosures. But the participation and commitment of the people could have been high if all were adequately and properly communicated (Birhane, 2002; Gebrehiwot, 1997).

There was severe shortage of fodder, firewood and timber in the area. For this reason all of the households depend on mountain Damota as a source of these products. Shortage of food and fodder has many implications for the management of exclosures (Nedesa al.,2005). Shortage of livestock fodder could make the protection and management of the emerging grasses in the exclosure more difficult in that more people will tend to harvest fodder from the exclosure that can threaten its sustainability. In the same way, the shortage of firewood and timber forces the community to use tree from their home garden on which they rely and hope as a source of income.

Government and the World Vision (*Carbon project*) have increased forest guards to protect the Damota forest. A legal system has been put in place to punish the illegal users of the resource either in prison or in cash. Due to the limited source of income, fodder, timber and others, some of the community members (9.9 %) were refusing the strategy and the presence of guards.

In addition to the amount of benefits and mode of ownership, who and how the resources are accessed is another important aspect to be considered for the sustainability of the AEs (Nedesa al., 2005). It was found that communities were not yet allowed to use any kind of benefit from the area exclosure. But, as to the expertise from agricultural office, the reason for not allowing resource use was due to the age of the exclosure, which was only 7 years old and the area needs some more time for complete rehabilitation. If proper actions and arrangements are not made, the intense scarcity of forest products coupled with high population pressure in the area may result in a conflict between conservation and utilization of the area. The waiting of the area for some time until it attains sufficient resilience is important, but it should not be protected from use forever.

In general, the present study generated empirical evidence, which demonstrated that area exclosure is important in enhancing the recovery of vegetation on degraded area that they are properly protected and sustainably managed.

Conclusion and Recommendations

Area exclosure can contribute to rehabilitation of degraded areas in a relatively short period of time. Exclosure can achieve the rehabilitation of vegetation coverage and environmental protection, while also contributing to improve the livelihoods. The study made on the composition, density, richness, diversity of woody species and structure revealed improvements, however, the low proportion of the seedling population may result in a gap in the structure of the forest in the future, so that, silivicultural activities should be carried to substantially improve the seedling population. On the other hand, for sustainable management of area exclosure, careful design of management strategy that integrates local communities and their needs and ecological recovery are needed. Integrating management of resources with understanding the status and level of the attitudes of the community can develop and strengthen the success of the strategy. For the future the following are recommended:

1. Formal and informal training for the local people is still needed on the ecological and socioeconomic importance of exclosure. This has the ultimate aim of enhancing their awareness, which in turn, is vital in ensuring the long term desired management, conservation and sustainable utilization of exclosure.
2. Exploration and introduction of affordable alternative sources of household energy and construction material fodder are recommended to relieve the pressure from the local people on the exclosure.
3. Enrichment plantation should be done and tree species to be planted in the AEs should be selected by the active participation of the community and in consultation with the *woreda* technical staffs.
4. Technical guidelines for resource management and benefit sharing should be developed in a participatory fashion.
5. It is vital to develop community management systems to manage and use exclosure areas. Exclosures can be viable systems if they have clearly defined users and resource boundaries as well as realistic rules established locally.

Acknowledgements

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INVESTIGATION OF PUBLIC PERCEPTION ON VARIOUS USES OF URBAN AND PERI-URBAN FORESTS IN ADDIS ABABA, ETHIOPIA

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Abstract

Urban forest refers to all trees and vegetation in urban and suburban areas. The existing urban forests are important for ecosystem services, air quality, education, recreation and aesthetic values. New settlement and removal of trees for various purposes is affecting the green coverage of Addis Ababa in an alarming rate. This study was conducted to 1.Evaluate perception of urban dwellers on different types of urban forests 2. Study the role of different types of urban forests for educational and recreational uses. 3. Identify the role of urban forests for watershed protection 4. Assess the tree species and planting niche preferences of dwellers. Yeka, Gullele and Bole sub-cities were selected purposively and a total of 156 respondents were designated using proportional sampling technique. The study employed a structured questionnaire, interview with key informants and FGD. Descriptive methods and SPSS tool were used to analyze the collected data. Finding shows, city trees provide a number of benefits but also it needs possible concerns. Specifically, urban forest has significant benefits for urban watershed management, recreation and education, but people, who have different educational background have dissimilar perception on educational benefits. Respondents preferred their private land and indigenous trees to plant. Thus, to increase different uses of urban forests, formulate a sustainable plan and strategy of urban forest development and management is mandatory.

Key words*: alarming rate, planting niche Urban forest, watershed protection.

Introduction

Urban forest refers to all trees and vegetation in urban and suburban areas. Trees are an accepted presence in the urban landscape as individuals in streets, parks and gardens or as components of woodlands as "relics" surviving from forest before urbanization, or as planted and spontaneous regenerated blocks on derelict sites. "Urban forest" is define as trees growing individually, in small groups or under forest conditions, on public and private lands, in cities and towns and their suburbs (CBP, 2004).

Trees on streets and on other publicly owned properties managed by public works agencies provide a multitude of aesthetic and environmental benefits to citizens, businesses and visitors alike. Beyond shade and beauty, trees also have practical benefits and a real monetary value that cities sometimes are unaware of—your urban forest provides valuable public services and could be worth over a million dollars. Unlike other public infrastructure components, properly planted and maintained trees increase in value over time (urban forest management plan). Street trees, as

well as parks, gardens and green spaces, are natural air conditioners and, within a limited range, noise attenuators. The noise attenuation capacity of trees is directly related to the density and width of planting zones (Mecklenberket al., 1972).

Urban forests are increasingly appreciate in environmental education for urban dwellers, and are part of environmental education worldwide. It is obvious that, urban forests greatly enhance outdoor recreation. Lower income residents tend to frequently visiting city parks more than richer citizens, yet the per capita green area is much lower. Only very few cities have delivered plans to increase green space in low-income accommodation. Recreation for poor neighborhoods must be based on values of the poor, offer affordable access, and combine recreation with other urban functions.

Urban forestry development activities in Ethiopia began around 1895 when Menelik II introduced Eucalyptus species to the capital, Addis Ababa. During his time, Eucalyptus plantations was establish around the city by distributing seedlings to each resident with the aim of satisfying the growing demand of urban dwellers for fuel wood. Since then, various attempts have made to expand the forest cover of Addis Ababa. For instance, the Addis Ababa Fuel wood Plantation Project and the Addis-Bah Project have established 12,700 and 7,480 ha of plantations in 1985 and 1987/88, respectively.

Addis Ababa did not meet the international minimum standard for open green space (9 m2 per city dweller) suggested by World Health Organization (WHO) (Kuchelmeister, 1998). The existing urban forests in city are also facing serious challenges from illegal settlers and massive conversion of green areas to mere buildings.
The objectives of the study are to:
- Evaluate perception of urban dwellers on different types of urban and peri-urban forests and green spaces.
- Study the role of different types of urban and peri-urban forests for educational and recreational uses.
- Identify the role of urban and peri-urban forests for watershed protection in and around Addis Ababa.
- Assess the tree species and planting niche preferences of urban dwellers.

Material and Methods

Description of the Study Area

Addis Ababa has an area of 54,000 ha; it receives average annual rainfall of 1161 mm, of which about 80% falls between June and September, the months of July and August being the wettest. The average maximum temperature ranges between 17 and 22 ℃ and the average minimum temperature varies between 11 and 14 ℃ (CSA, 2011).

Addis Ababa is situated in the Western part of the Awash River Basin (located in the central highlands of Ethiopia) at the geographic location of 8°50'- 9° 05' N latitude and 38° 39' - 38° 55'

E longitude and the altitude ranging from 2350 m a.s.l at Akaki in the south to 3300 m a.s.l at Entoto Hill in the North (CSA, 2011).

The city administration is divided into 10 sub-cities, which are Addis Ketema, Akaki-Kality, Arada, Bole, Gulelle, Kirkos, Kolfe-Keranio, Lideta, Nefasilk-Lafto and Yeka, In terms of area coverage Bole is the largest sub-city followed by Akaki- Kality and Yeka. Addis ketema is the smallest and followed by Lideta and Arada Sub-cities. The sub-cities are also divided in to weredas, which are the smallest administrative unit in the city. There are 116 weredas in the city administration. The Projected Population Size of Addis Ababa is 3.48 million (CSA, 2011).

Sampling method

Yeeka, Gulele and Bole sub-cities were selected purposely as the sample of the study. Because:
1. These three sub-cities have more urban forest than the remaining sub-cities of Addis Ababa,
2. Thereareperi- urban areas around the peripheries of these three sub-cities.
According to 2007census and housing enumeration Yeeka, Gulele and Bole sub-cities have 61, 923; 90,195; and79, 020 households, respectively. That makes a 231,138 households, the sample size was determined by using the Yemane's (1967) formula as follows:

$$n = \frac{N}{1+NE^2}$$

Where: n = sample size
         N = population size
         E = margin of error * desired

$$n = \frac{231,138}{1 + (231,138)(0.08)^2} = 156$$

Therefore, the sample size was 156from these three sub cities means Yeeka, Gulele and Bole 42, 61 and 53 respondents respectively taken proportionally from each sub-city.

Data collection methods

Primary data were collected using questionnaire, key informant interview, as well as personal observation. Secondary data were collect from analysis of documents and historical records.

Methods of data analysis

The analysis of the data from observation and interview were done simultaneously along with data collection. Descriptive statistics (such as percentage, table, pie chart and bar graph) and the Likert scale analysis were used to show respondents' attitude towards individual items of the questionnaire. To analysis, the collected data SPSS software and Descriptive analysis were used.

Results and Discussion

Possible benefits of city trees

Trees in urban areas are useful to moderate air temperature, which occurs during daytime and helps urban dwellers to get cool air during hot days. Among the total respondents who have not received formal education 89% of them agreed that urban trees helps to cool home in hot days as a major benefits but only 8% of them have an idea about urban trees reduce atmospheric carbon as a major benefit. This implies that, the respondents who have not received formal education have an idea about the use of urban trees to moderate atmospheric temperature by providing shad and bringing windy air in to the atmosphere than reduce atmospheric carbon.

The majority of the respondents believe that the major benefit of urban trees includes beatification of scenery, improving the fertility of the soil, erosion control, for protecting flooding and habitat for birds it increasing the biodiversity of city. Urban forests have Environmental benefits for humans and animals as Wind control - reduce heat loss from buildings; Sun control - hardwood species reduce solar radiation during the summer and' provide' sunlight during the winter; Precipitation and humidity control - control snow, reduce fog, rain screen, reduce runoff and create a habitat for wildlife (Hastie, 2003).

These days, urban forestry became a source of income for the livelihood of the poor in urban and peri-urban of Addis Ababa. Inhabitants in peri-urban areas of Addis Ababa are planting trees for sale. As a result, they could improve their cash (subsistence income) or get raw materials for house construction or for making furniture. Trees, which have medical value, could reduce expenditure for buying medicine.

Possible concerns about city trees

Retaining city trees within the city provides a number of benefits but also it has a number of possible concerns.

Table 3.2: perception of respondents on the blocking views concern of urban trees.

Blocking views	Frequency	Percent
Not a concern	70	44.9
Minor concern	70	44.9
Major concern	13	8.3
Not sure	3	1.9
Total	156	100

Source: Field Survey (2015)

The respondents were asked for the possible concerns of city trees with regard to blocking vicinity (Table3.2.) .Accordingly 44.9% of them perceived as minor concern; 8.3% of them as major concern; 1.9% of them had no perception; and 44.9% as no concern .Therefore, blocking of views or vicinity is not a significant concern. In addition to this, blocking of sunlight and induction of crime areinsignificantconcern of urban forest. The concern about the damage of the falling branches of trees andtree roots induced cracked sidewalksare significant.
In addition to these, respondents explained other possible concerns of city trees. Based on the interviews with respondents, the study revealed the following concerns of urban trees:

- They should have been planted in appropriate place;
- They induce electric fire
- They should consist of different species of trees on different parts of the city
- They should be conserved existing trees and also newly planted; and
- They should be provided with enough nutrients

Importance of Different Types of City trees

Trees in parks are very important types of urban forest followed by trees in yardsand roadside respectively.

Respondents Activity in urban Forestry

There is a good beginning of urban forestry activities in Addis Ababa and mainly carried out by the dwellers themselves.

Initiation taken by GOs/NGOs in urban Forestry

There was no significant initiation by both GOs and NGOs in urban forestry in terms of type and amount.

Recreational Uses of Urban and Peri-Urban Forest/Tree

Table3.3: perception of respondents on recreational uses of urban forests

Urban forest is a place you can go to relax	Frequency	Percent
Strongly Agree	60	38.5
Agree	55	35.3
Neutral	15	9.6
Disagree	17	10.9
Strongly Disagree	9	5.8
Total	156	100

Source: Field Survey (2015)

As a majority of the respondents agreed, urban forests are a place the people can go to relax. The needs to experience nature and to escape from the stressful rhythm of the city also constitute important reasons for people's visits to the park (Gobster, 2001).

Respondents time frequency to visit urban forest/trees

Table 3.4: Age of the respondents and time frequency to visit green areas/parks

Age of the respondents	On average, how often do you visit the green areas/parks or forest in your locality?						Total
	Several times a week	Once a week	Once or twice a month	Once in a six months	Occasionally	Never	
15-24	1	0	2	3	3	2	11
25-44	22	8	23	3	38	11	105
45-64	10	0	4	1	17	1	33
>65	2	0	1	0	4	0	7
Total	35	8	30	7	62	14	156

Source: Field Survey (2015)

The data implies that, a majority respondent have visited the green areas/parks occasionally. Thus, across different age group inhabitants, in Addis Ababa have very little habit for visiting parks or other urban forest for recreational uses.

Among the respondents, who have visited urban forest occasionally, about 45.9% of them spent their childhood in cities; 40.7% of them in sub- urban areas and 11.3% of them in rural districts. Among those respondents, who have visited urban trees several times a week, about 37.9% of them spent their childhood in rural areas; 18.5% of them spent in sub-urban and 13.5% in urban areas. This implies that, the people who have contact with nature during their childhood have a good habits and short time frequency to visit urban trees than the people who had spent their childhood in urban constituency. Also people preferred weekends than other daysto visit urban forest.

Table 3.5: Respondents preference time to visit urban forest

Respondents preference Time to visit urban forest	Frequency	Percent
Morning	17	10.9
Afternoon	78	50.0
Evening	14	9.0
At any time of the day	33	21.2
Total	142	91.0
Never	14	9.0
Total	156	100

Source: Field survey (2015)

As described (in Table 3.5), the sample respondents were requested to give their preference time to visit various types of urban and peri-urban forest. Half of the respondents chose the afternoon

times of the day; and the remaining 50% of them chose morning, evening and any time of the day. This shows that, the people like more afternoon time of the day to visit the urban forest than other times of the day.

The respondents'safety on the urban forests

The majority of the respondents have positive attitude towards the safety when they visit urban forest.

The respondents'activities in urban forests

People use urban forest mainly to attend community events, visit nature and meet with family or friends rather than other activities.

Recreational Elements of Respondents in Urban forest or Parks

Different types of urban and peri-urban forest provide various recreational elements and it depends on the users or visitors significance. According to (Roovers et al., 2002), urban nature fulfils many social functions and psychological needs of citizens, which make urban nature a valuable municipal resource, and a key ingredient for city sustainability.

Perception of Respondents on the Establishment of New Urban Forest

Out of the total respondents, 94.9% of them appreciated the establishment of new parks or urban forest in Addis Ababa. As a result, the research acknowledged that peoples live in urban areas is thankful for the construction of new parks or other types of urban and peri-urban forest due to a number of reasons.

Educational uses of urban and peri-urban forest/trees

Table 3.6: Educational backgrounds and perception of respondent on educational

Benefits of urban forest

Educational backgrounds of respondents	Type of educational benefits of urban forest								Total
	Teaching aids	lesson attractive	Helps students to understand their environment	Educational tripe	All Educational tripe	Provides reading place, shade and	Educational tripe	get relax when they out of class	
No formal Education	0	0	2	3	1	0	8	0	14
Elementary School(1-8)	2	0	0	0	2	3	14	1	22
High school (9-12)	7	1	0	1	13	12	13	0	47
Diploma	3	0	2	0	5	3	4	2	19
First degree	1	3	1	3	13	4	1	1	27
2nd Degree and above	0	0	0	0	9	3	0	0	12

61

Total	13	4	5	7	43	25	40	3	1	141

Source: Field Survey (2015)

Thus, this study shows that, people, who have different educational background have dissimilar perception on educational benefits of urban forests. In other words, the awareness of the people about the diverse educational benefits of urban trees decreases as educational level of the people decreases.

In addition to this, the sample respondents were asked to describe the benefits of urban forest for Higher Educational Institutes (HEIs) student's research works. As a result, about 73.7% of the respondents said that, it has benefit; 17.9% of them had no idea on the issue and 8.3% of them described as no benefit. Therefore, urban forests have great benefits for students of HEIs. Conner (2005) suggests that, Urban Parks endow with an opportunity for research partnerships with universities, scientific and industrial research organizations to inspect a wide range of biophysical, economic and cultural issues related to park and visitor management.

The national curriculums of Ethiopia value the natural environment in all-purpose. It ranges from grade 1 to12 in different subjects and in some faculties (for colleges and universities) based on the nature of the subject/field of study. On the other hands, it does not worth specifically trees in urban and prie-urban areas but, school curricula gives value for forest in general, teach students regarding the physical environment, conservation of natural resources, ecosystem, different climate regions and associated natural vegetation, causes ,effects and combating of climate change, plus drought, environmental protection and beautification etc.

Depending on the existing type, composition of the urban trees and nature of subject matter urban and peri- urban forests provides wonderful resources by way of which to support curriculum activities, helps curriculum developers to give examples and invite students on the way to visit trees in their nearby locality. According to Tibbatts (2002), Parks and green space provide schools with a living, breathing, totally interactive and frequently changing outdoor classroom, a wonderful resource with which to support core curriculum activities.

Since urban areas have been well covered with human made structures such as roads, buildings, institutions etc urban students in diverse grade level hardly ever get the chance to relate different types of urban and peri- urban forests with their much of theoretical knowledge about natural resources, plants and other related issues.

Perception of respondents on watershed function of urban forest

About42% of the respondents described watershed function of urban forest, as reducing soil erosion and runoff; 38% of them, as reducing soil erosion and runoff, protecting water bodies from sedimentation, providing clean water, recharging ground water resources, and protecting aquatic wild life habitat; and 12 % of them described, as protecting soil erosion, reducing runoff, providing clean water and recharging ground water. Therefore, the researcher justified that,

different type of urban and peri-urban forest have significant benefits for urban watershed management.

In terms of its effectiveness as well as price increasing vegetation and natural system combined with human made structures is good for better urban watershed management practice. According to, Cappiella et al. (2005) past approaches to restoring urban watersheds that have relied on structural solutions have failed to protect and restore urban streams. Many practitioners in the engineering community are now turning to vegetation and natural systems as a vital part of the solution; nevertheless, bringing these approaches together has not always been easy.

The current tree species and planting niche preferences of respondents

Eucalyptus and Junipers were the most common tree species preferred by the respondents and there are diverse species preferences in Addis Ababa.According to Bucur (2006), the main criteria to select trees for urban and suburban areas related to the growth and silvicultural requirements of each species.

People have preferred their private land, for planting niche than other place. In addition to this, people have gotten tree seeds mainly through purchasing from market.
The majority of the respondents have planted their preference trees for improving garden conditions. However, also they have other benefits of urban forest.

Tree species and Planting niche Preferences of Respondents in the Future

The majority of the respondents are interested to plant trees and they have different species preferences in the future, to some extent, they have perceived better for indigenous trees.
Still respondents preferred their private land to plant trees in the future than other place, like the current respondents preferences of planting niche.
The majority of the respondents have an aims of getting all benefits of convectional forestry through planting their preference trees in the future .It is beyond improve gardening condition unlike the respondents reason to plant trees in current situation.

Conclusion and recommendations

Conclusion

Urban forestry has various environmental, social and economic benefits. This research was intended to investigate public perception on the various uses of urban and peri-urban forest in Addis Ababa. Retaining city trees with in the city provides a number of benefits and also it has a number of concerns.Regarding the importance of different type of urban forest the result of this study shows, trees in parks are extremely important and followed by roadside tree plantation and trees in back yards respectively. Urban forests are a place the people can go to relax. Despite to this dwellers have visited the green areas/parks occasionally and across different age group inhabitants, in Addis Ababa have very little habit for visiting parks or other urban forest for recreational uses.The people who have contact with nature during their childhood have a good

habits and short time frequency to visit urban trees than the people who had spent their childhood in urban constituency. peoples live in Addis Ababa be thankful for the construction of new parks or other types of urban and peri-urban forest due to a number of reasons.

urban forest have educational benefit by providing teaching aid materials, making the lesson attractive, helping students to understand their environment and school to organized educational tripe, providing reading place and shade. Respondents who have different educational background have dissimilar perception on educational benefits of urban forests.Different type of urban and peri-urban forest have significant benefits for urban watershed management andin terms of its effectiveness as well as price increasing vegetation and natural system combined with human made structures is good for better urban watershed management practice.Eucalyptus and Junipers were the most common tree species preferred by the respondents and people have preferred their private land also have gotten tree seeds mainly through purchasing from market. The reason for they have planted their preference trees is to improving garden conditions.Finally, this study concludes that dwellers are interested to plant trees in the future and they have different species preferences. The majority of the respondents have an aims of getting all benefits of convectional forestry through planting their preference trees in the future .It is beyond improve gardening condition unlike the respondents reason to plant trees in current situation.

Recommendations

As the research have been shows the different uses of urban and peri- urban forests, to increase the various uses of urban trees the following recommendation provided:

- National curriculums should value the environment to increase the role of urban forests for education in different grade level and higher educational institution.
- Formulate a sustainable plan and strategy of urban forest development and management.
- The involvement of people in urban forestry should have increase.
- Initiation by government, NGOs on urban forestry (especially awareness programs) should have increase.
- Government and other concerning bodies should plant trees in appropriate place of the city property.
- The community should feel sense of ownership about urban forests.

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VALUES OF URBAN FORESTS: A CASE STUDY OF ADDIS ABABA, ETHIOPIA

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Abstract

Urban and peri-urban forests are important sources of livelihood diversification and ecologic services. Various urban dwellers in Sub-Saharan Africa depend on urban forests on varying degrees. This study was conducted to (i) identify and prioritize species and planting niche preference (ii) assess the role of trees and peri-urban plantations for the livelihood of urban dwellers (iii) assess the value attached (Willingness to Pay) to street trees and green areas by urban dwellers, (iv) evaluate awareness with regards to climate change and urban forests. Three sub-cities (namely Arada, Yeka and Kolfe-Keraniyo) and a total of 150 respondents were selected using a multistage sampling technique. A structured questionnaire and key informant interview were used as a data collection tool. The present findings show that trees are important for the livelihood of Addis Ababa's residents. Tree products collected by urban residents include fruits, fuelwood, wood for building, fencing and handicraft making and herbal medicines. At 0.05 alpha, the Pearson Chi-Square shows that generally households with lower income were found to use and/or sell tree products than wealthier households. About 65 % of the respondents were found to plant trees, mainly indigenous trees and the key reason behind it is their possession of medical properties. People hold higher WTP level (213 %) for the development of street trees compared to the WTP for urban parks and peri-urban forests. The study recommends that Addis Ababa municipality and sub-cities should focus on establishing new tree nurseries and expanding existing ones. Road-side trees are highly valued by respondents, meaning these resources should feature strongly in the master plan of the city.

Key words: Willingness to Pay, livelihood, fuelwood, tree product

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Introduction

An estimated 90% of poor people across the world depend on forest resources for at least part of their income (USAID, 2006). About 350 million people who live within or adjacent to the forests depend on the forest to a higher degree for subsistence and income (World Bank, 2004). Similarly, studies have shown that the urban poor largely depend on timber and non-timber forest products to diversify their income source (FAO, 1995).

According to CUFN (2005), urban forests include trees, forests, green spaces and related abiotic, biotic and cultural components in and around cities and communities (including peri-urban forests). Some of the most common examples of urban forests include trees on private property such as trees on homesteads, street trees, parks, and trees on the edges of towns (Bentsen et al., 2010). Whereas, urban forestry is a practice of planting, effectively managing and caring for trees in urban and peri-urban areas in order to originate economic, environmental and social benefits for urban dwellers (Horst, 2006).

Any of the world's largest cities rely on fully or partially protected urban and peri-urban forests catchment for their drinking water (Dudley & Stolton, 2004). Trees reduce storm, water runoff and have a big role in processing wastewater in urban areas. Urban trees can also protect soils and moderate harsh urban climates, for example, by cooling the air, reducing wind speeds and giving shade (Tyrväinen et al., 2005).

In addition to their ecologic services, urban and peri-urban forests are a great source of livelihood diversification in many parts of the world (Lanly, 2002). For instance, urban and peri-urban forest products are essential particularly for crafts like basket making and the commercial use of trees for construction, furniture, medicine and flooring industries. Furthermore indigenous craft industry thrives only when products like stones, wood and weaving grass are available (Kuchelmeister, 2000).

However, while the dependence of rural households on conventional forests and natural resources in Africa is well recognized (Kalaba et al., 2009; Legwaila et al., 2011), the benefits derived from these resources by households in urban areas are less understood (Kuchelmeister, 2000; Shackleton, 2006). Some authors (Bentsen et al., 2010; Kuchelmeister, 2000) have attributed this to the believe amongst scientists and development agencies in developing countries, that urban forestry is a young science and its contribution to livelihoods is perceived to be negligible. Thus, little is known about the tree products, or the different sources and strategies that urban households use. Few studies have been done in Ethiopia with regards to urban forests and their contribution to livelihood. For instance, more than two decades ago a study on the subject was done by Fekirte (1991). It demonstrated that many women, in Addis Ababa, back load branch-wood and leaves to markets in order to generate income and support their livelihoods.

Urban forestry is beyond a mere beautification of urban spaces. It has important ecological and socioeconomic services. Despite its importance however, the reality is that provision of food,

housing, sanitation and employment have the highest priority in urban settings of the developing countries (Konijnendijk & Gauthier, 2006). Therefore, in order to get the attention of decision makers and government authorities, research based evidences should come out that can signify the importance of urban forestry activities in supporting the livelihoods of urban communities.

The rapid expansion of the city of Addis Ababa and the lack of co-ordination while undertaking different development interventions like road construction and underground utility trenching work for telecommunication, sewers and water have posed a serious threat to its urban and peri-urban forests. And although the revised master plan allocates a total of 22 000 ha (41% of the city's total land cover), little has been achieved so far (Tenkir, 2012). To ameliorate the current situation there is an urgent need to identify and assess the economic benefits trees give to urban dwellers so that urban planners will gain an insight on the importance of urban and peri-urban forests. Thus, planners will formulate a sustainable plan and strategy of urban forest development and management and pursue it all the way through.

In many instances, research on urban-forestry usually concentrates on the public perception and on the degradation and destruction of these areas rather than on the benefits which can be derived from these forests by urban residents. Urban forests are important sources of livelihood for urban residents, especially the poor (Slater & Twyman, 2003). This study, therefore, seeks to highlight the extent to which urban forests can be used and managed for the benefit of the residents of Addis Ababa city.

Thus, the general objective of the study is to analyze the economic value of urban and peri-urban forests in the case of Addis Ababa city. The specific objectives of the study are to:
- Identify and assess types of forest products extracted from urban forests
- Assess the degree of dependence of Addis Ababa's dwellers on forest products for their livelihood
- Identify and prioritize the preferences of tree species and planting niche by urban dwellers in Addis Ababa
- Measure the value attached (Willingness to Pay) to trees and parks by the urban dwellers of Addis Ababa
- Assess the awareness of residents with respects to climate change with regards to urban and peri-urban forests.

Methodology

Description of the study area

Addis Ababa is the main center for economic, social and political affairs of Ethiopia (Gebre & Rooijen, 2009). The total area of the city is about 54 000 ha and the total human population, as of July 2010, was estimated to be 2,917,295 (CSA, 2010). Currently, the city administration covers an area equivalent to 54 000 ha and the revised master plan allocates a total of 22 000 ha (about 41% of the city) for green infrastructure, out of which 12,500 hectares of the land is expected to be made up by urban forests (Tenkir, 2012). However the vegetation coverage of Addis Ababa, including individual trees in private yards, is estimated to be 7,900 ha by the Urban Agricultural Office (UAO), which amounts to only 14.6% of the city's total area and is far less compared to the international standard.

Data type and collection method

The determination of dependence of households for their livelihood on forest products was considered to be a two-stage process. The first stage is whether respondents are using forest products to support their livelihood or not. The second stage involves what types of forest products they are extracting and to what extent they are dependent upon them for their livelihood. The second stage is called the "outcome" stage and was considered to be a sub-sample of the first stage, the "selection" stage.

Primary sources were employed; some secondary sources have been used when necessary. Quantitative and qualitative methods were used through a structured schedule. The schedule was organized as follows:

- A number or questions were designed to assess the dependence of respondents on urban and peri-urban forest products, in addition to questions designed to identify the types of forest products the participants employ either for own use or for market, and the magnitude to which their income is set up by forest related activities.
- The schedule also included questions on the planting niche and tree species preferences as well as the value attached to trees and green spaces by urban dwellers, which were done using the economic valuation method, Contingency Valuation.
- Additional questions were added in order to assess the awareness level of residents on issues related to climate change and urban forests.

The city of Addis Ababa has been selected for this study due to the fact that it is the largest city in the country and hosts more than 23% of Ethiopia's urban residents (PCC, 2008). The city of Addis Ababa is sub-divided into three divisions based on time passed since their settlement: the old, the middle-age and the relatively recent (Yimer et al., 2003). Within the old sub-division, there are the sub-cities of Arada, Addis Ketema and Lideta; while the sub-cities of Bole, Yeka, Kirkos and Gullele are in the middle-age division. The remaining sub-cities, namely Akaki-Kality, Nefasilk-lafto and Kolfe Keraniyo are found whithin the relatively recent division. Sub-cities found in the old city division have a low coverage of urban forests, while sub-cities under the middle-age and recent divisions, generally, have a coverage ranging from medium to high. From the older city division, Arada sub-city was randomly selected; Yeka and Kolfe Keraniyo were selected from the middle-age and recent city divisions respectively with a random selection. The selected sub-cities represent a relatively lower, moderate and higher coverage of urban forests, which can serve greatly to comprise respondents with different backgrounds.

Sampling procedure and sample size

According to the 2007 Population and Housing Census of CSA, the count of households in Arada is 49,564; 90,195 for Yeka and 97,287 for Kolfe Keraniyo. With a total of 237,046 households, the sample size (calculated with a confidence level of 95% and interval of 8) is equal to 150 households. The sample size is calculated using the following formula (Cochran, 1977):

$$Samplesize \;=\; \frac{z^2 \times p(1-p)}{e^2}$$

Where,   p= standard deviation (0.5 in this case)
                 e= margin of error (interval)
                 z= z score of the confidence level

A total of 150 households were assigned for all three sub-cities using PPS (Probability Proportional to Size). Accordingly, 31 households were selected from Arada sub-city, 57 from Yeka and 62 from Kolfe Keraniyo. From each sub-city a woreda was selected randomly. When selecting households, a simple random sampling technique was employed.

Methods of data analysis

The collected data was analyzed was using Stata 12.0. The analyses were presented using tables, graphs and charts.

The Pearson Chi-Square correlation was used to see if there were associations between habit of planting trees and ownership of house of residence as well as years of residence. Descriptive statistics were done on the WTP levels. All calculated monetary units are based on the Ethiopian currency, in Ethiopian birr (ETB), which was equivalent to 20.49 USD at the time of data collection (National Bank of Ethiopia, 2015). Regression analyses were also done to estimate the relationship between the various WTP levels and household characteristics. The analyses were done using a truncated OLS (due to existence of outliers) for the regression model:

$$Y_i = a + \beta X_i + e \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

The models used the underlining assumptions that the model error, e, is independently and normally distributed and has expected value of zero and equal variance in the target population (Douglas andPeck, 2001).

In Addition to the above, the study also employed a binary logit model. The model was used to estimate the awareness (on climate change and urban forests) of respondents based on household characteristics.

Results and discussion

Dependence on forest products

About 8% of the respondents make a living that is related to urban and peri-urban forests (i.e., at least 30% of their inputs has to come from these areas). When asked by how much the household income is formed by these urban forest related activities, each of the respondents stated different proportions that ultimately resulted in a mean of 28.07%. The highest level of income composition is observed in the fuelwood carrying and selling activity, with one respondent revealing that 71-80% of the household income is based on this business.

Among the respondents there are fuelwood sellers and fruit venders. As reported by Tenkir (2012) about 10,500 women in Addis Ababa are currently engaged in fuelwood collection and selling especially from peri-urban forest areas.

Types of forest products utilized and the rate of use

Half of the respondents have admitted to selling fuelwood and/or using it for own consumption. With 20 % of them, doing so seven or more times per year. According to the findings, 77.3 % of those who use fuelwood are doing so because it is much cheaper compared to the input cost of other cooking appliances. Roughly 23 % of people said they have sold and/or used timber from their own holding within the past 12 months. A lower proportion (18.7 %) has made handicrafts and wood objects (like traditional chopping boards, and simple seats) either for their own use or for selling on the market; with only one respondent having done so seven or more times within a year. Half of the respondents use fruits and seeds either for own consumption or for supplementing their livelihood by selling these products on the market. Furthermore 62% of the respondents were found to have been selling and/or using leaves and roots for medical purposes, with 21.7% doing so because they cannot afford the medical bills.

About 77% of the respondents use fuelwood because, as they have reported, is cheaper compared to other input types; nearly 67% of them use fuelwood also for big occasions. On the other hand, 33.3% said they are forced to use fuelwood with traditional cooking instruments, because buying other cooking appliances is not an option due to financial limitations. In addition to this, 46.7% of respondents said they use fuelwood when there are power cuts.

Use of forest products by income

The study evaluated the relationship between income and forest products. The study found that there is no statistically significant relationship between using and/or selling fuelwood, timber and wooden handicrafts and household income level. Whereas statistically significant relationships were found for the rest of the forest products, namely fruits and seeds, medicinal leaves, roots and oils, in addition to using of trees for hanging clotheslines. To further decide on the statistical relevancy of the relationship a Pearson Chi-Square test was performed. With alpha set to .05, the respective Pearson Chi-Square of the three variables indicates that there is a statistically significant relationship between household income and the three variables.

For instance, respondents with a household income of less than 5,000 ETB and above 14,001 ETB are more likely to never use or sell fruits and seeds from their own holdings. For the former, this may be because they may not be able to afford a spacious residential area, where they can plant trees (ex. condominiums); while the latter are less likely to utilize this resources for supporting their livelihood, because they have a higher income and hence are less likely to depend on these types of resources. In fact, only respondents comprised within the middle three income groups (5001-8000; 8001-11000; 11001-14000 ETB) are more likely to use or sell fruits and seeds from their own holdings. In line with the findings, studies have shown that home gardens and community gardens in low-middle income areas are the cheapest and the most readily available sources of nutrition (Ninez, 1985; Gallaher et al. 2013).

For the variable of using or selling medicinal leave and roots from own holdings, the same line of argumentation applies for it as well. The third and final element in the investigation is the use of trees for hanging wires and clotheslines. Households within the first two income groups (less than 5,000 ETB and 5,001-8,000 ETB) are more likely to use trees to hang wires and clotheslines. This finding is supported by a study conducted by Gopal and Nagendra (2014) in a

slum in India, which found that most trees in the area have the function of supporting clotheslines, tents and wires.

Tree preference and planting niche

A Chi-Squared test was computed with an alpha of .05 (with 95 % confidence) to test the A Chi-Squared test was computed with an alpha of .05 (with 95 % confidence) to test the existence of a relationship between habit of planting tree and owning own place of residence. Findings showed that there is indeed a relationship, meaning that people who own their houses are more likely to plant trees. This may be due to the fact that tenants lack stability, as they often don't stay for long in one place and don't feel as if they will stay for long enough to enjoy the grown tree.A vast number of the respondents (59%) prefers indigenous tree species, whilst only 4% said that they cannot distinguish between indigenous and non-indigenous species. The percentage share of those who prefer non-indigenous (exotic) species is lower than of those who are indifferent between the two.

Respondents were asked for the reasons for their preferences. About 28.8% said they preferred indigenous species solely due to the fact that they have medical properties. While 37.3 % said to prefer them due the combination of their medicinal properties and attractive nature and because they require less time and resources to grow. Only 3.4% of the respondents selected indigenous species solely because they believed they are fast growing. On the other hand, 58.3 % of the respondents preferred non-indigenous species solely because they believed these species grow faster than indigenous trees.

Although the majority of respondents prefer indigenous species, about 62.8 % of the forests within the city of Addis Ababa are made up of exotic tree species (Tenkir, 2012). Similarly, McConnachie et al. (2008) reported that 59.9 % of the trees in public urban green spaces in South Africa are exotic. Likewise, higher proportions (69 %) of trees in Togo were non-indigenous trees (Raoufou et al., 2011). Contrary to this, this trend is not observed in the developed countries. For instance, study reports in Europe, the US and Australia, show lower percentages of exotic tree species, 40.3, 32.1 and 40 % respectively (Clement & Moore, 2003; Frank et al., 2006).

The tree species preference rankings and the common uses reported by the respondents have been presented in Table 1. As shown, all trees have numerous uses. In fact, researches show that trees in urban areas are used for multiple purposes (Fuwape & Onyekwelu, 2011; Raoufou et al., 2011). For instance, people may plant trees for their yield of fruits, but use them in the meantime for other purposes, like hanging clothesline and wires, and later on as fuelwood (Uddin and Hasan, 2001).

Table 1: Tree Species Ranking and Their Common Uses

Specific name	Common name	Frequency	Rank	Common Uses
Malus Domestica	Apple	84	1	Fruit; Ornamental
Eucalyptus	Eucalyptus	55	2	Fuelwood; Medicine;

Globulus				Timber; Clotheslines
Persea Americana	Avocado	46	3	Fruit; Ornamental; Shade
Olea europea L. ssp. Cuspidata	Olive	36	4	Medicinal; Shade; Insect repellent; Teeth cleaning
Vernona Amygdalina	Bitterleaf	32	5	Medicinal; Shade; Clotheslines
Prunus	Plum	28	6	Fruit; Ornamental; Shade
Juniperus Procera	East African cedar	26	7	Ornamental; Fuelwood; Medicinal; Fencing material
Rhamnus Prinoides	Dogwood	26	7	Edible items; Clotheslines; Shade
Ensete Ventricosum	Enset	26	7	Fodder; Edible items; Ornamental

Source: Own survey

The study has found that 87% of the times, respondents plant the selected tree species within their compound. This has especially been observed for fructiferous trees, which may be due to their obvious economic benefit. Roughly 8% of the time, respondents prefer to plant the selected tree species around their fences, again this is frequently observed for species that grow thick like *Cupressus lusitanica, Juniperus procera* and *Doryalis abyssinica*. However, *Ensete ventricosum* is among the list. On the other hand, roughly 3% of the respondents indicated peri-urban areas as their preferred setting for planting trees.

According to the findings, about 79.3 % of the participants would get the seedling of their preferred tree species from the market, where as 10 % will use own seeds and seedlings. Only 4.3 % of the respondents expect to receive seedlings/seeds from the Municipality of the city of Addis Ababa; 5.5 % of the participants, instead, expect to get the seedlings from other sources such as neighbors and relatives. Most of the tree species that are bought from local markets are fruit trees like *Malus domestica, Prunus, Persea* Americana and Arbutus unedo; as well as the Coffea Arabica tree species. The tree species that is mostly expected to be supplied by the Municipality is the *Juniperus procera*.

Willingness to pay

Respondents were asked to air their Willingness to Pay for urban and peri-urban forests, using two different indicator values. They are: WTP for the development of street trees (WTP1) and for development of parks, trees in public areas and peri-urban forests (WTP2).

The following means are calculated by taking into account all observations (including the null values).

Table 2: Mean and S.D. of WTP levels

	WTP1	WTP2

Mean	55.95	26.16
Std. Deviation	126.52	40.93

Source: Own survey

However, the problem with Contingency Valuation methods is that sometimes null values are given for environmental services. If the null value genuinely reflects the true Willingness to Pay of the respondents, no problem arises. However, reality is that most of the time these type of responses are "protest" answers: either against the interviews or against the public administration or sometimes against both (Mitchell & Carson, 1989). Most studies, for simplicity's sake, simply take out the observations with null values and carry on with their analysis. However, this will not be accurate as true zero WTP levels will be excluded from the model, and hence create bias. In order to avoid such bias, this study has employed follow-up questions in order to determine whether a particular zero value reflects the true value that the respondent attaches to the environmental good or if it is indeed a "protest" answer. For the purpose of this study, those who answered the follow-up question with "I am not interested" and "GOs and NGOs should take care of it" are dubbed as protest answerers.

Table 3: Mean and S.D. of True Willingness to Pay

	WTP1	WTP2
Mean	58.28	30.90
Std. Deviation	128.62	42.82
Valid Observations	144	127

Source: Own survey

After the elimination of protest responses from the sample, the true Willingness to Pay was evaluated. The mean WTP level for street trees is higher compared to the mean value for the development of urban parks and peri-urban forests. This outcome is in line with the findings of a study done by Getz et al. (1982), which concludes that individuals attach greater importance to street lined trees than to parks and other wooded areas.

Further analysis was done in order to understand which factors influence the WTP levels. However, during preliminary examinations, the existence of outlier WTP levels was discovered. Therefore, in order to eliminate their effect, a truncated regression was performed by setting an upper limit at 151 ETB WTP values. Accordingly, Table 4 depicts results of the truncated OLS regression for the WTP level for the development of street trees.

Table 4: Results of Truncated Regression for WTP Levels for Street Trees (ETB)

WTP1	Coefficient	Std. Err.	z	P>|z|
Income	.0025924	0.0006593	3.93	**0.000**
Gender (female)	-13.51522	5.146693	-2.63	**0.009**
Age	-.1551678	0.1877337	-0.83	0.409
Education				
Primary school	-3.992978	7.576674	-0.53	0.598
Secondary school	23.71703	7.765135	3.05	**0.002**
Post-secondary	34.71325	8.204502	4.23	**0.000**
Marital Status				
Divorced	6.560617	7.542616	0.87	0.384
Widowed	8.263793	6.648226	1.24	0.214
Single	1.850077	7.986822	0.23	0.817
(constant)	20.70082	11.6882	1.77	**0.077**
/δ	25.86675	1.576088	0.41	0.000

P<0.10

Note: N=136; UL=151 ETB; Wald Chi2(9)=89.75; P>chi2=0.0000; Log likelihood=- 635.23

Source: Own survey

The findings show that age does not have a significant influence on the dependent variable. Similarly, neither of the dummy variables for marital status are statistically significant. On the other hand, income is positively and significantly related to the WTP level for the development of street trees; as income increases by 1 ETB, *ceteris paribus*, WTP level for street trees increases by approximately 0.003 ETB. The findings also suggest that, other things kept constant, females hold a lower WTP level by 13.52 ETB. Compared to those that have no formal education (the base group for education), the predicted WTP level of those that have secondary level education increases by about 23.71 ETB. Nevertheless to conclude whether education, itself, is statistically significant, a three-degree of freedom Chi-Square test was done. The result (0.0000) indicates that education level is statistically significant for this model.

The same model specification is employed for WTP levels related to the development of urban parks, trees on public spaces and peri-urban forests, with one exception: climate change awareness is added as an explanatory variable. This is because it was predicted that awareness on climate change related issues will have an impact on the WTP for these types of urban forests, more so than street-side and road-side planting. The results are presented in Table 5

Table 5:Results of Truncated Regression for WTP Levels for (peri-) urban forests (ETB)

WTP2	Coefficient	Std. Err.	z	P>|z|
Income	.0023923	.0006182	3.87	**0.000**
Gender (female)	-4.775715	5.088898	-0.94	0.348
Age	-.4572775	.1858701	-2.46	**0.014**
Education				
Primary school	7.338005	7.943056	0.92	0.356
Secondary school	22.54543	8.069199	2.79	**0.005**
Post-secondary	23.57897	8.803083	2.68	**0.007**
Marital status				
Divorced	11.68145	7.213062	1.62	0.105
Widowed	11.88944	6.775333	1.75	**0.079**
Single	-3.558567	8.076571	-0.44	0.659
Aware	13.79671	5.368406	2.57	**0.010**
(constant)	15.02572	12.00851	1.25	0.211
/δ	24.79787	1.575509	15.74	0.000

P <0.10

Note: N=124; UL = 151 ETB; Wald Chi2(9) = 51.60; P>chi2 = 0.0000; Log likelihood= -574.07306

Source: Own survey

Again, similarly to the first scenario, income has a positive and significance relation to the WTP level: as income increases by 1,000.00 ETB, while all other variables are kept constant, the WTP increases by 2.40 ETB. Age is also significantly related to the WTP level; however it displays a negative relationship, which means that as age increases by 1 year the WTP level decreases by 0.46 ETB, *ceteris paribus*. The two dummy variables for education show a significant and positive relation. With three-degrees of freedom Chi-Square test, the result (0.0270) indicated that overall education is statistically significant. On average, compared to the respondents without formal education, the predicted WTP of those who have a secondary school and post-secondary education level increases by 22.55 ETB and 23.58 ETB, respectively. The dummy variable for those who are widowed exhibits a significant relationship to the WTP level. However, the three-degrees of freedom Chi-Square test result (0.1884) show that the marital status of a person is not statistically significant to the model. Controlling for all other variables, those who are aware on climate change related issues will pay, on average, 13.80 ETB more than those who are not aware.

When we compare both models, income and education are significant determinants. While gender showed a significant relationship in the first and age in the second. As shown by numerous other studies (Verbic & Erker, 2007; Khuc, 2013), income and education do always have a positive and significant impact on WTP levels for environmental services.

In the study of the WTP for the development of street trees, it was found that women have a lower WTP level. This may be the result of, particularly in developing countries, men earning more income and having a greater decision-making power in the family, compared to their female counterparts. These findings are in line with previous studies by Ajewole (2001) and Adekunle *et al.* (2008). The second regression model shows that awareness is a significant determinant of the WTP level. According to a finding by Verbic and Erker (2007), aware and conscientious respondents are more likely to have a higher WTP, compared to those who are not.

Awareness on climate change and urban forests

To assess the awareness of Addis Ababa's residents, a number of questions on that regard were included in the schedule. Respondents were asked whether or not they knew of the concept of climate change and the role forests have with its regards. Unfortunately no follow-up questions were added to test their level of awareness on climate change. The majority of the participants (56 %) know about the concept of climate change and the role forests play in its mitigation. Based on this data, the research estimated the influences on awareness by using demographic features as explanatory variables (Table 6).

Table 6: Awareness Prediction with Logistic Regression

Aware	Coefficients	Std. Err.	z	P>|z|
Gender	0.192775	0.4375856	0.44	0.660
Education				
Primary school	1.450208	0.5877581	2.47	**0.014**
Secondary school	1.670992	0.5890114	2.84	**0.005**
Post-secondary	2.919702	0.7593606	3.84	**0.000**
Income	-0.0000215	0.0000536	-0.40	0.689
Age	-0.0236669	0.0159948	-1.48	0.139
(constant)	0.3535042	0.9949175	0.36	0.722

P <0.10

Note: N=150; LR Chi2(7)=45.53; P>Chi2=0.0000; Pseudo R2=0.2212; Log likelihood= -80.13

Source: Own Survey

The likelihood ratio Chi-Square of 45.53 with a p-value of less than 0.0001 means that the model as whole fits significantly. Gender, income and age have no statistical significance. However, the three indicator variables for education are statistically significant. Having attended primary school, versus no formal education, increases the log odds of being aware by 1.45. Having a secondary school education, as well, increases the log odds by 1.67, which is slightly higher than that of secondary school versus the base group. To test whether the overall effect of education is statistically significant a Chi-Square calculation was computed. The result (=0.0001) shows that the overall effect of education on climate change awareness is statistically significant.

The logistic regression on awareness has a McFadden's R-square of 0.221. According to Louviere et al. (2000), any value of pseudo R-square ranging from 0.20 to 0.40, is a very good

fit. To further demonstrate the goodness of fit of the model, a Hosmer-Lemeshow (HL) test was computed. With the most used 10 number of groups, the resulting Hosmer-Lemeshow chi2 (of 8 degrees of freedom) is 5.38, with a p-value of 0.7034. As the p-value gets closer to 1, it means that the model is well fitted.

Further analysis was done in order to check for specification error. The linear predicted value is significant at p < 0.001, while the linear predicted value squared is not significant, which means that the model has no specification error. The overall conclusion is that the model fits well to the data and has been specified correctly.

Conclusion and recommendations

Conclusions

Trees in urban and peri-urban settings are important to the livelihoods of Addis Ababa's residents. The dwellers' collect various tree products, including fruits, fuel wood, wood for building, fencing and making handicrafts as well as herbal medicines and the like. Considering all households in this study, it was found that almost half of the respondents use and/or sell fuelwood and fruits from their homes. Generally, households with lower incomes were found to use and/or sell tree products (fruits, herbal medicines and oils, use of trees for hanging clotheslines) than those who earn higher incomes.
A significant relationship was found between those who own a residence and those who lived in the same place for longer periods of time. According to the research findings, the majority of the people prefer indigenous trees. The common reason behind their preference was is that these trees have more medicinal properties compared to exotic species.

The apple tree (*malus domestica)* is the most preferred specie, followed by eucalyptus (eucalyptus globulus), avocado tree (*Persea americana*) and Olive (*Olea europea* L. ssp. cuspidata). Most of the selection of tree species is based upon their ability to yield fruits. While their medicinal properties come second. Most of the people would get their preferred species from the market, with only a smaller fraction being provided by the municipality.

People hold a higher WTP level for the development of street trees. The WTP level for the development of urban parks and peri-urban forests is considerably lower. The OLS regression done on both WTP levels indicates that income and education are statistically and significantly related to both WTP levels.

The majority of people were found to be aware of the concept of climate change and the role of forests. Education was found to be statistically related to individual's knowledge of climate change and the role forests have with its regards.

Recommendations

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- Due to the dependence of households on forest products, there is need for urban planners to create forest areas where those with low income and those that do not have access to electricity can collect tree products. Doing so would also serve to promote the conservation of indigenous tree species within urban areas. The municipality can also introduce affordable fees for collecting tree products from these areas, so that enough funds can be raised for planting new trees and sustainably managing the woodlands.
- The municipality could also get more involved in establishing new tree nurseries and expanding existing ones. This is so that tree seedlings can be distributed at lower charges. In addition to this, due to the fact that fruit trees are mostly preferred, providing residents with such trees will also serve as livelihood improvement of the dwellers of the city (especially the poor) in addition to expanding the city's forest coverage.
- Initiatives for developing urban forestry programs must pay significant attention to the more commonly recognized benefits of urban trees. For instance, the "ornamental and shade" dimensions can be addressed by selecting trees with such attributes for planting at the road-side.
- Road-side trees are highly valued by the people, meaning these resources should feature strongly in the master plan of the city.
- At a 95% confidence, it is concluded that those with higher education level have higher WTP levels, indicating that there might be lack of awareness among those with no education or lower levels of education. Awareness raising activities are, therefore, recommended.
- To supplement the findings of this study, it will be necessary to conduct a cost-benefit analysis with respects to Addis Ababa's forests, in order to make a stronger case for the development of these areas.
- Further studies should be done with respect to the awareness level of residents about climate change.

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ECOLOGICAL RESTORATION OF SOILS AND VEGETATION THROUGH AREA EXCLOSURE IN TANQUA ABERGELE WEREDA, CENTRAL TIGRAY, ETHIOPIA

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Abstract

Comparative study was conducted in an exclosure and an adjacent free grazing land in the interior of Tekeze river basin, Tanqwua Abergelle district, Ethiopia to characterize changes in chemical and physical soil properties and vegetation. A total of 16 circular plots (each with 10 m radius) were inspected. Soils of the exclosure had significantly ($p < 0.05$) higher soil organic matter (SOM), total nitrogen (TN), organic carbon (OC), carbon to nitrogen ratio (C/N), and magnesium (Mg^{2+}) but lower pH values as compared to the grazing area. No significant differences were detected in Na^+, K^+, Ca^{2+} and CEC values between the land uses. The abundance of woody tree/shrub species ha^{-1} in the exclosure was nine times greater than that of the grazing land. Based on the IVI, *Albizia amara, Dodonea angustifolia* and *Terminalia brownii* were structurally the top three most important tree species in the exclosure. From all recorded species, the proportion of trees/shrub, sapling and seedlings accounted for 69 %, 21 % and 10 % in exclosure and 59 %, 13 %, 28 % in grazing land, respectively. The overall woody species diversity was also significantly (p=0.003) higher (H'=1.42) in exclosure than in grazing land (H'=1.20), indicating different levels of disturbance have different effects on woody species diversity. Benefits from the exclosure included various wood and non-wood products, reduced runoff and gully rehabilitation and creation of small streams. Thus, to tackle the problem of land degradation, improve soil quality, reduce sedimentation of the Tekeze grand dam and maximize socioeconomic benefits, further expansion of exclosures and their thoughtful management is required.

Key words: Exclosure; free grazing land; Floristic composition; Diversity; Soil physicochemical

Introduction

One of the principal environmental problems in Ethiopia that is challenging rapid and sustainable development is land degradation, which is happening in the form of soil erosion and loss of soil fertility. Land degradation is heavily attributed to the large scale deforestation, which in Ethiopia has been taking place unrestrained for long years. Deforestation and/or over exploitation of the woody vegetation's, overgrazing, expansion of cropland and farming of fragile hill slopes and non-optimal use of natural resources are the main causes of land degradation in Tigray Region (Nyssen et al., 2002). The expansion of agriculture, especially towards the steeper slopes due to ever growing population, has exacerbated soil erosion.

Severely degraded lands are typically characterized by heavily eroded or nutrient deficient soils, hydrological instability, reduced primary productivity and low biological diversity (Verma et al., 1999). The prolonged degradation of dry land areas continues to affect the service year of grand Tekeze dam by sedimentation as well as the productivity and the diversity of forest resources. Hence, sustainable conservation and utilization of the remaining dryland vegetation resources and rehabilitation of those that have already been degraded would provide economic, social and ecological benefits. This requires designing economically feasible, socially acceptable and ecologically viable management and conservation strategies of dryland vegetation. In this regard, the government of Ethiopia has initiated a number of projects including soil and water conservation works and the establishment of area exclosure (Nedessa et al., 2003).

According to Nedessa et al. (2005), area exclosure in the Ethiopian context is defined as degraded land that has been excluded from human and livestock interference for rehabilitation. Primarily, human and animal interference is restricted in area under exclosure to encourage natural regeneration (Brhane, 2002). Exclosure is one type of land management and a tool for restoration of natural resources such as soil fertility, vegetation biomass and composition, fauna and water storage, biodiversity and generally productivity of the area. It is usually applied on steep, eroded and degraded area and becoming pertinent strategy in dryland areas where plantations are unsuccessful due to many reasons (Descheemaeker et al., 2006; Mekuria et al., 2007). Despite the fact that exclosures have proved instrumental in the re-vegetation and rehabilitation of degraded lands, comprehensive studies on vegetation diversity, composition, structure, status of regeneration of the developing flora as well soil physicochemical benefits that can be derived from such exclosures were lacking in the study area.

Tanqwua Abergelle Woreda in the lowlands of Central Zone of Tigray, and part of the Tekeze river watershed near the Tekeze grand dam, is among the areas affected by profound

land degradation and associated consequences. The unmanaged land use especially in the marginal dry mountain open lands resulted in ecological degradation and loss of endemic components of biodiversity and in sedimentation of the Tekeze dam. Hence this demands urgent response of protecting the degraded and susceptible areas, including the Tekeze grand Dam.

The general objective of this study was to investigate the role of area exclosure in rehabilitation and restoration of degraded land and identify options for improved management of rehabilitation areas in Abergele Woreda, Central Tigray. The specific objectives were (1) to investigate soil physicochemical properties in exclosure and open access grazing land, and (2) to compare and enumerate the regeneration status, woody species composition and structure between exclosure and adjacent open access grazing land.

Material and Methods

Study site description

Location

Tanqwua Abergele is one of the 47 Woredas in the Tigray Regional State, and is situated in Central Zone of the Region, and has a size of 2408 km^2. Abergele is bordered on the south west by the Amhara Region, on the west by the Tekezé River, on the north by Kola Tembien, on the east by Degua Tembien and on the southeast by the Debubawi (Southern) Zone of Tigray.
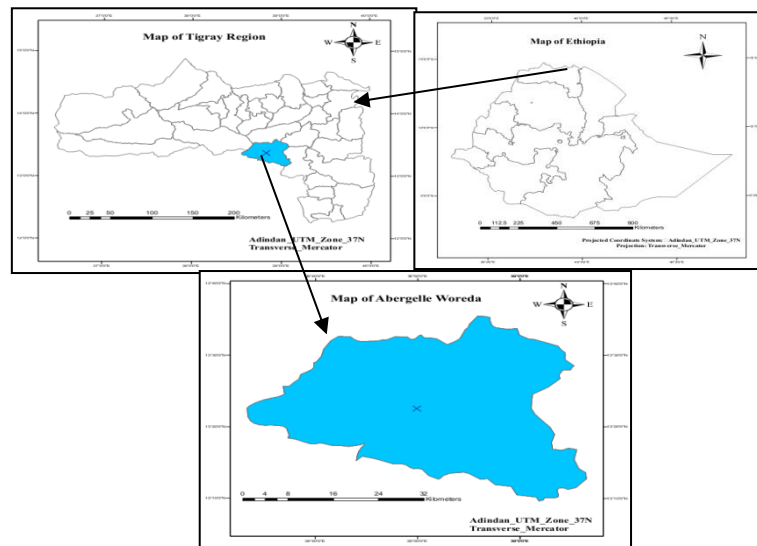
Figure 8: Map of study Woreda; Abergele district central zone of Tigray

The administrative center of this woreda is Yechilla, which is about 990 km north of Addis Ababa. Abergelle Woreda is located within $13^0 29'30''$ to $13^0 9'37''$N and $38^0 33'25''$ to $39^0 6'25''$E. The altitude of the study area ranges between 1700 m and 1900 m a.s.l.

Climate

The study area has an average monthly temperature ranges from $25 - 35\ ^0C$ and an annual average rainfall between 350 mm to 550 mm. Rainfall distributions is unimodal with a single rainy season, extending between June and September (WoARD, 2006).

Topography, geology and soil

The area is comprised of diversified topographic features; mountains and hills, alluvial and undulating plain with gentle to steep slopes. Rills, gullies and dry river beds are common features of the study area. Large parts of central Tigray zone, including Abergele Woreda, are covered by volcanic rocks, mainly basalts of tertiary age. Due to excessive erosion, large areas are covered by shallow soils which include Arenosols, Vertisols and Cambisols, as the major soil types of Woreda (AgSE, 2001). The soil in the area is largely light brown and has sandy loam texture (WoARD, 2006). The soils on sloping and sparsely vegetated hills are heavily eroded due to human activities and high intensity rainfall. This results in the formation of rills and gullies and flooding on low lying areas at the base of the hills. The soils on the hill tops of the area are rocky with poor agricultural potential.

Land use and tenure

The predominant land use types of the study Woreda are subsistence mixed farming which is rain fed crop production with livestock rearing. The average land holding of a household is 1.6 hectares, of which 87.4% is cultivated land, 0.2% pasture, 10.7% fallow, and 1.7% was devoted to other uses (CSA, 2001). Land tenure in this Woreda is distributed amongst 84.8% owning their land, and 14.9% renting (WoARD, 2006).

Population

The Woreda currently has a total population of 104,686 (i.e. 53,350 men and 51,336 women) with close to 44 persons per square kilometer (CSA, 2012). About 8.5% (8914 people) are urban dwellers. The mean household size in the area is 4.7 persons.

Vegetation

The natural vegetation is dominated by scattered indigenous trees and *Acaciaspp*. In the study area scattered indigenous trees such as *Albizia amara*, *Dodonea angustifolia,* and *Acacia spp.* indicate that the area has been covered by these trees some years ago. Exotic tree species such as *Eucalyptus globulus*, *Cassia alexandrina*, and *Azadirachta indica* tree are planted especially on homesteads and farm boundaries and structures (MTLZ, 2006).

Study design

The study was designed in such a way that data could be gathered on biophysical (soil and vegetation) aspects in the exclosure and grazing land. Biophysical surveys were systematically laid in the exclosure and the free grazing land. Locations of the plots were marked by GPS, straight forward direction in a given line transect and the turning points' at end of each line transect was kept at right angle using compass, and slope along transects was measured using clinometers. The plot shape for vegetation survey used was circular. The first transect line and the first sample plot on the first transect was laid randomly. Along each line transect, concentric circular sample plots were laid systematically at 150 m interval in the exclosure and grazing land. Each transect line was composed of four concentric circles (Figure 2), following Ostrum (2007). The distance between transect lines was 500 m. The total number of sample plots was 16.
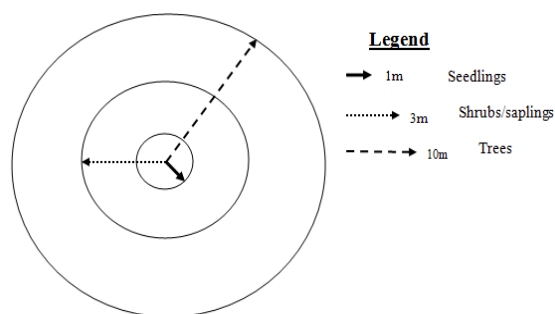
Figure 9: Layout of radial dimensions for concentric circles of a sample plot

Soil sampling

Within each position in the exclosure and free grazing land, two parallel transects were laid out and four soil sampling concentric circles along the transect lines were selected using systematic sampling. Then four composite soil samples were collected from each transect line of the two land use type i.e. a total of eight composite samples from each land use used for chemical soil properties and soil texture. Auger soil sample was used for taking individual composite samples to a depth of 15 cm and undisturbed soil sample were taken by core sampler for analysis of bulk density to the depth of 0-10 cm and10-20 cm.

Accordingly, the eight composite samples were analyzed for soil pH, organic matter content, Cation exchange capacity, total nitrogen, available phosphorus and available potassium, exchangeable bases, soil texture and bulk density.

The soil physicochemical properties were analyzed at the National Soil Testing Center, Addis Ababa. Soil pH (1:2.5 soil-water suspensions) was determined with electrodes, organic carbon by oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid medium (Walkley and Black, 1934), where 58% of the soil organic matter content was soil organic carbon. Total nitrogen was determined by semi-micro Kjeldahl and available phosphorus by sodium bicarbonate ($NaHCO_3$) extraction (Olsen) procedures. Available potassium was extracted by sodium acetate method and measured by flame photometer. Cation exchange capacity was measured by ammonium acetate (1 N NH_4OAc) extraction and, exchangeable

calcium and magnesium by ammonium acetate extraction and measured by the atomic absorption spectrometry (AAS) method (Page et al.,1982).

Physical degradation was assessed using bulk density and texture. Bulk density of undisturbed soil sample was taken using core sampler. Mass of solid soil and the water content of the core was determined by weighing the wet core and then dried to a constant weight in an oven at 105^0C for 24 hours and reweighing after cooling. Bulk density was then calculated from the measurement of the bulk volume, using the core length and the diameter of the cutting edge of the sampler. Soil texture is analyzed using Hydrometer method (Carter, 1993).

Vegetation survey

To assess the regeneration status of woody plants, through examination of their population structures, all individuals encountered in the plots were grouped arbitrarily into seedlings (individuals with height <=1m), sapling/shrub (individuals with height > 1m and diameter size <=2cm) and trees (individuals with DBH of >2cm). Individuals with more than one stem (forked into two and more stems below 1.3 m (breast height) above the ground were treated as individuals of the different tree and individuals (single stem, forked or growing in a bunch) were considered as single individual in counting individuals for density calculation (Derero et al.,2003).

Here the difference between trees and shrubs will be; trees are woody, perennial plants that have one central stem, are generally more than 2cm in DBH and normally have a distinct head; while shrubs are woody, perennial plants that have number of stems usually produced from near the soil line of the plant. Saplings/Shrubs are generally less than 2cm in diameter and seedlings are individuals with two leaves above cotyledon with height < 1m (Derero et al., 2003).

All tree species at the sizes of tree and sapling/shrub were measured. Heights and DBHs for the trees were measured and recorded. Diameters and heights were measured using diameter tape and hypsometer, respectively. Within each circular sample plot, the number of individual seedlings of different species was directly counted. During counting chalk and ribbon was used to mark trees and shrubs as they were counted, to ensure that they were not missed, or double counted.

All woody plants with in the sample plots were identified and recorded. Voucher specimens were collected, coded, pressed and dried for subsequent identification. Plant species identification was made using a combination of farmers' personal knowledge, Flora of Ethiopia and Eritrea (Edwards *et al.,* 1997), and Useful Trees and Shrubs for Ethiopia (Azene*,* 2007). Some plant specimens, which were difficult to identify, were submitted and identified at the National Herbarium of Ethiopia, Addis Ababa University.

Soil data analysis

The soil data was subjected to one-way analysis of variance (ANOVA). But, for computation of bulk density two-way analysis of variance (ANOVA) was used. The Multiple Comparisons test using Honest Significance Difference (Tukey's HSD) was employed for mean separation for those properties that were significantly different. The level of significance used was at $p = 0.05$. Data should be analyzed using SAS (Statistical Analysis Software) (Ver. 9). The outcome of this result could be used for inferring the contribution of exclosure for sustainable management of land.

Vegetation data analysis

For structural data analysis, woody species density, IVI, height and DBH were used for description of vegetation structure. The vegetation data of the tree species was calculated and summarized on Microsoft Excel spreadsheet andPAST software (Ver. 11) using the formulas listed below.

Importance value index (IVI) was used as a measure of species composition that combines frequency, abundance and dominance importance values (Newton, 2007).

Importance Value Index (IVI) for each species = RD + Rd + RF ....Equation (1)

Relative Density (RD) = Number of individuals of tree species/Total number of individuals * 100.........Equation (2)

Relative dominance (Rd) (relative basal area) = Basal area of individual tree species/Total basal area * 100.....Equation (3)

Relative frequency (RF) = Frequency of tree species/Frequency of all species *100...................Equation (8)

Many measures exist for the assessment of similarity or dissimilarity between vegetation samples of the two land uses. From many alternatives available, the Sorensen similarity coefficient is applied to enumerate data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample (Kent and Coker, 1992). The Sorensen coefficient of similarity ($\mathbf{S_s}$) is given by the formula;

$$S_s = \frac{2c}{2c + a + b} \ \ldots\ldots \text{ Equation (4)}$$

Where: $\mathbf{c}$ = the number of species in common
$\mathbf{a}$ = number of species in one site and
$\mathbf{b}$ = number of species in other site

Results and discussion

Land use and soil physicochemical properties

It was assumed that the exclosure and the adjacent communal grazing land had similar conditions before the establishment of the exclosure. The most evident impact of grazing on the rangeland ecosystem was removal of a major part of above ground biomass by livestock and therefore the input of aboveground litter to the soil decreases.

Soil chemical properties which showed significant increases in the exclosure when compared to the grazing land were Mg2+, TN, OC, SOM and C/N (Table 4).

Table 16: Mean (±S.E.) of soil chemical properties in exclosure and free grazing land

| Parameter | Mean (±S.E.) of soil chemical properties | | | |
	Exclosure	Grazing land	p-value	% of Reduction
pH	6.08±0.13	6.55±0.14	0.027*	7.18
EC	0.05± 0.003	0.07± 0.03	0.412[ns]	28.57
Na^+	0.12± 0.02	0.11± 0.02	0.688[ns]	8.33
K^+	0.26± 0.03	0.31± 0.04	0.281[ns]	16.13
Ca^{2+}	8.44± 1.14	6.94± 1.94	0.518[ns]	17.77
Mg^{2+}	1.54± 0.11	0.10± 0.23	0.049*	93.51
CEC	14.66± 0.89	12.42± 2.19	0.359[ns]	18.04
Bas.Sa	69.63± 5.15	60.50± 8.68	0.381[ns]	15.09
T.N	0.19±0.016	0.12± 0.02	0.019*	58.33
OC	1.21± 0.09	0.62± 0.14	0.003**	48.76
SOM	2.08 ± 0.16	1.06 ± 0.24	0.0031**	49.04
C/N	6.34± 0.32	5.25± 0.16	0.008*	17.19
Av.P.Ol.	3.30± 0.44	2.81± 0.66	0.554[ns]	14.85

** Significant at $P < 0.01$ "*" = Significant $P < 0.05$ and "ns" = No significant difference at $P<0.05$

Soil pH

The overall mean concentration of soil pHin exclosure was 6.08 indicating slightly acidic, which is optimum for many plant species growth (Arifin et al., 2012).The significantly (*p=0.027*) lower soil pH value in exclosure as compared to the open access grazing land may be probably due to higher infiltration in the exclosure facilitated by the higher vegetation cover which implies leaching of bases down the soil profile as well as lower break down of the soil organic matter due to higher clay percentage in the exclosure. Hinsinger et al. (2003) noted that the secretion of organic acids from the roots and amounts of CO released from roots and micro-organisms could lead to the decrease in pH value.

Exchangeable cations and CEC

No significant change (*p=0.412*) of CEC was detected between the two land uses. The overall mean concentration of Mg^{2+} in the exclosure (i.e. 1.54 cmol kg^{-1}) was higher than the critical level of 0.5 cmol kg^{-1} reported for both tropical and temperate soils, which indicates that it is adequate for most plants (Arifin *et al.*, 2012). But, the overall mean concentration of Mg^{2+} in grazing land (i.e. 0.1cmol kg^{-1}) was below the critical level of 0.5 cmol kg^{-1} indicating there

is possible deficiencies for plants. The significantly higher ($p=0.049$) magnesium enrichment of the soil in the exclosure can only be brought about by deep-rooted plants, which absorb cations from deeper soil layers and recycle them into the soil during leaf decay (Saikh et al., 1998). The overall mean concentration of Na^+ in the exclosure (12 cmol kg^{-1}) was lower than the critical level of 15 cmol kg^{-1} reported for both tropical and temperate soils, which indicates unlikely adverse effects i.e. not appropriate for most plants (Arifin et al., 2012).

The mean concentration of K^+ in the exclosure was 0.26 cmol kg^{-1} indicating moderately adequate level for most plants (Arifin et al., 2012).The higher level K^+ outside the exclosure may be a result of grazing; it results from the substantial vegetation differences. Outside the exclosures rather more of K^+ is likely to be adsorbed in the soil colloids because of the low biomass available to assimilate K^+, whereas inside the exclosure more K^+ is likely to be contained within the biomass rather than the soil.

Soil organic matter, soil organic carbon and total nitrogen

The mean concentration of SOM and OC (%) in the exclosure was 2.08 and 1.21 indicating moderate to adequate levels for most plants respectively, (Arifin et al., 2012). Besides, the mean concentration of TN in the exclosure was 0.19 representing moderate to adequate levels (Arifin et al., 2012).

The soil organic carbon (SOC), soil organic matter (SOM) and total nitrogen (TN) mean values showed a declining trend from exclosure to the grazing land. This may occur as a result of less biomass return in the free grazing land (Mikola et al., 2001). The improvement in organic matter, TN, OC and Mg^{2+} content following the exclosure is an important sign of soil restoration. The significant difference in total nitrogen and organic carbon between exclosure and free grazing land is due to differences in SOM content and intensities of soil erosion. This is because of the fact that presence of organic matter improves both the chemical and physical properties of the soil. Reduction in organic matter content of a soil is an obvious reason to expect relatively low nitrogen content in the free grazing land. This observation indirectly suggests that the biological conservation measures through exclosures have contributed to the sustainable management of land through replenishing soil nutrients. The higher SOM and TN contents in exclosure areas as compared to their values from free grazing lands can be explained by the difference in soil erosion and biomass return (Buyinzaand Nabalegwa, 2010). According to Zhong et al. (2004), changes in species composition could affect the organic matter and nutrient contents.

The higher SOM, TN, OC and Mg^{2+} contents in exclosure compared to free grazing lands was related to the restoration of natural vegetation, which has increased above biomass and below-ground litter inputs. The higher clay content of the soil of the exclosure might have also contributed to a higher accumulation of organic matter. In exclosures, where the canopy of shrubs and under story vegetation has been restored, the soil surface is protected from the erosive energy of falling raindrops, which prevents splash erosion. The higher SOM in protected areas also improves the soil physical properties such as soil structure and total soil

porosity. This in turn increases the amount of water infiltrated into the soil and decreases the amount of runoff that can be generated from a given amount of rainfall. Water infiltration in the soil may be enhanced both by preferential flow along tree roots and accumulation of organic matter on the soil surface, which may reduce volume, velocity, and erosive capacity of surface runoff (Jiang et al., 1996).

One of the effects of SOM is to retain cations and protect them from leaching and removal by runoff (Buyinzaand Nabalegwa, 2010). The higher CEC in exclosure as compared to that of free grazing land can be explained by the difference in SOM among the land use types. It is obvious that there is a direct relationship between organic matter and CEC.

The exclosure area showed no significant difference in sum of cations than open grazing land. The role of SOM in storing and supplying nutrients explains the significant correlation between SOM and soil nutrients such as TN and CEC. The CEC of soils is determined by their SOM content, the amount and type of clay minerals present, and extent of plant biomass. Cover estimates for the vegetation and the litter layer were highly variable over time but tended to be higher inside exclosures. Grazing generally results in the removal of biomass and thus reduction of cover (Wesche et al., 2010).

Soil physical property

Soil bulk density

The bulk density in the exclosure (1.42 g/cc^3) was below the critical level (< 1.5 g/cc^3) which indicates there was no adverse effect (Arifin *et al.*, 2012), and is suitable for the overall plant growth, seed germination, water percolation, runoff reduction and high nutrient stock. Irrespective of land use type, soil bulk density showed no significant (*p=0.964*) variation with depth. At the free grazing land the significantly (*p=0.0005*) higher bulk density on the thinner top soil were consistent with impacts of grazing and less dense vegetation cover (Table 5). Animal trampling is likely to have caused the higher bulk density, while relatively sparse vegetation and more bare ground provide the opportunity for wind and sheet erosion to reduce top soil depth (Manaaki, 1996). The repeated trampling by animals enhances the proportion of ground that was bare and increases soil bulk density (Tian et al., 2007). Similarly the soil bulk density was greater than the critical value (i.e., 1.5 g/cc^3) in the open grazing land, and it indicates that there have been possible adverse effects in the soil in terms of water infiltration and related bio-physicochemical activities and reactions.

It is obvious that protection of areas from livestock grazing improves soil physical features. The avoidance of animal trampling as well as the high SOM content and the presence of extensive shallow root systems in the exclosure areas contributed to a significant decrease in bulk density (Zhong et al., 2004). The increase of SOM and nutrient content which accompanies grazing exclusion, can be a result of an increase in the amount of plant litter on the one hand and a decrease in soil compaction on the other hand (Xie and Wittig, 2004). Soils with abundant SOM tend to be resistant to compaction and surface crusting, which acts

to aid water infiltration into the soil (Tian et al., 2007). High soil bulk density and penetration resistance as an indication of soil compaction affect soil infiltration and runoff. Overgrazed rangelands are under severe erosion risk because of soil compaction (Aksakal, et al., 2011).

Table 17: Effect across the land use and depth wise on soil bulk density (g/cm^3)

Depth	Mean value of Bulk density		Overall land use effect
	Grazing land	Exclosure	
0-10	1.59±0.036	1.40±0.05	1.5±0.04[*]
10-20	1.56±0.039	1.44±0.036	1.5±0.03[*]
Overall depth effect	1.58±0.03[ns]	1.42±0.03[ns]	

"*" = Significant difference at *P < 0.01* and "ns" = Not significant difference at P<0.05

Soil texture

In this study, significant differences ($p < 0.05$) of soil textural fractions were detected between the lands uses (Table 6). With respect to land use type, clay and sand proportions were significantly ($p < 0.05$) higher in soils under exclosure and open access grazing land, respectively. Generally, from the average value of textural composition, the soil type of grazing land and exclosure was predominantly sandy loam and sandy clay loam, respectively, USDA (1987).

Table 18: Mean (±S.E.) physical soil properties of (0-15 cm) across the land uses

Textural class (in %)	Average value of texture		p-value
	Grazing land	Exclosure	
Sand	69.50± 3.16[a]	59.00± 1.73[b]	0.0113*
Silt	11.00± 1.41[a]	15.50± 0.50[b]	0.0096*
Clay	19.50± 1.84[a]	25.50± 1.76[b]	0.0337*

"*" = Significant difference and "ns" = Not significant difference at P<0.05, Means within the columns of same letter, are not significantly different at p=0.05

The higher clay content in the exclosure means that there is relatively low soil erosion in the site. Erosion leads to the selective removal of clay particles leaving the sand particles in the free grazing land which reflects the differences in their vegetation cover. The low organic matter, the trampling effect of livestock and the sparse vegetation aggravate soil erosion which discerningly removes clay. The general trend in soil texture after forest has been converted in to the other types of land use has therefore been an increase in the sand and a decrease in the clay contents (Beweket, 2003).

Woody vegetation rehabilitation

Species composition

There are major disparities in species composition, regeneration status, richness and species diversity resulting from termination of grazing. A total of twelve woody species belonging to

seven families were recorded from the exclosure and grazing land. In the grazing land there were nine times fewer stems ha^{-1} than the exclosure. *Albizia amara* (68 %) and *Dodonea angustifolia* (18 %) was the major woody tree species observed in the exclosure, and *Senna singueana* (80 %) in the grazing land. A total of four species were found to be common to both the exclosure and grazing land, those are *Senna singueana, Dodonea angustifolia, Albizia amara*, and *Eucleadivinorum*. From all recorded species, the proportion of trees, shrubs and seedlings accounted for 69 %, 21 % and 10 % for exclosure and 59 %, 13 % and 28 % for grazing land respectively.
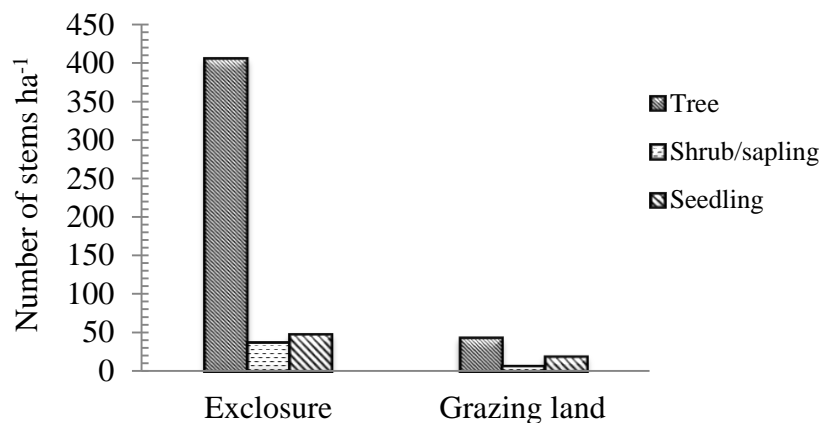
Figure 10: Number of stems ha^{-1} of species growth stage and/or form in exclosure and grazed land

Species similarity between the exclosure and the grazing land

Sørensen similarity percentage indicates that, only 40 % of the species in the exclosure were observed in the free grazing land.

Abundance of woody species in the exclosure and the grazing land

The frequency category in the two land uses shows that woody species have high occurrences in the exclosure than grazing plots. Relative dominance ranges from 1.8 % (*Dodonea angustifolia and Acacia tortilis*) to 50.4 % (*Terminalia brownii*) for exclosure and 0.6 % (*Dodonea angustifolia)* to 87.67 % *(Albizia amara)* for grazing land (Table 2).Woody tree species density varied between the exclosure and free grazing land. The density of all woody species in the exclosure was about nine times higher than in the grazing site.

Table 19: Abundance of woody tree species in exclosure and grazing land

No	Species	Number of individuals/ha

		Exclosure	Grazing land
1	*Acacia etbaica*	4	
2	*Acacia tortilis*	32	
3	*Albizia amara*	**916**	1
4	*Ampelocissus schimperiana*	24	
5	*Dodonea angustifolia*	**211**	24
6	*Euclea divinorum*	8	4
7	*Maytenus senegalensis*		4
8	*Senna singueana*	60	127
9	*Terminalia brownii*	92	
	Total density	1347	159

Important value indices (IVI) of woody species

In both sites much of the IVIs' values were attributed to few tree species.*Albizia amara, Terminalia brownii* and *Dodonea angustifolia* were some of the threatened woody species in the grazing land. From the farmers interviewed, the most preferable woody tree species for construction purpose include *Terminalia brownii* and *Albizia amara*. The high IVI value of *Sennasingueana* in grazing land may be due to the less preference of the species by the local community for different services. Then again, for fuel wood purpose the most desirable woody species includes *Acacia etbaica* and *Acacia lahay*, which were almost nonexistent in both of the land uses.
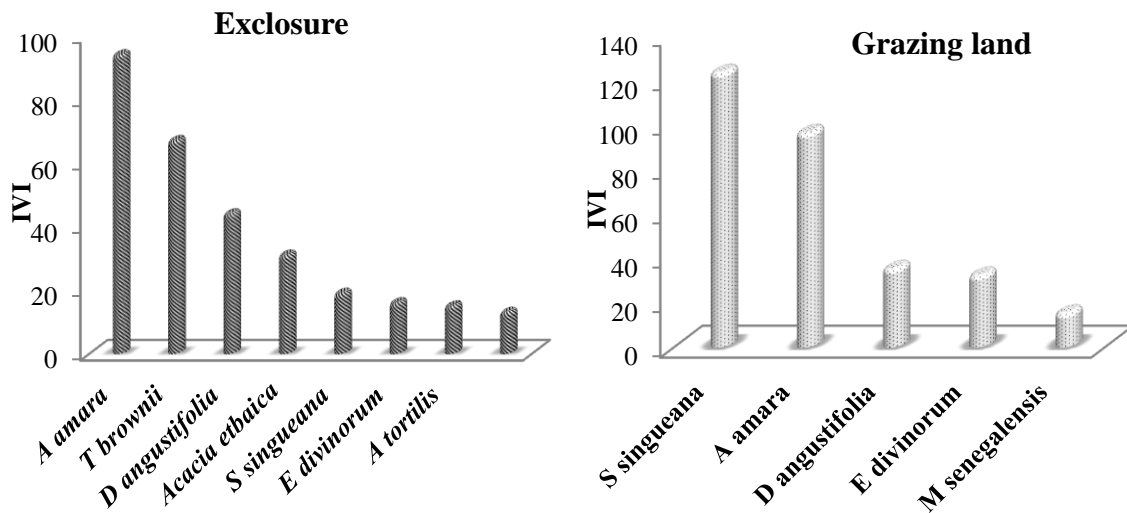
Figure 11: Rank of species in exclosure and grazing land according to their IVI

Population structure of woody species and regeneration status

Diameter class distribution

As the DBH class size increases, the number of individuals progressively decrease in the exclosure. The evidence from this study suggests that, few large trees and some small to medium-sized individuals were observed. More than 48 % i.e. roughly half of individuals had DBH less than or equal to 11 cm (DBH classes 2 and 3) in the area exclosure. On the other hand, for the grazing land the first DBH class holds about 96 stems ha^{-1} (60 %) down to 4 stems ha^{-1} with broken distribution at the middle classes (Figure 6). The possible reason for such distribution pattern might be the existence of high rate of regeneration and discontinuity in recruitments.

The rank of threat factors comprises harvest for firewood and charcoal, drought, agricultural expansion, house and trade in decreasing order. This rank tells us that large trees were harvested illegally from the exclosure which may result in dominance of small sized species. Moreover, the high density of individuals in lower diameter size class might be cofounded with large number of shrubby individuals particularly *Dodonea angustifolia* species. Typically, disparity in structure of species within and between the exclosure and grazing land were due to floristic and bio-physicochemical structures, which are associated with differences in site conditions and management (Senbeta et al., 2002).
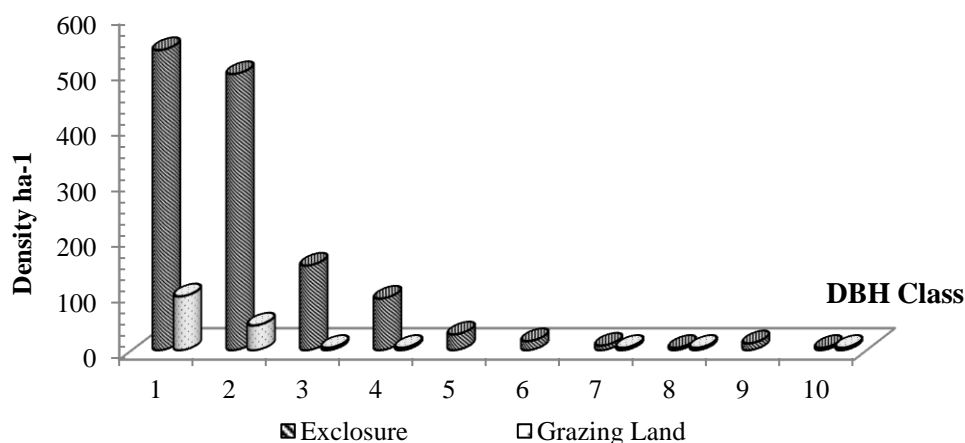
Figure 12: DBH size class distribution of the woody tree species across the land uses
Diameter size class 1= (2-5], 2= (5-8], 3= (8-11], 4= (11-14], 5= (14-17], 6= (17-20], 7= (20-23], 8= (23-26], 9= (26-30], 10= (>30) cm

Height class distribution

The density and frequency distribution of height classes for woody species, reveals that the highest proportion (71 %), of individuals with height class >3m were found in the exclosure. More number of individuals ha^{-1} were found in lower height classes, which contributed to larger proportion (> 94 % for height < 8m) as indicated in Figure 9. Trees such as *Ampelocissus schimperiana*, *Acacia etbaica* and *Maytenus senegalensis* were only found in the exclosure and were threatened in the grazing land. This could suggest that the study site

was dominated by small height individuals. Thus the study confirms that the number of individuals decreased as the height of the individuals increased indicating long time disturbance.
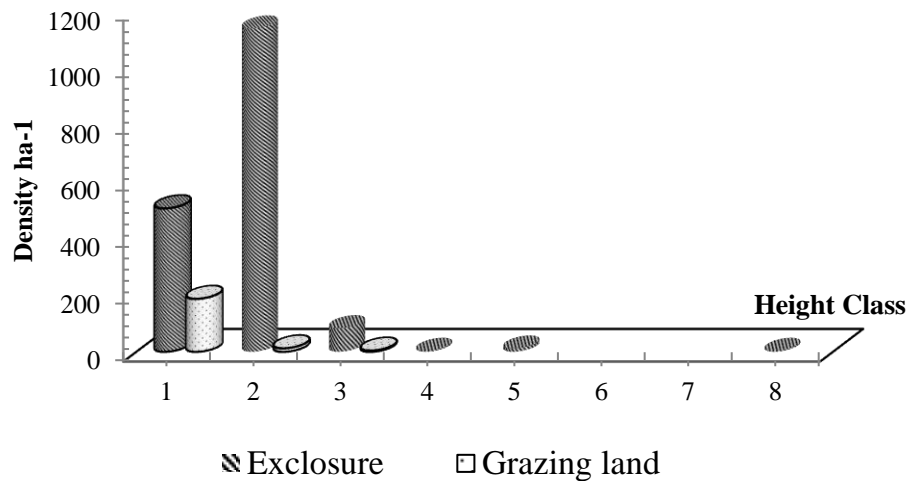
Figure 13: Height size distribution of all woody plants within in the exclosure
Height class 1= (1-3], 2= (3-6], 3= (6-9] 4= (9-12], 5= (12-15], 6= (15-18], 7= (18-21], 8= (>21)

Regeneration status of woody species

Population structures of trees in the forest and factors affecting their potential regeneration have significant implications to the management, sustainable utilization and conservation of the forest. The current regeneration status of a given population for selected tree species that devises good development for exclosure include *Albizia amara, Dodonea angustifolia*, and *Senna singueana*. But, for grazing land *Senna singueana* and *Dodoneaangustifolia* were the dominant regenerating woody species which also acquires relatively high IVI and density ha^{-1} (Table 4).

Based on the comparison of the regeneration status among the four selected woody species, which are common to both land uses with relatively better IVI; *Senna singueana,* was the species represented with better density of regenerating species at grazing land. As compared to the other four species; *Acacia etbaica*, *Acacia tortilis* and *Aloe spp.* was found to be species with poor regeneration status at grazing land, where as *Euclea divinorum* and *Acacia tortilis*was found to be poor regeneration in exclosure. At exclosure, *Senna singueana* and *Dodoneaangustifolia* were the top two species with better density ha^{-1} in terms of seedling and sapling/shrub respectively.

External disturbances such as human caused disturbance including intensive removal of trees for timber, construction and fuel wood can place significant pressure on regeneration status of

the selectively removed species. Though this, the analysis confirmed that, there is good regeneration in the exclosure.

Table 20: Density ha^{-1} of seedlings and saplings/shrubs in the exclosure and the grazing land

Species name	Seedling density		Sapling density		Total	
	Exclosure	Grazing	Exclosure	Grazing	Exclosure	Grazing
Senna singueana	68	32	32	16	100	48
Dodonea angustifolia	56	24	72	4	128	28
Albizia amara	20	0	191	0	211	0
Euclea divinorum	20	8	52	8	72	16
Dichrostahys cinerea	12	0	32	0	44	0
Acacia etbaica	4	0	0	0	4	0
Aloe sp.	4	0	32	0	36	0
Acacia tortilis	4	8	4	4	8	12
Maytenus senegalensis	0	4	0	4	0	8

Conclusion and recommendations

This study assessed the effects of exclosure on soil physicochemical properties and vegetation composition. This study assessed the effects of land use conversion on soil chemical and physical properties. Long periods of continuous grazing led to changes in some of the physical and chemical properties of soils. Theexclosure shows higher significant differences ($p < 0.05$) than grazing land for soil organic matter (SOM) content, total nitrogen (TN), organic carbon (OC), carbon to nitrogen ratio (C/N), and magnesium (Mg^{2+}) but lower pH. The increment in SOM content of the soil under exclosure can indicate that if properly managed, the sequestration of carbon in these soils will be prominent and can potentially offset degradation by increasing water holding capacity, Cation exchange capacity and resistance to erosion. The difference in soil nutrients content between the land use types is mainly due to differences in soil erosion and biomass return.

In addition, a total of twelve species of vascular plants belonging to seven families were identified in the study area. Of which family Fabaceae was the most dominant one. The study revealed that the exclosure had higher density and diversity of woody species than the free grazing land even if the degree of protection from interference of the exclosure was not so strong. The woody seedlings abundance was much better in the exclosure than in the open grazing area, thus supporting further regeneration. Moreover, the increase in biomass could be explained by the positive effect of exclosure to improve site quality.

The study indicates that free grazing lands should be changed to protected areas before soil organic matter and other nutrient contents are depleted more. Moreover, the erosion processes may be very active resulting in further degradation and siltation of grand dams.

To be more effective in conserving exclosures and rehabilitating of degraded lands, continuous follow up after closing degraded lands and awareness creation is required. Generally, biodiversity improvement by exclosures can be achieved by sustaining the livelihood of the stakeholders.

In order to mitigate the existing biodiversity, ecological and environmental crises and promote the sustainable management of the exclosure, the following recommendations are forwarded:

- Provisions of strong extension services, regular forums and informal training to the local people on the need as well as ecological and socioeconomic importance of exclosures to boost their awareness;

- Enrichment planting is necessary because the species diversity found in the study area is not as richer;

- Formulation, development and implementation of strong bylaws, including balanced focus on protection and utilization of the exclosures as well as decisions on the amount of punishment fines; and

- In depth socioeconomic study on identification and implementation of appropriate and viable management options for exclosures, including distribution of available benefit equally and fairly among participants.

Acknowledgments

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EVALUATION OF THE ADAPTABILITY AND RESPONSE OF INDIGENOUS TREES TO ASSISTED REHABILITATION ON THE DEGRADED HILLSIDES OF KURIFTU LAKE CATCHMENT (DEBRE ZEIT, ETHIOPIA)

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Abstract

Removal of trees and shrubs from hillsides exposes a site to erosion that threatens soil aggregation and stability. The present study aims at evaluating the performance of five indigenous tree species under two modes of planting: trees planted with water harvesting structures namely infiltration pits as a treatment vis- a- vis trees planted without the mentioned treatment across two slope classes (0-17 % and 18-27 %) on the degraded hillsides of Kuriftu Lake Catchment. The study handled three factors: Slope, species types and water harvesting structure assigned as main plot, sub plot and sub-sub plot factors respectively in split-split plot design. Adaptability varied by tree species and water harvesting structures significantly augmented seedling establishment for some of the tree species evaluated. Height of Acacia abyssinica planted on steeper slopes (18-27%) and without infiltration pits was significantly lower than for conspecifics planted with infiltration pits. *Dodonaea angustifolia* proved to be the best adapted to the site and showed no need for water harvesting regardless of planting position across the degraded hillside. Height of *Acacia seyal* declined significantly on steep slopes when planted without infiltration pits. Olea africana performed better on gentle slopes with pits but also grew well on steeper slopes with pits. Euclea schimperi proved to be the least effective of the species evaluated. In conclusion the study recommends that for future rehabilitation tasks in similar areas Dodonaea angustifolia could be planted without pits regardless of its location across the slope for significantly higher performance. It would be highly recommendable to plant Acacia abyssinica with infiltration pits both in higher and lower slopes , for it is relatively less moisture stress tolerant. Though *Olea africana* is relatively hardy after establishment, it is recommended to assist this tree species with infiltration pits in higher slopes to acquire a comparable performance as to lower slopes. On the other hand, planting of *Acacia seyal* should be restricted to lower slopes with infiltration pits, for it was found out to be less tolerant to highly moisture stressed micro site conditions of up slopes.

Keywords: Infiltration pits; Kuriftu Lake catchment; water harvesting

Introduction

The Ethiopian landscape is characterized by chains of high mountains, rift valleys, plateaus and flat plains. Elevations range widely over short distances from 110 m asl to 4620 m a.s.l. Rivers cross the high mountains resulting in small to huge rifts and enormous plateaus. In addition to regional patterns of rainfall and temperature local climates are affected by the rain-shadow effect of mountains. Annual rainfall in Ethiopia varies on average from100 mm in the lowlands to 2,800 mm in the highlands.Many hillsides in the Ethiopian highlands have been degraded by excessive harvest by smallholder farmers of firewood and food. These hillsides are commonly owned and their management and rehabilitation has been complex. A study conducted in Northern Wello, Ethiopia demonstrated, however, that with sufficient seed sources in surrounding remnant vegetation and in the soil seed bank, natural regeneration is a potential solution to rehabilitate degraded hillsides. If natural regeneration cannot be effected, degraded hillsides can be reforested by plantation using tree species that can withstand local site conditions (Singh et al., 2012).Among the major lakes of potential scenic value in the Ada Liben woreda, East Shoa zone of Oromia is Lake Kuriftu with a total area of 4 ha at an elevation of 1,883 m a.s.l. The lake is located at 8°46′28″N and 39°00′38″E (Fig. 1). Total annual rainfall at the lake is 745.6 mm (station record), which is adequate for normal tree growth and establishment. The soil in the study area is characterized as Vertic Andosol, a very fine textured soil of volcanic origin and the most productive soil type of Ethiopia gave adequate supply of water (Mesfin, 1998). Although annual rainfall is sufficient to maintain tree growth, soil moisture and soil depth are concerns due to the typically shallow soils and poor moisture storage conditions on the study area.

Soils on hillsides that are devoid of vegetation are subject to accelerated soil erosion since the intensity of runoff increases with gradient. Unwise utilization of soils results in the loss of the productive potential of soil. The severity of erosion depends on a combination of many factors, including the amount and intensity of precipitation, soil texture, slope steepness, and the amount of ground cover (Hillel, 1998).Slope gradient controls runoff and drainage, and hence affects the water content of soils (Toumey, 1974). Soil depth and moisture content vary almost directly with gradient when other conditions are held constant. For successful rehabilitation of hillsides such as those at Kuriftu Lake catchment there should be a mechanism to enable water infiltration and increase soil moisture content, and thereby contribute to tree establishment and growth. Water harvesting is the collection of runoff for productive purposes as opposed to leaving it to cause erosion (FAO, 1991). In semi arid and drought-prone areas, it is a productive form of soil and water conservation. In semi-arid areas, rainfall is often accompanied by large amounts of surface runoff. Thus it is importantto use the limited amount of rainfall as efficiently as possible. One way to do this is to use surface runoff by water harvesting. Another is to encourage infiltration and storage of rainwater (Anschutz et al., 2003).
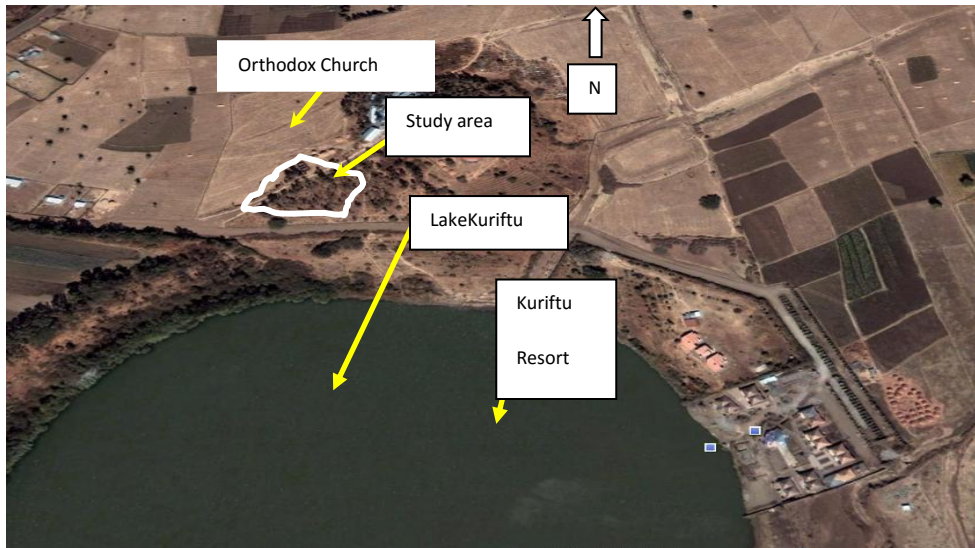
Figure1: Kuriftu Lake Catchment and the study area.Sources:

Apart from some minor uses for recreation and water supply, the potentials of Kuriftu Lake have not been fully utilized in an environmentally friendly approach. Due to severe soil degradation caused by human infringement, few naturally growing trees remained on the hillsides surrounding the lake. Information was inadequate on the tree species potentially useful for reforestation the hillsides, particularly with respect to moisture stress and shallow soil depths. Knowledge of integrating water harvesting with tree planting on hillsides was also not available although this concept was not new to the area. In contrast, in the highlands of Ethiopia where natural resources are highly threatened due to decades of unsustainable farming of marginal hills, treatments are widely practiced to restore degraded sites. Treatments of watersheds are designed to slow surface flows to increase infiltration. These include construction of Continuous Contour Trenches (CCT) or hillside terraces, stone bunds, soil bunds and contour vegetation strips. These practice result in control of soil erosion, retention of soil fertility, and increased soil moisture, infiltration and groundwater recharge. Construction of stone bunds or stone-faced trench bunds, for example, is widely adopted by many farmers in Ethiopia to retain rainwater and reduce runoff that causes erosion. These technologies are water harvesting practices intended to store rainwater for crop productionand enhance groundwater recharge.

The technology originated in India and has been practiced in the Blue Nile basin, the Tigray region, North Shoa and the Awash basin of Ethiopia (SLMP, 2010; Zemadim et al., 2011). Continuous Contour Trenches (CCT) is also promoted by the extension service in Ethiopia because CCTs do not require the use of stones and are positively rated by farmers (SLMP, 2010). Though these systems are increasing productivity in the highlands, they lack basic elements of water harvesting structures like cross ties and infiltration pits that facilitate surface water infiltration and increase the availability of moisture near at the rooting zone, thereby increasing seedling survival in semi arid areas such as the Kuriftu Lake catchment. Problems arising from hillside soil erosion and land degradation in the study area stimulated this research to identify plantation tree species and water harvesting techniques that could be used for future rehabilitation options. We evaluated five indigenous tree species; viz. Acacia abyssinica, Euclea schimperi, Olea africana, Dodonaea angustifolia and Acacia seyal, for their adaptability on 0.25

ha land for five years. The objectives of our study were: (1) to evaluate the adaptability of indigenous tree species for plantation; and (2) to evaluate the role of water harvesting structures in reforestation of degraded hillsides.

Material and Methods

There are many indigenous tree species whose environmental requirements match the conditions of the study area. We selected the five species listed above based on two environmental parameters, total annual rainfall and temperature. We classified the hillsides in two slope gradient classes. Because slope gradient controls runoff and water infiltration, thereby impacting seedling establishment, it was considered the first factor (factor 1) with the two different gradient classes as its levels.

Continuous contour trenches or hillside terraces are practiced in low to high rainfall (250 to 3000 mm) regimes, and on mild to steep slopes (5 to greater than 60% slopes). The technology reduces the speed of flowing water, traps rainwater and enables it to percolate to aquifers (Zemadim et al., 2011). The two slope classes identified for this research were slope class I (0−17%) and slope class II (18, %−27,%). Slope class I had thicker soils and better micro-site conditions while the slope class II was relatively degraded with shallow soils and poor micro-site conditions. Slope gradients were measured using an impulse hypsometer that operates through generation of IR radiation.

Tree species was assigned as factor 2. Tree species vary in their capacity to survive a given set of site conditions. Accordingly, the five tree species listed above were considered as levels for the factor 2.The third factor considered for the research was water harvesting structure. In semi-arid areas, rainstorms are usually heavy and soils generally cannot absorb the amount of water that falls during short rainfall events. As a result, rainfall in semi-arid areas is often accompanied by surface runoff. These climatic characteristics of semi-arid regions dictate the importance of efficient use of rainfall. One way to do this is water harvesting. Another is to encourage infiltration and storage of rainwater i.e. soil moisture retention or conservation (Anschütz et al., 2003). Based on this fact the five evaluated tree species were planted as seedlings with and without infiltration pits on the two slope classes. The third factor had two levels, i.e. level zero referred to plantings without infiltration pits and level one referred to plantings with infiltration pits.Contour bunds for trees are the most simplified form of micro catchments for better soil and moisture conservation (FAO, 1991), and were constructed along contours over the entire study area (Fig. 2). As the name indicates, the bunds followed topographic contours at close spacing, and by provision of small earth ties (cross ties) the system was divided in to individual micro catchments. Contour bunds were made by digging a furrow along the alignment following a somewhat curved path and heaping the soil down slope. This was followed by compaction and stabilization of the structure by planting grasses and construction of infiltration pits of dimension 40 cm×40 cm×20cm in each micro catchment.
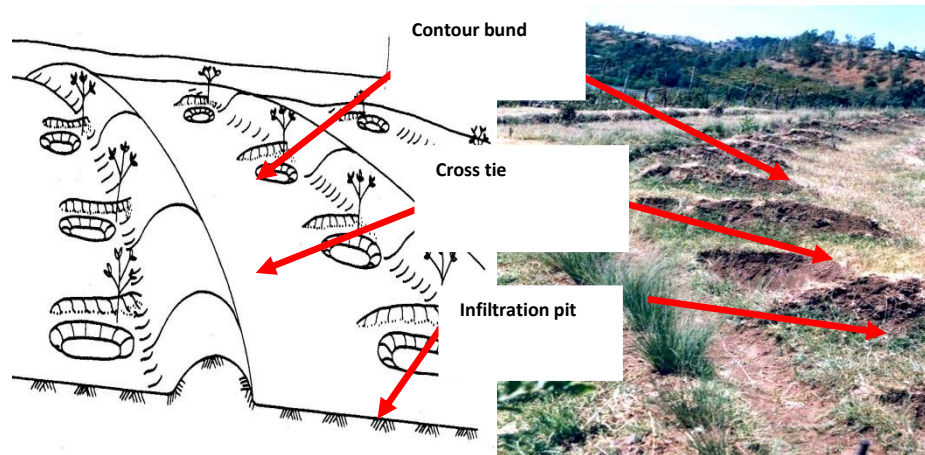
Figure 2: Alignment of Bunds, infiltration pits and Cross ties constructed in the field (Kuriftu Lake catchment- June 2004)

Line level technique was used to bring alignment of the bunds along the contour. Bund height was at least 25 cm on lower slope classes and 30 cm on higher slope classes, based on recommendations for arid and semi-arid areas.

The study area was divided into three blocks. The experimental design used was split-split plot. Slope was assigned as main plot factor with its levels S1 and S2. Water harvesting structure (with levels H 0 and H 1) was a sub-plot factor and species type (with levels A, B, C, D, E) was a sub-sub-plot (split-split plot) factor. This resulted in 3 blocks (I-III) each with 2 main plot treatments (S1 and S2) attached to 2 sub-plot treatments (H 0 &H 1) and this combination was further attached to 5 treatments, i.e. the five tree species for evaluation (A-E) in split-split plots. The assignment of treatments and levels was carried out through step wise randomization procedure of the split-split plot design with three replications .Pure, viable seeds of the selected tree species were collected and their seedlings were raised in the nursery at Debre Zeit Agricultural Research Center using standard procedures and substrate mixtures in June 2004, the year prior to the onset of field work. Seedlings were raised for 7−10 months in the nursery until they attained heights of about 40 cm. 15 seedlings of each species were planted on plots of about 50 m2 across the slope at a spacing of 1.5 m and in the space between the infiltration pit and the crosstie . Planting was carried out after the first runoff was harvested.

We recorded tree height, collar diameter, and survival at five years after planting. The raw field data were then summarized by mean values of 15 trees per plot per species for the variables mentioned above and then transferred to data summary sheet of split-split plot design prior to subsequent analysis using statistical software. Data collected on survival, height and diameter of trees starting from the onset of the dry season were then subjected to statistical analysis (ANOVA) to assess differences between treatment means at $\alpha=0.05$. Survival count data were log transformed to approximate normality before parametric testing.

Results

The study proved significant differences in mean height and diameter growth among species tested on the hill side of the study area at alpha=0.05. Evaluated tree species showed significant variability of height and diameter performances in lower and higher slope classes (Fig. 5). The decline in performance of some species in higher slope class (due to poor moisture conditions) was proved to be redeemed through the use of water harvesting structures. Mean height and mean diameter of A. abyssinica grown with infiltration pits were significantly greater than for all other combinations of species and treatment (Fig. 4, 5). Dodonaea angustifolia proved to perform equally comparably in higher slope classes (where the soil is shallow and moisture is limiting) without infiltration pits as in lower slope classes with pits. This signified its relative moisture stress tolerance (Fig. 6).
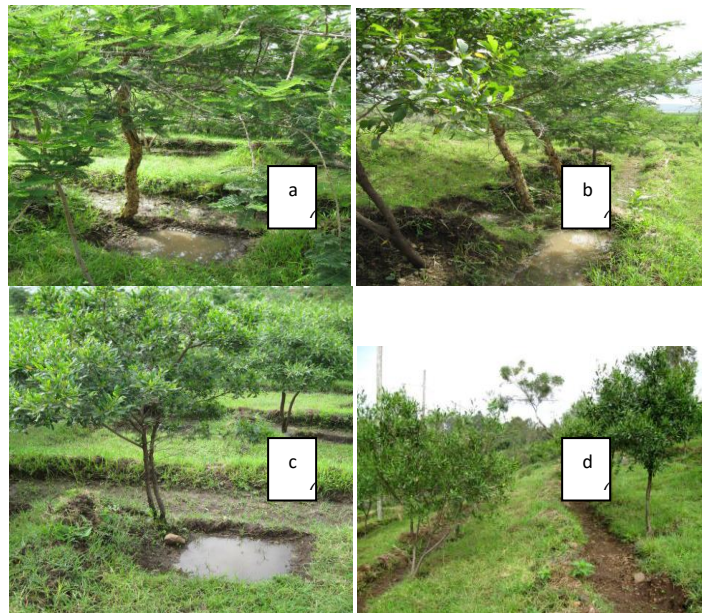
Figure3: Trees species under varying planting conditions (3years after planting)(a). *Acacia abyssinica* with pit- slope class I. (b) A*cacia abyssinica* with pit –slope class II. (c).*Dodonaea angustifolia* with pit- slope class I. (d).*Dodonaea angustifolia* without pit –slope class II.
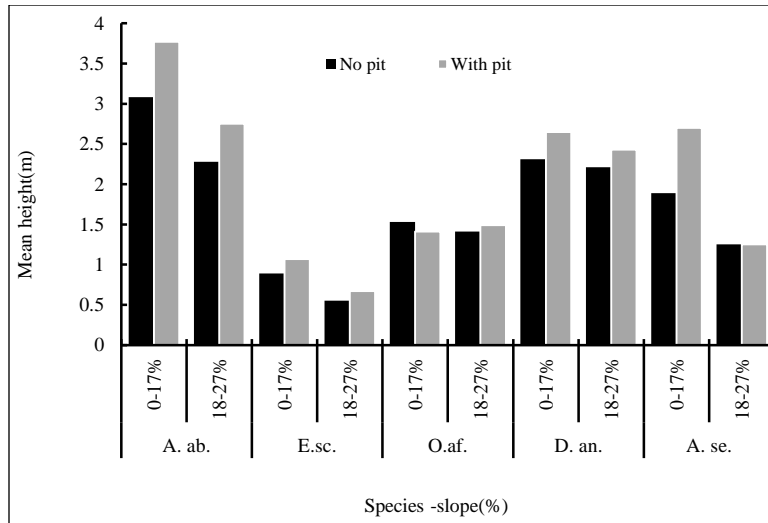
Figure4: Height distribution of evaluated tree species

The use of pits in higher slopes for Olea africana proved a closely comparable mean height and diameter to its counterparts in lower slopes (Table 1). Thus the use of pits would be recommendable for this
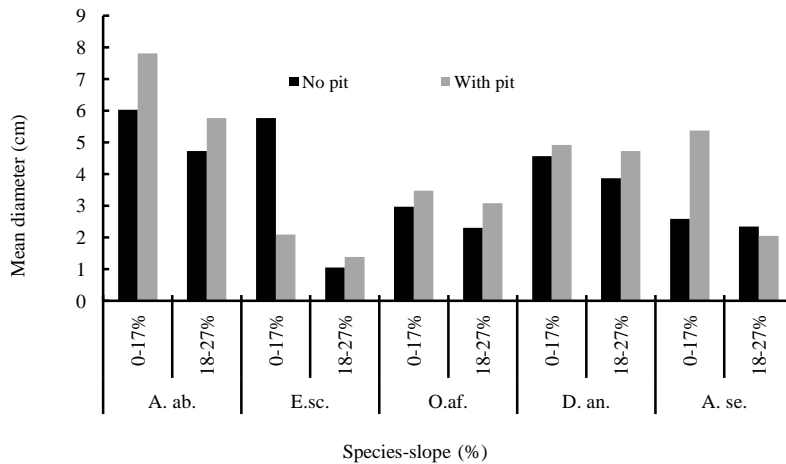
Figure 5: Diameter distribution of evaluated tree species
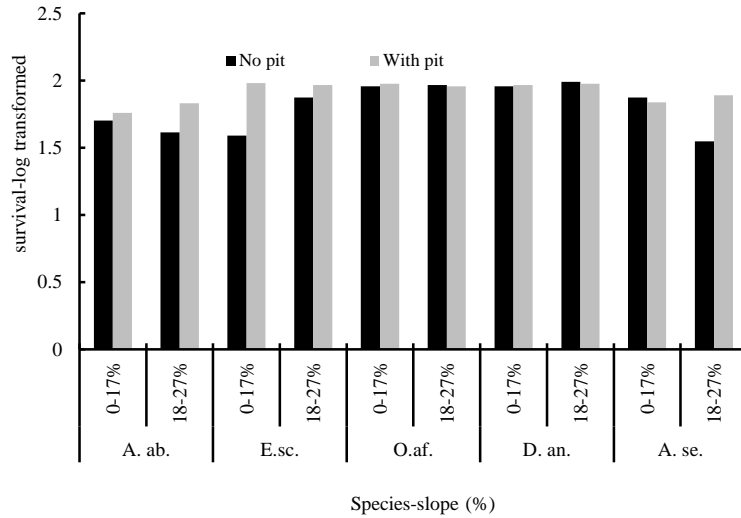
Figure 6: Survival of evaluated tree species

Species in higher slopes. Planting Acacia seyal in higher slopes without pits resulted in a significantly lower height and diameter that could not be redeemed through the use of pits Mean height and mean diameter of Euclea schimperi were the least for all combinations of treatment. The species with significantly higher diameter and height like Acacia abyssinica gave rise to relatively lower survival. This was mainly attributed to stem decay disease the cause of which is under scrutiny (Table 1). The disease selectively attacked A. abyssinica around four years of age after planting. Euclea schimperi with the least height and diameter performance gave rise to a highly significant survival equally comparable to Dodonaea angustifolia and Olea Africana (Table 1).

Table 1: Multiple mean comparisons of height, diameter, and survival

Species	Slope class	Pit/No pit	Height(m)	Diameter(cm)	Survival
Acacia abyssinica	I	0	3.08(b)	6.03(ab)	1.703(abcd)
		1	3.77 (a)	7.81(a)	1.760(abcd)
	II	0	2.28 (cd)	4.73(bcde)	1.613bcd)
		1	2.75 (bc)	5.77(bc)	1.830(abc)
Euclea schimperi	I	0	0.89(ghi)	1.64(hi)	1.590(cd)
		1	1.07(ghi)	2.09(ghi)	1.980(a)
	II	0	0.55(i)	1.05(i)	1.873(ab)
		1	0.67(hi)	1.39(hi)	1.967(a)
Olea africana	I	0	1.53 (efg)	2.97(efghi)	1.957(a)
		1	1.41(efg)	3.48(defgh)	1.977(a)
	II	0	1.41(fgh)	2.31(ghi)	1.967(a)
		1	1.49(efg)	3.08(efghiI)	1.957(a)
Dodonaea angustifolia	I	0	2.31(bcd)	4.57(bcdef)	1.957(a)
		1	2.65(bcd)	4.92(bcde)	1.967(a)
	II	0	2.21(cde)	3.87(cdefg)	1.990(a)
		1	2.43(bcd)	4.73(bcde)	1.977(a)

Acacia seyal	I	0	1.89(def)	2.59(fghi)	1.873(ab)
		1	2.70(bc)	5.38(bcd)	1.837(ab)
	II	0	1.25(fghi)	2.35(ghi)	1.547(d)
		1	1.25(fghi)	2.05(ghi)	1.890(ab)

Notes: Slope class I is 0–17%; Slope Class II is 18%–27%; (0) is Seedlings without pit; (1) is Seedlings with pit; Different letters in the height, diameter, and survival columns indicate that means are significantly different at alpha 0.05. LSD for height is 0.68. Standard error of the mean for Height is 0.240 at alpha 0.050. LSD for diameter is 1.79. Standard error of the mean for diameter is 0.628 at alpha 0.050. LSD for survival is 0.24.Standard error of the mean for survival is 0.085 at alp. 0.05.

Discussion

According to Blanko and lal (2008), restoration refers to the process of repairing and returning damaged or degraded soils to a condition similar to the pre degradation level of capability for supporting plant growth and maintaining environmental quality.T his study proved the best performing tree species for successful restoration of the degraded hills at Kuriftu. It was also found out that tree species have significantly differing performances in their response to management or earthwork practices.

The performance of some species was less influenced by their planting location across theslope as well as by the presence or absence of infiltration pits. The study proved that regardless of its planting locations across the slope, infiltration pits are prerequisites for significantly better performance of Acacia abyssinica while the use of pits across the slope is not crucial for Dodonaea angustifolia. This would suggest that Dodonaea is relatively hardy towards poor soil moisture conditions. Tesfaye (2000) also argued that Dodonaea is a promising species to colonize barren areas suggesting that it could be used at early stages of restoration before reintroduction of other late successional species.

Planting *Acacia seyal* should be restricted to lower slopes with infiltration pits for it was found out to be less tolerant to highly moisture stressed site conditions of up slopes where the soil is relatively shallower. This was disclosed by a significant decline in its height and diameter performance in higher slopes though it was assisted with infiltration pits. On top of survival the ecological role that a species play counts a lot especially in the rehabilitation degraded hill sides and this is typically linked with growth and enlargement of the species under consideration. Thus even though *Euclea schimperi* revealed comparably higher mean survival value over the best performing tree species like *Acacia abyssinica*, *Olea africana* and *Dodonaea angustifolia*, it would be the least preferred for the rehabilitation of the study area due to its very low height and diameter performance.

Conclusion and recommendations

The evaluation study revealed significant performance differences among evaluated tree species. It also indicated the role that water harvesting structures play in enhancing the performance some tree species. In conclusion, this study recommends that for future rehabilitation tasks in similar

areas *Dodonaea angustifolia* should be planted without pits regardless of its location across the slope for significantly higher performance. It would be highly recommendable to plant Acacia abyssinica with infiltration pits both in higher and lower slopes for it is relatively less moisture stress tolerant. Though *Olea africana* is relatively hardy after establishment, it is recommended to assist this tree species with infiltration pits in higher slopes to acquire a comparable performance as to lower slopes. On the other hand, planting of Acacia seyal should be restricted to lower slopes with infiltration pits for it was found out to be less tolerant to highly moisture stressed site conditions of up slopes.

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SOCIO-ECONOMIC DETERMINANTS OF SUCCESS IN REHABILITATION OF DEGRADED LANDS IN HADIYA ZONE, ETHIOPIA

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Abstract

Success of the ongoing efforts to rehabilitate degraded lands is hampered by a number of factors including perception of local people and level of institutional services. The objective of the study was to identify the socio-economic factors affecting rehabilitation process of degraded lands and their significances in two contrasting sites in rehabilitation success in Soro Woreda, Hadiya Zone. A total of 108 households were selected by simple random sampling techniques from the two sites. Both qualitative and quantitative data were generated through interview with key informants, survey questionnaire, and focus group discussions. Descriptive statistics was used to analyze association of implementation of rehabilitation of degraded lands in both sites and socio-economic determinants. The socioeconomic factors that differed significantly between the two groups were age structure of the community, grazing land size, forest land size, frequency of institutional services received, experience of planting trees and grass as rehabilitation measures, perception on the need to protection rehabilitation area and perception on proper management of rehabilitation area. The result showed that 98 % of the respondents in Sheraagreed that the rehabilitation area was managed properly while it was only 22 % in HaricheUyayawho agreed on the same. However, 84.9% of the interviewees in the former and 65.4 % in the latter mentioned that they benefited from the rehabilitation of degraded lands. The results also showed that rehabilitation of degraded lands could be successful provided some early benefits are derived from the efforts. Addressing the knowledge and perception barriers through continuous engagement with farmers and better institutional services, and working towards progressive integration between main actors/or government and local community members is essential in ensuring success in future land rehabilitation endeavours.

Keywords: land degradation; rehabilitation; socio-economic determinants; poverty alleviation.

Introduction

Land degradation is one of the major socio-economic and environmental problems affecting billions of people in the world (UNEP, 1997; Dregne, 2002). It is also one of biggest problems in Sub-Saharan Africa, threatening the lives of millions of people (Scherr and Yadav, 1996; Blayet al., 2004). In countries, where agriculture is the dominant source of subsistence and national income, are currently facing severe problem of shortage of food and other agricultural produces due to land degradation. The problem of land degradation is severe in Ethiopia leading to low agricultural productivity and hence aggravates food insecurity (Tsegaye, 2006). Currently,

rehabilitation of degraded land has become a possible way of fighting land degradation and its effects (Heleore, 2010).

In most of the developing countries, the major factor for land degradation is improper and unsustainable land management (Giri, 2010; Tsegaye and Bekele, 2010). Human interference on the environment leads to loss of productivity of soil and natural vegetation (Barry, 2010). The major causes of land degradation in Ethiopia are rapid population growth, severe soil loss, deforestation, low vegetation cover and unbalanced crop and livestock production (FAO, 1986; Taddese, 2001; Holden and Shiferaw, 2004; Bekuma, 2010). The underlying factors are very complex and attributed to various socio-economic factors (GEF, 2006). Population growth and poverty coupled with the weak institutional arrangements remain the binding factors that exacerbate the rate and consequences of land degradation (Akhter, 2010).

Cognizant of its effect on human welfare and environmental health, integrated implementation of rehabilitation activities on degraded lands are underway with the notion of fighting land degradation and its consequences (Blayet al., 2004; Heleore, 2010). In the development process, government of Ethiopia as a key role player and local community members as main actors and beneficiaries can be involved in the rehabilitation process (Baly et al., 2006; Heleore, 2010). However, the role and interest of actors' differ, and consequently these differences and roles determine the success of the rehabilitation efforts (Gebreselassie, 2006).

The government of Ethiopia has been taking initiatives and measures to rehabilitate degraded lands through community participation (Nedessa et al., 2005). The government of Ethiopia has allocated resource for rehabilitation and this has been incorporated in development plans of each administration level in order to contribute to the government strategy on environmental protection(Braun and Grote, 2000; Jacobs and Schloeder, 2001; Katorobo, 2005; Gebremedhin et al., 2006; Faye, 2008).

Population pressure and the land shortage in the smallholder farming condition can be drivers of depletion of natural resources. Land degradation and deforestation in Ethiopia are damaging the land and forests to contribute food security and other profits such as fuel wood and fodder (Bishaw, 2001; Kebede, 2011). This is true for the study area SoroWoreda (District), Hadiya Zone where improper land use exists. Therefore, it is imperative to rehabilitate thedegraded land so that the community livelihoods improve through the environmental rehabilitation.

Furthermore, it is important to document if there are differences between local community perception and attitude with regard to rehabilitation of degraded land. Therefore, the success or failure is not only measured by what is achieved on the ground. Here it is important to identify and explore the socio-economic determinants and processes contributing to the success or failure.

Thus, this study was conducted with the objective of identifying the local people's response to the rehabilitation efforts, and the associated socio-economic factors that determine the success or failure of the measures undertaken in SoroWoreda, Hadiya.

Material and Methods

Description of the Study Area

SoroWoreda is located between 7^0 23' to 7^0 46' N latitude and between 37^0 18' to 37^0 23' E longitude in Hadiya Zone of the Southern Nations, Nationalities and Peoples Region (SNNPR), Ethiopia (Figure 1). The total land area coverage of the Woreda is 58,061 ha which comprises a total of 46 rural Kebeles (the lowest administrative unit). The study has been conducted in two Kebeles; namely, Shera and HaricheUyaya, which are located around 32 km from Hossana, 197 km away from Regional capital of Hawassa and 264 km from Addis Ababa (HZPEDO, 2003). The total population of the Woreda is about 219,159, of which 50 % are male and 50 % female (CSA, 2012).

The altitude of SoroWoreda ranges from 840 m at the Gibe River Valley to 2850 meter above sea level at the highest point on Shonkola Mountain. About 14 % of SoroWoreda is highland, 53 % middle altitude and the rest 33 % lowland. Accordingly, the Woreda agro-ecological zones are stratified into three climatic zones: *Dega*, *Woina-Dega* and *Kolla*, (highland, midland and lowland) respectively. The mean annual rainfall in the Woreda ranges from 1001 mm to 1400 mm. It has a bimodal rainfall distribution where the main rainy season (locally known as (*Hagaye*) occurs from June to August and the short rainy season (*Qaraxo*) from March to May.The mean annual temperature ranges from 17.6 ^{O}C to 27.5 ^{O}C.
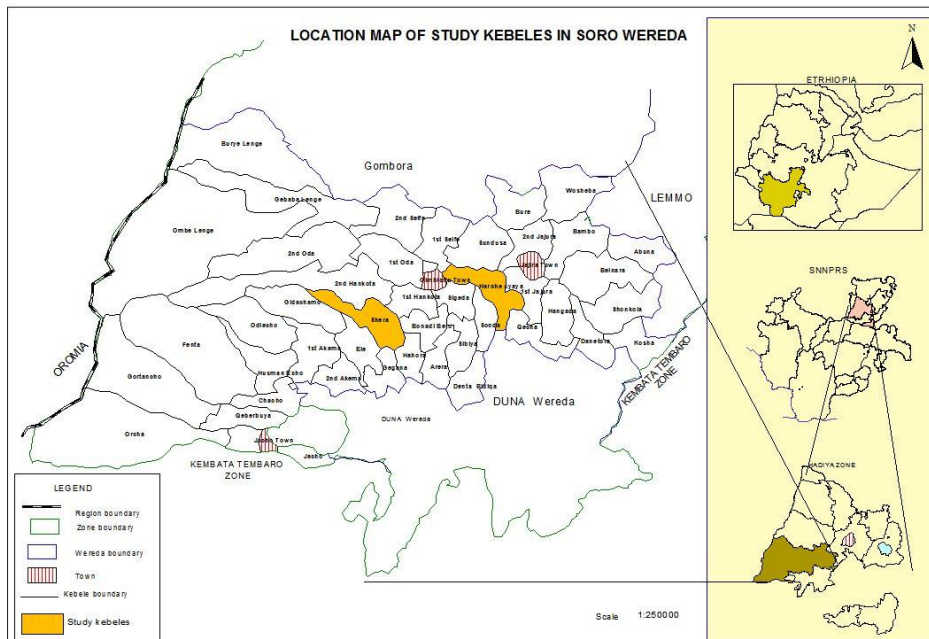
Figure 14: Location of the study area in SoroWoreda, Hadiya Zone, SNNPR, Ethiopia

Sampling Techniques

Two Kebeles were purposively selected among the 46 rural Kebeles of SoroWoreda in consultation with experts and development agents. The two Kebeles, Sheraand HaricheUyaya were selected based on the presence, success and/or failure in rehabilitation practices, accessibility, similarity in agroecology and time of commencement of the rehabilitation activities.

A simple random sampling technique was employed to select sample households.Using the list of householdsin the Kebeles as a sampling frame, a total of 108 households (about 6% of the population) were selected for the study.Accordingly, 53 households from Shera and 55 households from HaricheUyaya were respectively surveyed.

Methods of data collection

Both qualitative and quantitative techniques were employed to generate data. Accordingly, determining factors and the reasons behind success and/or failure in the rehabilitation process of the degraded lands were assessed. The data were collected from two main sources: primary and secondary sources. Primary data was obtained through field observations, key informant interview, a formal survey/questionnaires and focus group discussions. Various information on demographic, household socio-economic characteristics and institutional factors that may influence and/or support rehabilitation of degraded lands were gathered.

Data analysis

The primary data collected from household survey were checked, arranged, coded and entered into computer and cleaned and analyzed using Statistical Package for Social Science (SPSS version 16.0). Chi-square and t-test were used to assess whether any significant differences exist between Kebeles socio-economic factors and locale people perceptions towards the rehabilitation of degraded lands. Data collected from field observations, key informant interviews and focus group discussions were also qualitatively assessed.

Results and discussion

Economic characteristics of the sample households

Among the 108 sample household heads, male headed constituted 92.5 % in SheraKebele and 96.4 % in HaricheUyayaKebele while female headed were only 7.5 % and 3.6 %, respectively in two Kebeles (Table 1). During discussion with key informants in both Kebeles the elderly mostly supported the rehabilitation activities whilethe youngsters tended to cultivate agriculture marginal lands to fulfil their needs. The elderly people analyzedthe pervious land status, risks related to deforestation, and the consequences of land degradation, and consequently they could see the benefits of

the rehabilitation activities and thus, they were supporting the rehabilitation attempts. As noted earlier, age of farmers couldplay either positive or negative role in conservation decision (Bekele, 2003).

The size of the sampled households ranged from 3 to over 10 persons and the mean household size were7. The results indicated that family size greater than 10 was 22% in Shera and 27 % in HaricheUyayaKebeles (Table 1). The study result showed that larger households' size was one of the determining factors for the success of rehabilitation of degraded lands.

The majority (68 %) in Shera and (66 %) in HaricheUyayaof the household heads were literate, from elementary to high school (Table 1). Educational status may increase households understanding on the causes and consequence of land degradation and it is expected that educated household head can make informed decision on rehabilitation measures on degraded lands. Education and training is suggested to increase awareness and knowledge about land degradation problems and improve rehabilitation activities (Blay et al, 2004; UNFFS, 2005). However, the outcome of household survey showed that there was no relation between educational levels and involvement in rehabilitation of degraded lands in study area.

Table 21: *Sample household head by sex, age, family size, educational level and source of livelihood*

HHs		Kebeles				t-value	χ^2
		Shera (53)		HaricheUyaya (55)			
		No	%	No	%		
Sex	Male	49	92.5	53	96.4		0.7(ns)
	Female	4	7.5	2	3.6		
Age	20-35	35	66	17	30.9		
	36-50	14	26.4	29	52.7		
	51-65	4	7.5	9	16.4		
	Mean	34.6		40		-2.62**	
	SD	10.6		10.9			
Family size	4-Mar	6	11.3	8	14.5		
	7-May	12	22.6	13	23.6		
	9-Jul	23	43.4	19	34.5		
	> 10	10	22.6	15	27.3		
	Mean	2.75		2.77		0.8(ns)	
	SD	0.9		1			
Educational levels							
Cannot read and write		17	32.1	18	32.7		1.1(ns)
Elementary		20	37.7	21	38.2		

school				
High school	16	30.2	15	27.3
Vocational school	0	0	1	1.8
Source of livelihood				
Agricultural crop production & animal rearing	52	96.2	51	92.7
Trade	0	0	3	5.5
Selling fuel wood	1	1.9	1	1.8

ns=not significant, ** significant at 0.05 level

The average land size of sample respondents was 1.22 ha and 1.08 ha in Shera and HaricheUyaya, respectively. Moreover, there was a serious shortage of grazing land at the household level in both sites but those in Shera had significantly ($p < 0.001$) higher grazing land.

In addition, Table 2 shows that a considerable proportion of the sample respondents owned land size between 0.5 and 1 ha. From this, 92.7 % of them in HaricheUyaya and 79.2 % in Shera owned land size ranging $\leq$ 0.5 to 1 ha. However, significant variation in grazing land was one of determinant factors for success of rehabilitation of degraded lands in HaricheUyaya than Shera (Table 2). Similarly, study by Mgangaet al (2010) reported destruction by grazing animals contributes to rehabilitation failures.

Table 22: *Land use patterns and landholding size of the sample households*

		Shera	HaricheUyaya	t-value
Land use type& landholding		Mean$\pm$ SD	Mean$\pm$ SD	
Cultivated land		0.61$\pm$ 0.33	0.64$\pm$0.41	
Grazing land		0.24$\pm$ 0.10	0.18$\pm$0.09	3.31**
Tree plant/forest land		0.15$\pm$ 0.11	0.13$\pm$0.07	1.10**
Homestead		0.22$\pm$ 0.09	0.23$\pm$0.13	
Average size		1.22	1.08	
Land size	Shera	Percent	HaricheUyaya	Percent
$\leq$ 0.5ha	7	13.2	9	16.4
0.5-1ha	19	35.8	18	32.7
1ha	16	30.2	24	43.6
2ha	11	20.8	3	5.5
>2ha	0	0	1	1.8
Total	53	100.0	55	100.0

** is significant at 0.05 levels

The major livestock in the area are cattle, sheep, goat, poultry, and donkey. Households use livestock for different purposes such as cash income in case of emergency, means of transportation and source of manure. The majority of the respondents (98% in Shera and 96% in HaricheUyayaKebeles) said there was decline in livestock population, associated with shrinkage and degradation in grazing lands and shortage of feed. But the existing livestock were still negatively influencing the rehabilitation area in HaricheUyaya than Shera (Table 3). High livestock concentration and uncontrolled grazing can have a major influence on rehabilitation areas negatively (Lamb and Gilmour, 2003; Blay et al., 2004; Mganga et al., 2010).

Table 23: Livestock holding, dynamics and determinants

Type of livestock		Shera			HaricheUyaya		Average
	Mean	Max.	Min.	Mean	Max.	Min.	
Cattle	3.51	20	0	3.56	30	0	3.54
Sheep	0.91	3	0	0.93	5	0	0.92
Goats	1.25	8	0	0.56	4	0	0.91
Horse	0.04	1	0	0.02	1	0	0.03
Donkey	0.30	2	0	0.36	2	0	0.33
Poultry	3.21	30	0	2.60	10	0	2.91
Mule	0.04	1	0	0.04	1	0	0.04
Dynamics and determinants				Shera		HaricheUyaya	
			No	%	No	%	
Dynamics of livestock	Increasing		1	1.9	2	3.6	
	Decreasing		52	98.1	53	96.4	
	Shortage of feed		45	84.9	53	96.4	
Factors	Droughts		7	13.2	1	1.8	
	Disease		1	1.9	1	1.8	
	Communal		5	20.8	2	3.6	
Grazing lands	Surrounding homestead		48	79.2	53	96.4	

The survey result showed that the frequency of visit by development agents (DAs) varied among the sampled households. About 51% of the respondents got extension service at least three times per month in Shera whereas only 40% HHs in HaricheUyaya were visited by DAs, only once and twice in three months. The chi-square analysis indicated that association between visits by DAs and the probability of implementing rehabilitation was significant ($p < 0.05$) (Table 4). An institutional service plays a great role in enhancing awareness about rehabilitation of degraded land and the possibility of households to decide rehabilitation activities. The frequency of contact in extension service increases the possibility of the households to participate in rehabilitation of degraded lands.

Table 24 : Frequency of institutional services offered to the sampled households

Households	Kebeles	χ^2

	Shera (53)		HaricheUyaya (55)		
	N<u>o</u>	%	N<u>o</u>	%	
Once per month	7	13.2	6	10.9	9.9**
Twice per month	9	17	7	12.7	
Three per month	27	50.9	20	36.4	
Once per three months	9	17	13	23.6	
Twice per three months	1	1.9	9	16.4	

** is significant at 0.05 levels

Regarding perception towards land degradation hazards, almost all of the HH lands were affected by land degradation in both Kebeles. Population pressures, deforestation, over grazing and poor agricultural practices were some of factors mentioned by respondents as responsible for land degradation in the area (Table 5 and Figure 3).

Table 25: **Land degradation and rehabilitation measures by households**

Problems	Shera		HaricheUyaya		χ^2
	Yes	No	Yes	No	
Observed the problem of land degradation in the area	53(100.0%)	0	53(96.4%)	2(3.6%)	1.96(ns)
Farm land exposed to land degradation	47(88.7%)	6(11.3%)	50(90.9%)	5(9.1%)	
Measures	Shera	Percent	HaricheUyaya	Percent	χ^2
Practice of terracing	32	60.4	26	47.3	
Planting trees and grass	11	20.8	2	3.6	14.93**
Fallow system	0	0	1	1.8	
Strip cropping along the contour	10	18.9	26	47.3	

** is significant at 0.05 levels

The chi-square test indicated that household measures taken to protect land degradation were significantly (*p < 0.002*) different between the Kebeles (Table 5). The ways of local peoples perceiving rehabilitation of degraded lands were other determinant factors for success or failure of activities in the study area.

Land degradation and rehabilitation activities

The survey result showed that, the overall impacts of land degradation in the Shera and HaricheUyayaKebeles has reduced productivity of both crop and livestock, reduces farm plot size and poor soil fertility (Figure 2). Obviously, as indicated in various reports, land degradation is the most critical environmental issue facing many countries associated with severe socio-economic and environmental impacts (e.g. Bogale, 2002; Yamiet al., 2006).
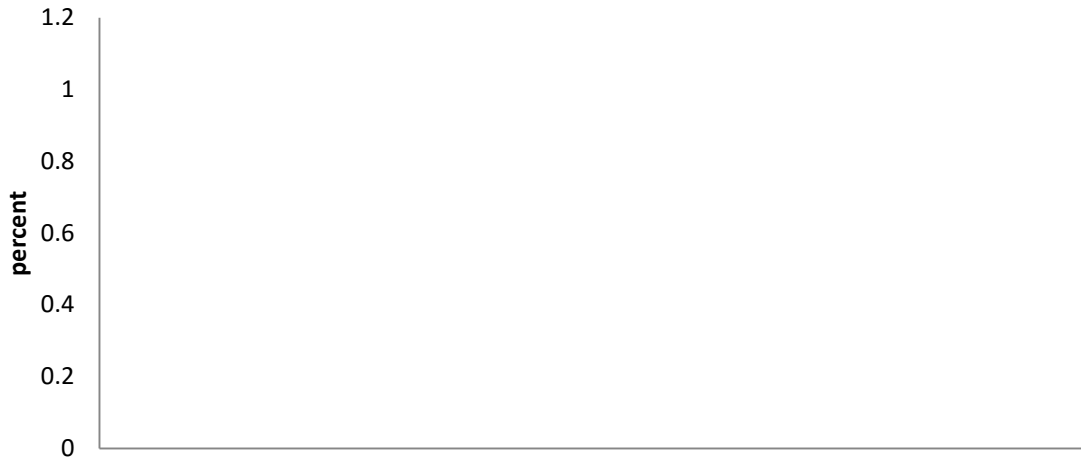
Figure 15: Impacts of land degradation in the study area

According to the respondents, the major factors responsible for land degradation in the study area were population pressure, deforestation and poor agricultural practices, in decreasing order of importance (Figure 3). Population growth has long been considered the prime cause of environmental degradation and clearing of vegetation cover from the landscape (FAO, 1995; Beyene, 2003; Zeleke et al., 2006).
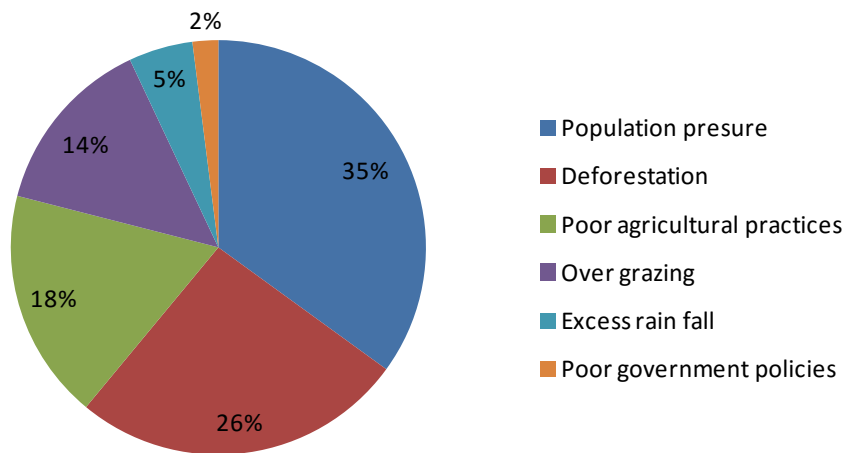
Figure 16: The major causes of land degradation based on their level of destructive effects in their locality according to the respondents

Factors influencing rehabilitation activities

During focus group discussion and key informant's interviews, it was understood that rehabilitation effort of degraded land was progressing well in Shera. In the study it was found out that at the initial stage of the rehabilitation process, lack of awareness was

one the factors that determine the success of rehabilitation measures in both Kebeles (Table 6). As reported by Amede, (2002) and Shono et al. (2007) lack of early awareness can be a possible cause of land degradation, and awareness raising is an integral component of rehabilitation of degraded lands. The issue of awareness creation was considered as the bolded word during the whole discussion with key informants, focus group discussion and household interviewees. Also key informants from Woreda underlined lack of awareness as the most important determinant factor in rehabilitation process.

Shortage of grazing land was another prominent factor determining the rehabilitation process in HaricheUyaya(Table 6).Grazing can have a major influence on rehabilitation negatively and contributes to rehabilitation failures (Lamb & Gilmour, 2003; Blay et al., 2004; Mganga et al., 2010).

Variation in institutional capacity to implement the activity was another factor that determines success in rehabilitation process in the study area. This can be in terms of extension service about rehabilitation of degraded lands (Table 4). Rehabilitation efforts made in Ethiopia so far failed mainly for the lesser attention to socio-economic and institutional frameworks (Babulo et al., 2010). The lack of commitment and coordination quality of the extension service contributed to the failure of the rehabilitation activity in HaricheUyaya. Similarly, Ezeaku and Davidson (2008) pointed out that lack of commitmentcould undermine the management and effectiveness of land degradation and their rehabilitation efforts.

Actors involved in the processes of rehabilitation of degraded lands

During the household survey, key informant interview and focus group discussion three actors were identified. These include local communities, government and non-governmental organizations. However, government and local community members were the prominent actors of the rehabilitation activities in the study area (Table 8).

The interviewees from the two Kebeles revealed that there was progressive integration between main actors/or government and local community members as compared to previous years.Rehabilitation provides opportunities to build new relationship between governments and local communities (Lamb & Gilmour, 2003; Shono et al., 2007). There was improved performance of rehabilitation activities in order to assure the sustained achievement of the desired outcomes in Shera than in HaricheUyaya (Table 5). The intention of rehabilitation offers the vision of creating improved relations between people and the environment in which they live (Higgs, 1997; Blay et al., 2006; Sudmeier-Rieux and Ash, 2009).

Perception of the local people towards rehabilitation of degraded lands

All respondents knew the presence of the rehabilitation of degraded lands in their locality from their own experience and through extension services from the Woreda Agricultural Office. The majority of the respondents (over 90%) in Sheraand

HaricheUyaya participated in the site selection as well as in the establishment of the rehabilitation sites (Table 6).

Table 6: *Perception of local people towards rehabilitation of degraded lands*

Subject of concern	Shera				HaricheUyaya				χ^2
	Yes	%	No	%	Yes	%	No	%	
Knowledge of the presence of rehabilitation area	53	100	0	0	55	100	0	0	
Participation on site selection	52	98	1	1.9	52	95	3	5.5	
Participation in rehabilitation of degraded lands in the area	52	98	1	1.9	54	98	1	1.8	
The need to protect the rehabilitation area	46	87	7	13	36	66	19	35	6.72**
Proper management of rehabilitation area	52	98	1	1.9	12	22	43	78	65.08**
Benefits obtained	45	85	8	15	36	65	19	35	
Shortage of fuelwood	45	85	8	15	51	93	4	7.3	
Shortage of grazing land	39	74	14	26	50	91	5	9.1	
Lack of awareness	48	92	4	7.7	52	95	3	5.5	

** = significant at 0.05 levels

When respondents asked about the importance of protecting the rehabilitation of the degraded lands, almost 87% in Shera but 66% in HaricheUyaya were interested. The chi-square test showed that there was significance difference (p < 0.01) between two Kebeles with regard to the need for rehabilitation of degraded lands.

Consequently, from the total respondents, 98% said that the rehabilitation of degraded lands has been properly managed in Shera. However, in HaricheUyayaKebele 78% of the respondents stated that there was no proper management of the rehabilitation areas. The chi-square test revealed that significant difference (*p < 0.001*) between Kebeles on the management of rehabilitation of degraded lands (Table 6). On the other hand, shortage of grazing land (accounted 73.6 % in Shera and 90.9 % in HaricheUyayaKebeles) and fuel wood (84.9 % in Shera and 90.9 % in HaricheUyayaKebeles) was reported as the causes of land degradation (Table 6). Most of the respondentswere changing their strategy to cope with the shortage of grazing land and fuel wood which they were facing. The majority of the respondents (79.2%) in Shera and (63.6 %) in HaricheUyaya used rotational grazing at the front yard of their homestead or leaving some part of land from cultivation fields. In both Kebeles,only 9.4 % and 20.0 % of the respondents were using cut and carry system and the others decreased their livestock numbers (Table 7). However, Babuloet al (2005) reported that

more people have been compelled to harvest fodder from the area of rehabilitation in northern Ethiopia.

Initially, the majority of the respondents (84.9 %) in Shera agreed to establish rehabilitation of degraded lands in their locality. While in HaricheUyaya lesser proportion of the community (53.6 %) were interested to take part in the rehabilitation effort. Thus, the chi-square test also showed significant variation ($p < 0.034$) on decision to establish rehabilitation area (Table 7).

Table 7: Position of agreement on establishing rehabilitation and alternative strategies to manage shortage of grazing lands

Households	Shera	%	HaricheUyaya	%	χ^2
Response agreement scale					10.43**
Strongly disagree	4	7.5	2	3.6	
Disagree	3	5.7	14	25.5	
No comment	1	1.9	4	7.3	
Agree	15	28.3	16	29.1	
Strongly agree	30	56.6	19	24.5	
Strategies					
Reduce livestock size	5	9.4	7	12.7	
Focus on other feed source	1	1.9	2	3.6	
Use rotation grazing	42	79.2	35	63.6	
Use cut and carry system	5	9.4	11	20	

** significant at 0.05 levels

As indicated in Table 7, about 93% of the communities were aware of the existence of local community regulation in the areas. From the sample respondents 83%said that both government and community were responsible for the management of the rehabilitation area.Similar studies conducted in Wollo, Ethiopia noted the importance of participation of peasant association leaders and members at grass root level for the success of enclosure of degraded lands (Mengistu et al., 2005).

Table 8: Local people perception towards responsible body

Respondent response	Frequency	%	Responsible body	Frequency	%
Yes	100	92.6	Government	5	4.6
No	8	7.4	Community	13	12.0
Total	108	100	Both	90	83.3

Success of rehabilitation of degraded lands

Participants of the focus group discussions and key informants explained the success of rehabilitation activities started with identifying the problem of land degradation and its impacts.Similarly, Blay et al. (2004) indicated the participation of the local communities as a key to success in any community-based development.The status of gradual decrease in vegetation cover and gradual removal of topsoil through erosion, then it has to be treated as degraded land (Figure 3). Success ofrehabilitation practices depends on a combination of policies and the close involvement of local communities, and can be achieved if there is the absence of negative human interference in the area at least for two to six years (IUCN, 2010; Babulo et al., 2010).

The communities in the two Kebeles observed that there was good regeneration of grasses, trees and reduction of flooding risks after the rehabilitation of the degraded lands (Figure 4). For the success of rehabilitation area, planting of suitable tree species and safeguarding was carried out. Like *Eucalyptus camaldulensis* and *Grevillea robusta* trees were highly needed by the people to plant in rehabilitation area.According to Tadesse et al. (2010) *Eucalyptus*species can be considered for successful rehabilitation of degraded lands.

From the field observation and survey results, it was noted that the lands under rehabilitation process still require more effortsin HaricheUyayaKebele (Table 5). The area under rehabilitation process in SharaKebele was success in vegetation cover than observed in HaricheUyayaKebele. In Ethiopia, rehabilitation starts with area closure that involves the protection and resting of severely degraded land to regenerate its productive capacity (Blay et al., 2004; Tekalign, 2010).

Naturally regenerated and planted tree species in the rehabilitation sites and their uses. The following were among the native species regenerated and planted in the area: *Croton macrostachyus, Syzygiumguineense, Vernonia amygdolina, Acacia species, Podocarpus falcatus, Ficus sycomorus, Olea europaea, Erythrina brucei, Maesalanceolata, Maytenusarbutifolia, Justiciaschimperina, Sclerocaryabirrea, Prunus africana, Rosa abyssinica, Albizia gummifera, Allophylusabyssinicus and Dodonaea viscosa.* Some of exotic species selected and planted in the area were *Grevillea robusta, Leucaena leucocephala, Sesbania sesban, Acacia decurrens, Acacia melanoxylon, Acacia saligna, Aloe vera, Cupressus lusitanica, Casuarina cunninghamiana*and*Eucalyptus camaldulensis.*

Rehabilitation of degraded lands for poverty alleviation

Rural poverty forces the poor to depend more in search of the remaining natural resources (FAO, 2003; Zeleke et al., 2006). Several attempts in Ethiopia towards ensuring food security are no-a-days related to working on rehabilitation of degraded lands. Poverty can affect the success of rehabilitation of degraded lands while its success helps in alleviating poverty (Shiferaw and Holden, 2003; GebreEgziabher, 2006); According to the key informants from the SoroWoreda agriculture and rural development department, rehabilitation of degraded land has become one of the strategies to alleviate poverty in the area.

During focus group discussion it was observed that, the productive safety-net program (PSNP) was highly contributing to the rehabilitation effort in Shera than in HaricheUyaya, and hence serving better as an incentive to mobilize the local community members in the former Kebele. Similarly, Tadesse (2010) reported that PSNP have been contributing to rehabilitation efforts in Konso special Woreda.

Socio-economic significance of rehabilitation programs

Among the respondent, 84.9% in Shera and 65.4% in HaricheUyaya confirmed that they have benefited from the nearby rehabilitation of degraded lands (Table 5). Their first benefit that was stated by the respondent households was grass for their livestock. The communities living around the area, where rehabilitation was taking place, were beneficiaries from recovery of the degraded land, as they could use at least grass for their cattle through cut-and-carry system and roofing material (Figure 4). The goals of rehabilitation of degraded lands could be for productions of grass for fodder and roof building, fire wood and construction woods and for in improving the overall ecological conditions of degraded areas (Mengistu et al., 2005; Descheemaeker et al., 2006).

Figure 17: The major changes observed after rehabilitation of degraded land

Conclusion and recommendations

Both government and local community are equally important in achieving success in rehabilitation of degraded lands. However, progressive integration between main actors/or government and local community members is essential in ensuring success in the participatory land rehabilitation programs. With regards to the community participation, socio-economic factors and their perceptions affect their level of engagement and the success of rehabilitation efforts in degraded lands. The indicators of success or failure include age of the household head, land holding size, grazing land, land management practices, livestock management, institutional services and awareness about purpose of rehabilitation. Out of these, the institutional services provided to the community, social capital expressed in terms of the experience in rehabilitating landscapes, and the societal perceptions towards the rehabilitation needs and efforts were the key determinants of success to which measures could be ascribed.

Specifically, the local community members exhibited varying interests in the activities of the program. Some community members were reluctant to participate in the program because they want the land for cultivation and grazing. Therefore, for success in the degraded lands rehabilitation, the level of engagement of the community should be redesigned so that they all embrace and own the process. In order to improve community's interest and increase the level of participation, the local people, civic societies and other stakeholders and actorsshould involve in formulating tailored rehabilitation measures is essential.

Acknowledgements

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ECOSYSTEM MANAGEMENT

ECONOMIC VALUATION OF BONGA NATURAL FOREST

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Abstract

Bonga natural forest is found in the south western part of Ethiopia. There is no information available on the economic value that Bonga natural forest can contribute to the local communities and the surrounding environment. Knowledge about forest economic helps to formulate policies and management strategy. This study was carried out with an objective of investigating the total economic value of Bonga natural forest. Contingent Valuation (CV), Cost Benefit Analysis, Watershed Protection and Soil Conservation Cost analysis were used in the study. The study revealed that fuel wood and construction material benefits were ranked first and second, respectively. Next farm implement tools, soil erosion protection, improvement of climatic change, wild coffee, and medicinal uses were identified in importance order. The mean willingness to pay for the studied forest on the single bounded and bivariate probit estimates were estimated 51.3 and 59.57 Eth. Birr /ha, respectively. The net present values to conserve Bonga natural forest in its present state is found to be 13,687 (minimum) and 49,359 Eth. Birr/ha (maximum). The result from computed of watershed protection and soil conservation cost was 28,667 and 64,339 Eth. Birr/ha for minimum and maximum, respectively. In conclusion, the total economic value of Bonga natural forest is the best estimated by watershed protection and soil conservation cost method which is 64,339 Eth. Birr/ha that is losing of 1 ha forest is equivalent the cost to bring back the forest as it was before.

Keywords: Forest valuation; Opportunity cost, willingness to pay, Bonga Natural forest

Introduction

Ethiopia's south-western plateau covers a total area of 161,424 ha on the highlands surrounding Bonga town which is the forest name Bonga natural forest is derived. It lying within 07°00'-7°25'N Latitude and 35°55'-36°37'E Longitude. It stretches across the boundaries of five contiguous woredas; namely, Gimbo, Menjiwo, Tello, Decha and Chena, all within the same zone (Keffa Zone). The altitude of the area varies from the lowest at 1000 m.a.s.l to the highest peak at the highest peak at 3350 masl to 75 % of the total area constitutes Weina Dega, while only 9 % and 15 % falls under Wet Qolla and Wet Dega agro- climatic zones, respectively. Besides these, there is comparatively very small element of sub-afro alpine habitat.

Bonga natural forest was identified as one of National Priority Area, among 57 other forests, beginning as of early. 1980s. Bonga natural forest falls under the category of moist evergreen

montane forest. According to Friis (1992), a substantial proportion of the same forest (i.e. between 1500-2200 m.a.s.l) is termed as: "Afromontane rain forest".

It was demarcated in 1986. However, despite the designation and demarcation of its boundaries, the forest is still experiencing a persistent human pressure and results an ever-increasing expansion of agriculture. A growing number of people, both from adjacent areas, and immigrants from other parts of the country began establishing new settlements, within the designated state forest territory. Bonga natural forest is designated by the Ethiopian government as National Forest Priority Areas (NFPAs) in order to reduce the degradation of the forest resources and conserve remnants of forests in different ecological zones even though, it was not practical.

Bonga natural forest lacks the information on the economic value that it contributes to the local communities and the surrounding environment. Knowing economic value of any forest is vital to formulate policies and management strategy. To justify this gap, the research project was set with an objective of investigating the total economic value of Bonga natural forest.

The main goal of this study was to determine the total economic value of Bonga Natural Forest; applicable for determining the total values of the forest contribution to the community and surrounding environment.

Methodology

Study sites

The study was carried in Bonga natural forest which is found in kaffa Zone, Southern Nations, Nationalities and Peoples Region (SNNPR). The specific study sites were: Saja, Achewa Yeyebito and Michiti peasant associations (PA). All of them found within and nearby the Bonga natural forest.

Saja PA

The Saja peasant association's land is used mainly for farming and grazing. The major forest products in the area include coffee, honey, timber, firewood, various tools and equipment for different purposes. The PA inhabits 412 households.

Achuwa PA

Achuwa PA, the land use system included: farming, grazing and investment. There is a community-based organization known as Achuwa Participatory Forest Management, Development and Protection Association. As its name indicates, the main purposes of the association is managing, developing (expanding), and protecting the demarcated forest. Moreover, it plants different species seedlings including coffee.

Yeyebito PA

Yeyebito PA the major land use systems in this area include: farming, grazing, coffee plantation, honey production and plantation. It was reported that 50% of the land is covered with forest. The major forest products being produced by farmers include honey, coffee, spice (korerima and

Timiz), firewood and house construction materials. There were also some investment enterprises and community-based organizations in the area running forest related businesses. Among the investment organizations include Green Coffee Agro-Industry and Kafa Lam (Homeland) Coffee Private Limited Company with prime aim of coffee production while Apiculture Agro-Industry works on honey production. There is also a Community Based Organization (CBO) known as the Bita Genet Participatory Forest Protection, Development and Use Association that protects, develops and uses the demarcated forest. Main objective CBO is to plant various tree species including coffee, protect and generate income out of, especially honey and coffee products.

Michiti PA

Michiti PA is bounded by Wish-wash town in the east, by Dudi forest in the west, Wushwush Tea Plantation project in the south and Botera Chira and Kasha River in the North. The inhabitants use their land for grazing, farming, bee production. About 60% of the area is covered with forest. Residents use the forest as sources of firewood, house furniture, tools, honey, coffee and spice (Timiz and korerima). These are investment enterprise that works on forest protection, such as Beka Forest Association that executes plantation of various tree species, protection and production of coffee as well.

Sampling techniques

For measuring total economic value & non-use values of ecosystem services of Bonga Natural Forest. The following investigation techniques were employed.
Contingent Valuation Method that followed by WTP Questionnaire
Watershed Protection and Soil Conservation Cost Analysis
Market survey for those items that have marketed and,
Opportunity cost analysis

Sample method selection

Contingent valuation method (CVM)

In the absence of organized markets, appealing approach to revealing the preference of individuals is the use of Contingent Valuation Method (CVM) (Mitchell and Carson, 1989).
The double bonded dichotomous choice approach which was applied (Carson, Honemann and Mitchell (1986) in this approach, the respondent was asked a question requiring a yes or no answer about whether he would pay a specified price. If the respondent says yes, another WTP question is asked using a higher price randomly chosen from a pre specified list. If the answer is no, the follow up question proposes a randomly chosen lower price (Mitchell and Carson, 1989).

Questionnaire design

The questionnaire included description of the study area, attitude/perception of the respondent about his /her area's environmental problems, relation between the respondent and forest resources. Total willingness to pay of the individual to the different benefits and services of the studied forest and finally, the results obtained from the different elicitation methods were disaggregated the total willingness to pay of the individual to the different benefits and services derived from Bonga natural forest.

Model specification

The data was analyzed by descriptive statistics.
Probit model: to identify factors affecting the WTP of households for the studied forest. The model followed Cameron and Quiggin, 1994.Bivariate Probit Model estimates the mean WTP from the double bounded dichotomous followed Haab and McConnell, 2002. Watershed Protection and Soil Conservation Cost.In this study, analysis depends on comparative role of forests as compared with other land use Secondary data sources were consulted to arrive at possible estimates and the analysis relied mainly on a study by FAO/IISA (1991). Based on these data, two hypothetical situations were assumed to give indicative values for the intangible value of this forest for soil conservation.

Assumptions:

The forest is undisturbed humid forest with litter layer of at least 50 mm, a canopy with 75% cover with 90% area covered by at least 50 mm of litter. The above humid forest is converted to maize cultivation with 80% vegetative cover, with intermediate input. The soil susceptibility to erosion is intermediate. Bare ground of soil loss due to rain induced erosion is 0.5 cm of topsoil per annum.Maize output/ha is 35 – 55 quntals and the price per quntal is 425 – 750 Birr in nearby markets.Cover factor (C) for the humid forest is 0.001 and the soil loss for this cover is 0.001×0.5 cm $= 0.005$ cm. On conversion to maize with conditions stated, C for stated conditions is $= 0.30$, soil loss per annum for this cover is 0.30×0.5 cm $= 0.15$ cm. Valuation of grazing Secondary data were used as substitute method in estimating the value of forest fodder. From literature, the minimum dry fodder requirement for livestock is 4 - 9 kg per day (Ganesan 1993). Secondary data were used for carbon Sequestration and Cost benefit analysis.

Results

Household characteristics

Respondent's age ranges from 20 to 81 years. About 42.26 % of the 1474 respondents were below 30 years, 25.08% between 31 and 40 years, 16.84% between 41 and 50 years and 9.33 % between 51 and 65 years and 6.49% above 65 of age. 41.78 % of the respondents were females and 58.22% were males.
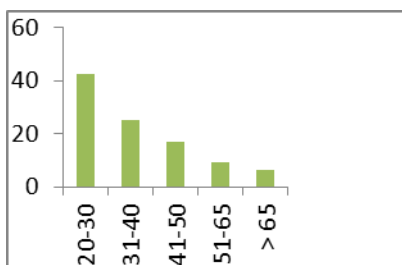
Figure 1: *Age group in % (source: survey data)*

Education level of respondents ranged from illiterate to Grade 10 and above. The majority of the respondents (47.31%) were illiterate whereas 23.78% were above grad five.
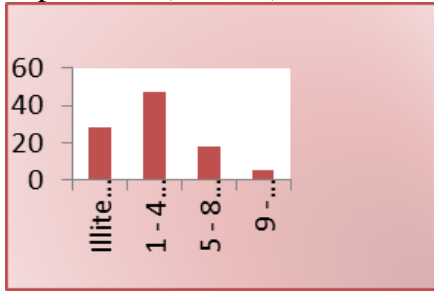
Figure 2: *Educational level in % (source: survey data)*

According to the survey data, the size of land owned by the family an average ≤ 2.5 ha/hh. This is expected to affect the WTP negatively. In other way, the larger the size of land owned by the family implies more income from crop production and this might affect the WTP positively.
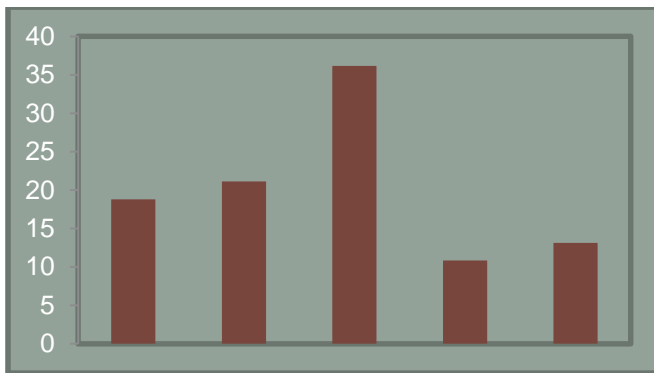
Figure 3: *Farmland size in %*

Environmental problems

According to the respondents (39.72 %), deforestation was the very serious problem of environment. Climate change and Soil erosion were also great problems for the studied forest. Shortage and un-timeliness of rain and climatic warming and soil erosion were reported as environmental problem by about 42.25% of the responded.
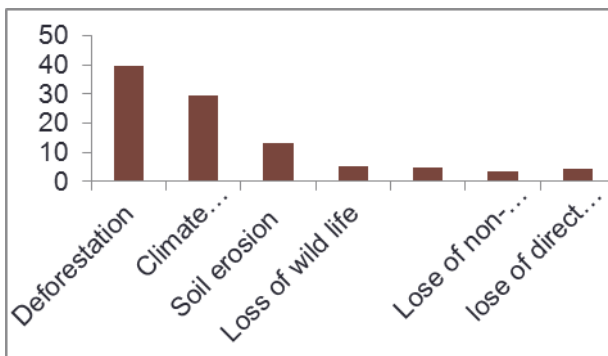
Figure 4: *Environmental problems identified by the respondents (source surveyed data)*

Bonga natural forest benefits to the community as responded by the by the respondents are as follows: Fuel wood an construction material(1st and 2nd on rank), farm implement tools, soil erosion protection, improvement of climatic change, wild coffee, spices were significantly identified by the respondents too.
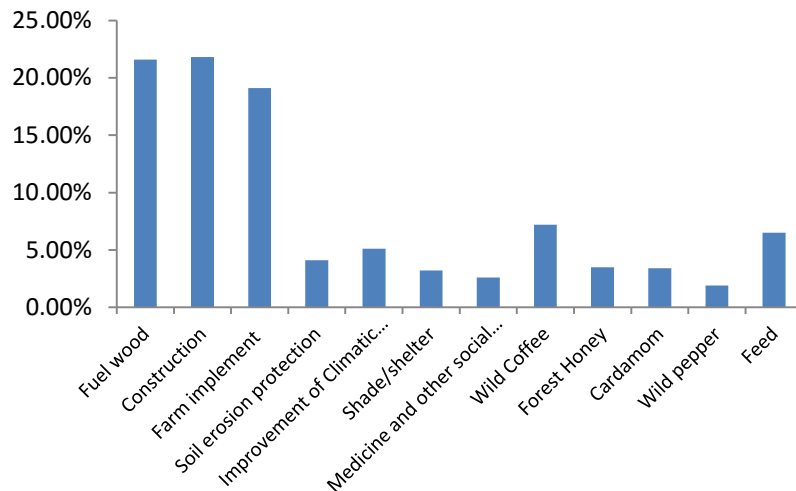
Figure 5: *Identified goods and services of Bonga natural forest (Computed from the survey data)*

Household income and wealth

To detect a representation for wealth, it was tried to calculate the values of total livestock owned by the family. Based on this approach, mean value of total annual income from crop production and off-farm activities was 8145 ETB per household. Taking the mean family size as 3.75, per capita income becomes 181 ETB per month, which is high as compared to the 62.7 ETB national average per capita incomes (IMF, 2001).

Determinants of WTP

Both probit and bivariate probit models were estimated for the single bounded and double bounded dichotomous choice models.Probit estimate for the single bounded dichotomous choice model for Bonga Natural Forest

Table 1: *Respondents Age, Sex, Family Size, Education Level and livestock Owned in the study area Bonga forest*

Variables	Probit
Respondents' age	-0.018** (0.0052)
Respondents' sex (0 for female,1 for male)	0.038 (0.1672)
Family size	0.032 (0.0231)
Respondents' Education level	-0.0027 (0.0331)
Respondents' livestock owned by family	0.000056** (0.00003)

Family income	0.000018 (0.00004)
Dummy for Beka study site(1 for Beka,0 otherwise)	0.4** (0.2133)
Dummy for Gewata study site(1 for Gewata,0 otherwise)	-0.08 (0.2312)
Bid amount	-0.007*** (0.0024)
_cons	0.45 (0.5632)
Number of observations	1479 (-023.13)
-2ln(LR/Lu)	36.37

***, **,* indicate significance levels at 1%, 5% and 10%, respectively (figures in parentheses are standard deviations).

The measure -2 ln (LR/Lu) shown in the above table represented a full test of significance. The null hypothesis is that the parameters of all variables including the constant are equal to zero. Under the null hypothesis, the tabled Chi-square for 11 digress of freedom at 99% confidence level equals 24.725 for probit model, at this level, the hypothesis is rejected.

Results of probit analyses revealed that among the variables that were expected to affect the willingness to pay of a household for Bonga Natural forest are sexes of the respondents, family size, and education level. But all of them did not significantly affect the willingness to pay.Surface price the sign on this variable is negative and is significant at 10% level. This implies that the probability of a 'yes' declines with increases in the bid; which makes sense.Wealth of the household this had a significant and positive effect on the willingness to pay for the studied forest.

The mean willingness to pay increased as the initial bid increased this indicates the presence of starting point base. The mean values for starting prices 10 ETB higher than the initial bids but mean values for the rest of the prices were lower than the initial bids.

Table 2: *Willingness to pay for the different surface bids*

Surface bids	Bonga Natural forest		
	Minlower	Max	Mean
10	0	40	11.4
15	0	50	12.9
35	0	30	8.9
50	0	70	32.1
70	0	80	36.9

Different benefits and services that the society drives from Bonga Natural Forest were identified. Values attached by the society to these different benefits and services were identified. Average willingness to pay for the different benefits and services of Bonga Natural Forest.

Table 3: *Willingness to pay for different benefits and services of the forest*

Type of benefits and services	Willingness to pay in Birr	Willingness to pay in %
Fuelwood	9.07	18
Construction	6.8	16.5
Farm implement	5.5	8.25
Soil erosion protection	3.9	5.85
improvement of Climatic Change	3.7	5.55
Shade/shelter	2	3
Medicine and other social services	3.4	5.1
Wild Coffee	7.95	11.9
Forest Honey	4.25	6.37
Cardamom	3	4.5
Wild pepper	1.6	2.4
Feed	8.4	12.6
Total	59.57	100

The higher average MWTP values were given to Fuelwood, Construction, Feed and Wild Coffee This result confirms that more value is attached for the direct use of Bonga Natural Forest followed by indirect use (i.e. 38.2 Birr and 21.37 Birr respectively). The total means value of Bonga Natural Forest is 59.57 Birr.

Mean willingness to Pay

The mean willingness to pay (μ) was calculated using the formula (Haab and Mconnell,2002) Using these coefficients and the formula, the mean willingness to pay for Bonga Natural Forest on the single bounded probit estimate was 51.3 ETB. For the double bounded bivariate probit estimate of the studied forest, the mean willingness to pay 59.57 ETB.
This amount was higher than the mean willingness to pay amount from the open-ended question which was 36.37ETB.

Aggregated benefits

The second estimate of the double bounded bivariate model to calculate as mean willingness to pay for the studied forest and the aggregated benefits of the society are summarized as follows:

Table 4: Mean willingness to pay and the aggregated benefits of Bonga natural forest

Studied Forest	Population size	Mean WTP for Bonga Natural Forest (ETB)	Total WTP for Bonga Natural Forest (ETB)	Bonga Forest Area in ha	WTP for Bonga Natural Forest (ETB)
Bonga Natural Forest	657780	59.57	39.18	760144	51.55

Total benefit derived from Bonga Natural Forest in terms of monetary value was found to be 39.2 million ETB or 51.55 ETB per ha/year.

  Watershed Protection and Soil Conservation Cost

Watershed Protection and Soil Conservation cost analyzed for Bonga forest. Soil loss measured in terms of incremental top soil eroded due to rain induced erosion is $(0.15 - 0.005)$ cm $= 0.145$ cm.

 Gross value of maize is Minimum   =   35 x 425 Birr /ha
=   14875   Birr /ha
            Maximum   =   55 x 750 Birr /ha.
=   41250   Birr /ha
Using yield loss equation, $Y = 1.2 X$,
            Where Y = productivity loss in percent;
                  X = soil loss in cm (source: FAO/IIASA 1991),

The soil loss of 0.145 cm caused by changed land use causes a reduction in yield of $1.2 \times 0.145 = 0.174\%$ or Minimum is 14875 Birr /ha and Maximum 41250   Birr /ha. Soil conservation value of this forest under the assumptions stated can, therefore, be estimated at minimum 14875 and at maximum 41250 Birr /ha. This will, however, change with different sets of assumptions. Using this scenario, the estimated benefit for this forest under the above assumptions is at minimum 11307142000 and maximum 31355940000 Birr per annum (total forest area is about 760144 ha).

Valuation of grazing

An average household in the study area has three cattle, two, goats and one donkey. According to local administration officials, 89.3 of fodder is obtained from forests and the number of free ranging animals at any time is 1160790 (193465 hh x 6 livestock/hh) and 93.8% of the households graze their animals inside the forest which is 181470. The actual livestock grazing in the forest is 170219 (0.938 x 181470).

Secondary data were used as substitute method in estimating the value of forest fodder. From literature, the minimum dry fodder requirement for livestock is 4 - 9 kg per day (Ganesan 1993). The livestock grazing within Bonga forest is 170219 kg and therefore requires a minimum 248519740 and maximum 559169415 kg or 248519.74 and 559169.415 tons of fodder each year. Forest grazing is not an all year round activity and provides 89.3% of fodder resources for each cattle/year. Thus, the forest provides 221928 and 499338 tons of fodder and this is equivalent to 125640880 and 282691606 bales of hay. Based on these assumptions, the conservative value of forest grazing is 5653839600 and 12721122270 Birr per annum. Therefore, the value of Watershed Protection, Soil Conservation and grazing is from 16960981600 to 44077062270 Birr per annum.

Carbon sequestration

Total carbon stock of Bonga forest was found to be 182259324 ton (Dr. Zewdu 2005.unpublished). The average price of sequestered carbon was $9.2 per tons in 2011. So, the carbon stock of Bonga natural forest is equal to 9.2 x 18225932, which is equal to $ 167678574 or 3038335768 Birr. The total value of Bonga forest (direct use + indirect use + non-use) summarized in the following table.

Table 6: *Minimum and maximum payment for direct use + indirect use + non-use of Bonga forest area in Value per ha*

Range	Unit	Direct use in billion	Indirect use in billion	Non-use in billion	Total Bonga forest value in billion	Bonga Forest Area in ha	Value /ha
Minimum	Birr	1.79	16.96	3.04	21.79	760144	27626.34
Maximum	Birr	1.89	44.08	3.04	49.01	760144	64474.63

Opportunity costs of conserving Bonga forest

In the absence of the forest, the land occupied by Bonga natural forest could be put under commercial tea plantation. Therefore, the opportunity cost of maintaining this forest is the net benefits foregone from the potential commercial tea plantation. In this analysis, Wush-Wush Tea Plantation was be used to calculate the opportunity cost of conserving Bonga forest because tea growing is an established economic activity in the area. The opportunity cost of conserving Bonga forest is the net revenue obtained when the forest is converted to tea production. Net benefit of conservation is the total economic value of the forest less the cost of maintaining it. This included the costs of managing the forest in a year and the opportunity cost (OC) of the forest in its present state as a conservation area.

It will not be possible to obtain data on operational costs for Bonga forest because there are no operational activities on going but it was assumed to be negligible. Therefore, the net conservation cost per ha could be summarized by the expression below:
NBconservation = NBdirect use +NBindirect use + NBnon-use – OCconservation (Ref..)

Minimum   =   27626.34 - 14979.88   =   12646.46
Maximum   =   64474.63 - 14979.88   =   49494.75
Cost benefit analysis of Wush Wush Tea plantation

Table 7: *Tea plantation production cost benefit analysis at wish-wash tea plantation, Kafka zone southwestern Ethiopia*

No	Description	Total Cost /ha in Birr
1	Total tea plantation cost	86044.22
2	Total Revenue from selling tea	101024.1
	Gross Profit	14979.88

Source: - Cost Benefit Analysis at Wush Wush Tea Development Office At Wush Wush Town

Conclusion and recommendations

The study revealed that fuel wood and construction material benefits were ranked first and second, respectively. Next farm implement tools, soil erosion protection, improvement of climatic change, wild coffee, and medicinal uses were identified in importance order. The mean willingness to pay for the studied forest on the single bounded and bivariate probit estimates were estimated 51.3 and 59.57 Eth. Birr /ha, respectively. The net present values to conserve Bonga natural forest in its present state is found to be 13,687 (minimum) and 49,359 Eth. Birr/ha (maximum). The result from computed of watershed protection and soil conservation cost was 27,626.34 and 64,474.63 Eth. Birr/ha for minimum and maximum, respectively. In conclusion, the total economic value of Bonga natural forest is the best estimated by watershed protection and soil conservation cost method which is 64,339 Eth. Birr/ha. This meant that losing of 1 ha Bonga Natural Forest is equivalent the cost to bring back the forest as it was before estate or ecosystem.

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CARBON STOCKS ALONG ALTITUDINAL GRADIENT IN GERA MOIST EVERGREEN AFROMONTANE FOREST, SOUTHWEST ETHIOPIA

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Abstract

Forest plays an important role in the global carbon cycle serving as carbon sinks of the terrestrial ecosystem. Carbon stock estimation enables us to understand the current status of carbon stocks and to derive its near future changes for the advance of sustainable forest management. This study was carried out to estimate the variation of carbon stock along altitudinal gradient in the Gera Moist Evergreen Afromontane forest, Southwest Ethiopia. Stratified systematic sampling method with a nested plot approach was used to collect data. The sampling sites were selected by dropping a regular interval of 100 m elevation gradient. Three quadrats of 100 m apart each other were established from each sampling site. A total of 30 rectangular quadrats having a size of 20mx100m were established to collect data. Within these quadrats, five $1m^2$ sized subplots (four at the corners and one at the centre) were established to collect samples of soil, litter and non-tree vegetation. The biomasses woody of plant species collected form the study area was calculated by using Chave et al. (2014) model. The estimated mean carbon density of the forest was 345.9 (t ha^{-1}). This is equivalent to 1268.35 t ha^{-1} of CO_2 gas.The estimated mean carbon stocks were greater in all carbon pools at the higher altitude (2334 -2539 m a.s.l.). The carbon density of Gera Moist Evergreen Afromontane forest can be considered as medium when compared with other studies done elsewhere in the tropics. The forest has a considerable amount of carbon stocks to mitigate climate change in line with its other use and non-use values.

Key words: Forest strata, Forest with coffee, Forest without coffee, Aspect, Anthropogenic disturbance

Introduction

Atmospheric CO_2 uptake by the vegetation is believed to play a vital role in the global climate change of the century to come (Chave et al., 2001). Woody and other live biomass are important indicators of the potential of forests to provide various products and services, including carbon sequestration. Forest carbon stock can be grouped into two main components biotic (vegetation) and pedologic (soil) carbon stock (Bhat et al., 2013).

Carbon stocks in a forest vary depending upon various factors and processes operating in the systems. These include: land use, land use changes, soil erosion geographical location, plant species, age of stand and deforestation (Bhat et al., 2013). It can also be affected by different

environmental factors such as: altitude, aspect and slope by affecting the distribution of tree species (Adugna Feyissa et al.,2013). Therefore, it is important to study the effects of these factors on biomass accumulationto manage the forest resourcesin a sustainable way.

Ethiopia as one of the country in tropics, little is known about inter site and temporal variability of forest biomass when compared to the large amount of information available in other continents (Chave et al., 2001; Abel et al., 2014). The country lacks periodic inventory and monitoring offorests,but itisvital to evaluate the magnitude of carbon fluxes between aboveground biomass (AGB) and the atmosphere over time (Abel Girma et al., 2014). In Ethiopia, information on forest carbon stocks is limited and fragmented (Belay Melese et al., 2014; Adugna Feyissa et al.,2013).

Moist evergreen Afromontane forests are the main remnant forests, which currently exist in Ethiopia (Feyera Senbeta, 2006). But, deforestation in combination with changes in forest management has caused great changes in this pristine forest type particularly, in the southwest Ethiopia. This situation in turn causesloss of biodiversity and decline total biomass of the forest (Kitessa Hundra, 2013). Therefore, all the problems stated above initiate research works regarding carbon stock estimation in the forest resources of the country. Accordingly, this research work on carbon stock estimation was done to provide firsthand information about carbon stock sequestered in different carbon pools in relation to altitudinal gradient in Gera Moist Evergreen Afromontane forest, Southwest Ethiopia for the implication of sustainable forest management.

Material and Methods

Description of the Study Area

This study was conducted in Jimma Zone, Gera District in Oromia Regional State. It is located 445 km far from Addis Ababa. The Forest is part of the Belete-Gera National Forest Priority Area. It is geographically located in between $7^0 13'–7^0 56'$ N and $35^0 57'–37^0 37'$ E (Figure 1 below). The Forest is administered by Oromia Forest and Wildlife Enterprise. The elevation of the study area ranges from 1400–3000 m a.s.l. (secondary information from Gera District Agricultural Office), but the elevation range of the Forest from which samples taken for this study ranges from 1819 to 2539 m a.s.l.
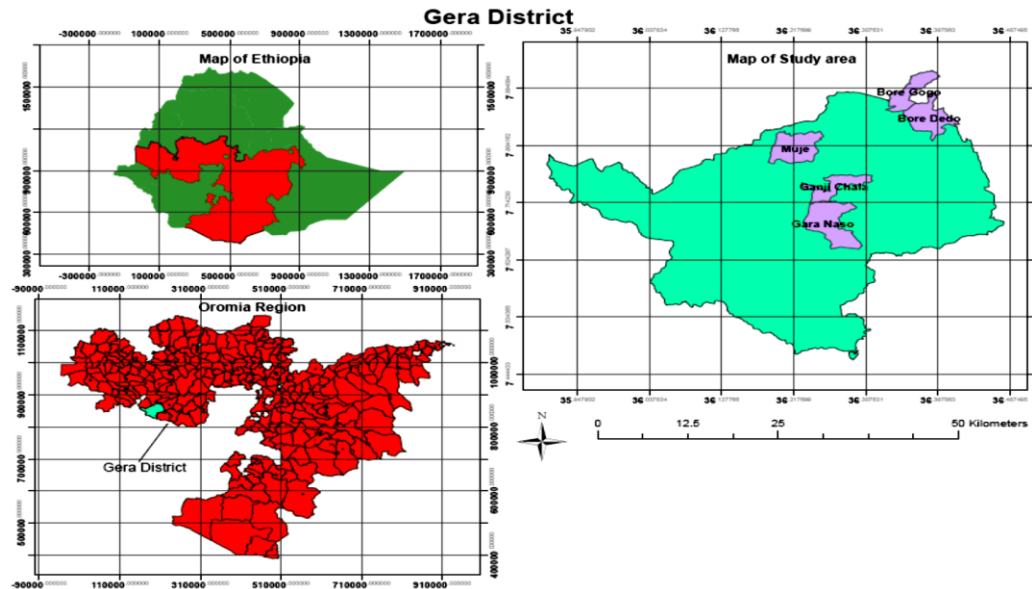
Figure 1: Map of Ethiopia showing Oromia Region and the study Area (Gera forest)

A twenty years climate data (rainfall and temperature) were taken from Ethiopian Metrological Agency (EMA) for Agaro station, the nearest weather station to the study site. The mean monthly temperature of the study area is 20.4 C^0. The annual rainfalls in the study area ranges from 746 – 2152 mm. Most rain falls between May and September, although occasional rainfall occurs throughout the year and the dry months in the study area are December to February. The study area has an undulating terrain with high altitudinal variation and characterized by mosaics of annual crop fields and large and small forest patches.

Sampling technique

The natural forest in the study area naturally exists in to two forms of forest strata (forest with coffee and forest without coffee system). Therefore, samples were taken from these two forest strata. In the present study, the elevation between 1819 and 1228 m a.s.l. was considered as lower altitude (forest with coffee system) and the elevation between 2334 and 2539 m a.s.l. was considered as higher altitude (forest without coffee system). Stratified systematic sampling method with nested plot approach was used. This approach is designed to collect discrete data for stands that had a range of stem diameter class or uneven aged forest type.

Ten sampling sites were taken by dropping a regular interval of 100 m elevation gradient starting from 2439 to 1819 meter at sea level (a.s.l). The remaining three sample sites were taken just by considering aspects in addition to altitude due to unable to go beyond 2539 (m a.s.l.) because of inaccessibility of the area. Therefore, the altitudinal variations between these sites were not uniform. From each sampling sites three rectangular quadrats were established. The intervals between two consecutive quadrats were 100 m apart from each other. The sizes of quadrats were 20m x 100m (2000 m²), which are important to capture heterogeneity of a forest that was adopted from Hairiah et al. (2001). Accuracy can be improved if trees with a DBH > 30 cm are sampled in a 20m x 100 m sampling area.

Data collection

Diameter at breast height (DBH) and height of all the trees and shrubs with DBH between 5 cm and 20 cm were measured in one of the nested plots (20m x 20m) and trees with DBH ≥ 20 cm were measured on the larger quadrats (20m x 100 m). Tree DBH was measured by using caliper for those trees which have a circular trunk and by diameter tape for those trees which have buttressed trunks. The DBH of forked trees at or below the DBH point were measured just below the forked point as suggested by Pearson et al. (2005).

Wood specific densities of the collected woody plant species were collected as secondary information from ICRAF wood density database (www.worldagroforestry.org) and Global wood density database (Zanne et al., 2009).

To estimate carbon stock in non-tree vegetation (NTV) carbon pool, all woody plant species with diameter < 4.9 cm and other non woody plant species at ground level were clip, cut into pieces and put into a plastic bag. The fresh weight of the mixed composites of the five subplots (four at the corners and one at the center) within the main plot was recorded. Then 100 g of well mixed subsample from composite was taken and brought to Addis Ababa University Ecology Lab, Addis Ababa for dry biomass calculation. The same procedure was followed for litter sample for fresh and dry weight biomass determination.

Soil samples were taken from the smaller subplots to a depth of 30 cm. Two types of soil samples were taken; one for bulk density by using a 5 cm diameter and 5 cm height core sampler, and the other for chemical analysis by using soil auger. The soil samples from the four corners and the center of the plots were composited and brought to Bedele Regional Soil Laboratory Research Center, which is located at Bedele, Ilu Ababora Zone, and Southwest Ethiopia.

In each plot, environmental data such as: elevation, aspect and anthropogenic disturbance were recorded. According to Zhu et al. (2010), the one among many factors that affect the amount of carbon stocks in a given forest is anthropogenic disturbance level. Therefore, if possible it is worth to classify a given forest into disturbance regime in order to quantify accurate carbon stock. In the current study, level of anthropogenic disturbance were recorded where the sampling plots are established and ranked subjectively. The disturbance was ranked 'Very high' when there was anobservation of charcoal production, cutting of trees, debarking of tees, grazing in and around the plot and short distance of it from agricultural land or village. The disturbance was ranked as 'High' when cutting, debarking, short distance from village and grazing was observed in and around the plot. The disturbance was ranked as 'Medium' when slashing and canopy opening for the purpose of increasing coffee production was observed in and around the plot; and finally the disturbance was ranked as 'Less' when the sampling plot was far from agricultural land and village and absence of above listed disturbance factors.

Plant specimens pressed, air dried and brought to Addis Ababa University for identification. The plant specimens were dried in the drying room and woody plant species identification was done by using Flora of Ethiopia and Eritrea and authenticated plant specimens in the ETH.

Data analysis

Data were arranged in Microsoft excel and analyzed by Minitab version 16 for other statistics. Moreover, appropriate allometric equation models are important tools that used to convert field data (species, basic wood density, DBH and height) into the oven-dried weight of biomass and carbon estimates (Brown et al., 2004).

In the current study, the equation developed by Chave*et al*. (2014) (eq. 1) used to estimate the AGB of the Forest which relates DBH, tree height and wood specific density as dependent variables.

AGB $_{est}$ = 0.0673(ρHD^2)$^{0.976}$………………………………..…………… **eq. 1**

Where AGB$_{est}$ = above ground biomass (kg), D =DBH (cm), H = height (m), and ρ = basic wood density (g cm^{-3}).

Litter layer

After the litter subsamples dried in drying machine at 70 c^0 for 24 hour, dry mass of the subsamples recorded and the dry masses of litter samples were calculated using the following formula (Pearson *et al*., 2005):

$$B_L = \frac{W \text{ subsample (dry)}}{W \text{ subsample (fresh)}} X \text{ W Field } X \text{ BEF} \text{ ---eq. 2}$$

Where, B$_L$is the litter dry mass (t ha^{-1}), W subsample (dry) - the oven dry weight of subsample, W subsample (fresh) - the fresh weight of subsample, WField - the fresh weight of sample collected from the sampling area and   BEF - biomass expansion factor.

Finally, carbon is taken as 50% the dry biomass of the liter sample (Clark & Kellner, 2012; Basuki et al., 2009; Gibbs et al., 2007; Pearson et al., 2005 and Hairiahet al., 2001). The same procedure was followed to estimate the carbon stock of non-tree vegetation carbon pool.

Belowground biomass

Since direct measurement of BGB is expensive and time consuming task, it is derived from AGB (shoot root ratio). The BGB is 20% of AGB (Gibbs et al., 2007; and Ponce-Hernandez, 2004):

BGB = 0.2 X AGB …………………………………………………………………….**eq. 3**

Where: BGB – belowground biomass, AGB – aboveground biomass

Extrapolating carbon stocks from a per plot basis into a per hectare basis requires the use of expansion factors. This standardization is required so that results can be easily interpreted and also compared to other studies.

Biomass expansion factor = $\dfrac{10000 \text{ m}^2}{\text{Area of plot,frame or soil core m}^2}$ …………………….**eq. 4**

Soil organic carbon

 For convenience and cost-efficiency, soil sample is advised to sample to a constant depth, maintaining a constant sample volume rather than mass (Brown et al., 2004).Soil bulk density is one of the parameter needed to calculate soil organic carbon.

Soil bulk density (g cm^{-3}) = $\frac{\text{Oven−dry sample mass (g)}}{\text{Sample Volume } (cm^3)}$ .... **eq. 5**

The Volume of the soil was calculated using the formula:

V = h πr^2 .... **eq. 6**

Where h= height of core sampler in cm, r= radius of core sampler in cm and V= Volume of the soil in cm^3.

The carbon concentration of the soil sample was calculated by using ferrous sulphate solution method. Finally, the carbon stock of SOC was estimated by following the equation:

SOC = BD X d X % CX100...**eq. 7**

Where, SOC = soil organic carbon (t ha^{-1}), BD = soil bulk density (g cm^{-3}), D = the total depth at which the sample was taken (30 cm), and % C = carbon concentration (%) determined in the laboratory.

Total carbon stock

The total carbon stocks (carbon density) were calculated by summing up all the carbon stocks of each carbon pools of the forest. The total carbon stock was then converted to tons of CO_2 equivalent by multiplying it by 44/12, or 3.67 (Pearson et al., 2007). Carbon stock density of the forestwas calculated as:

C density = AGC + BGC + LC + NTVC + SOC ....**eq. 8**

Where: C density = the summed carbon stocks in all carbon pools (Mg ha^{-1}), AGC = aboveground tree carbon (Mg ha^{-1}), BGC = belowground carbon (Mg ha^{-1}), LC = litter carbon (Mg ha^{-1}) NTVC = non-tree vegetationcarbon (Mg ha^{-1}) and SOC = Soil organic carbon (Mg ha^{-1}).

Note: the equations used from eq. 4-8 above were adopted from Pearson et al. (2005).

Results and Discussion

The distribution of plant species in the Forest showed variation with elevation. The diversity of woody plant species in the Forest is higher in the lower forest stratum or forest with coffee system (1819-2200 m a.s.l.) than higher forest stratum or forest without coffee system (2334-2539 m a.s.l.). Logically, altitude increases species richness, height of treeand DBH of trees becomes decreased (Zhu et al., 2010). In the present study except less species richness others were recorded reversely. This may related to higher anthropogenic disturbance at lower forest stratum due to the presence of coffee. The presence of coffee in the forest poses a problem on the Forest in the form of slashing under growth vegetation, debarking trees and canopy opening to maximize coffee productivity. Thecharacteristic woody plant species recorded at lower forest stratum include *Albizia gummifera, Coffe arabica, Ehretia cymosa, Olea capensis, Olea welwitschii* and *Sapium ellipticum.* Whereas the characteristic woody plant species at higher forest stratum include: *Ekebergia capensis, Hagenia abyssinica* and *Pouteriaadolfi-friederici.*

Carbon stocks against altitude

The result showedAGC has no regular increasing or decreasing pattern with increasing altitude (Table 1). AGC stock at strata level showed a distinct variation (i.e. higher altitude sequestered more carbon stock than lower altitude) (Table 2). The presence of more woody plant species with higher DBH class is one of the reasons that greater AGC and BGC at higher forest stratum were estimated. The other reason may be related to anthropogenic disturbance at lower forest stratum. Similar finding was reported from Egdu forest and Mount Zequalla forest (Abel Girma et al., 2014; Adugna Feyissa et al., 2013) (Appendix 1). Since BGC was derived from AGC it showed the same increasing or decreasing pattern with AGC against altitude. The variation of means carbon stock in these carbon pools in relation to altitude were significant (p - value < 0.005) which is 0.000.

Table 1: The estimated value of carbon stocks at sampling site in the Gera Moist Evergreen Afromontane forest

Sampling site	Elevational range (m a.s.l.)	Mean C (Mg ha^{-1}) in different carbon pools				
		AG	**BG**	**NTV**	**Litter**	**Soil**
1	1819-1846	72.46	14.49	1.76	1.73	142.57
2	1898-1943	285.11	57.02	1.48	6.83	122.50
3	2033-2043	89.44	17.89	0.92	4.29	135.37
4	2114-2189	102.28	20.46	2.00	2.60	165.62
5	2200-2268	149.40	29.88	0.90	2.16	124.92
6	2328-2338	98.77	19.75	1.00	1.32	150.98
7	2431-2436	174.89	34.98	3.86	6.60	198.63
8	2437-2442	229.50	45.90	3.09	3.23	249.26
9	2445-2475	100.90	20.18	4.98	3.41	207.26
10	2483-2539	78.19	15.64	2.04	18.62	229.04

Non-tree vegetation carbon (NTVC) did not show a clear increasing pattern with increasing altitude at sampling site. It was greater at higher forest stratum than lower forest stratum (Table 2). This may be due to less anthropogenic disturbance, low tree density per hectare which makes suitable for undergrowth vegetation and higher precipitation in the higher altitude. The mean variation of carbon in this pool with respect to altitude is not significant (p-value > 0.005). This result is similar to the research report done by Swai et al. (2014) (Appendix 1).

In the same way litter carbon was greater at higher forest stratum (Table 2). According to Fisher and Binkly (2000; cited by Adugna Feyissa et al., 2013), litter carbon stock in a given forest is determined by the condition of a forest (species, stand age and density) and climate. Therefore, its variation with altitude and forest type may be the result of these factors. In addition to these, anthropogenic factors had paramount effect on accumulation of carbon in different carbon pools. Maximum value of litter carbon was recorded due to the presence of more dead wood laid on the ground cut by human being. While minimum value of NTV carbon was recorded as a result of trembling due to anthropogenic factors. The variation of mean litter carbon with altitude was

statistically insignificant (p - value > 0.005). This result showed similar pattern with previous research reports (Belay Meles et al., 2014; Adugna Feyissa et al., 2013).

In the present study, SOC seamed increased with increasing altitude, but the increasing trend is not sharp (Table 1 above). SOC globally increases with precipitation (altitude) and clay content, even though it is mainly determined by carbon output (decomposition) and decreased with increase in temperature (Zhu et al., 2010).Table 2 shows biomass and carbon stock values at both forest strata (higher altitude or forest without coffee and lower altitude or forest with coffee system) in different carbon pools.

Table 2: The estimated value of biomass and carbon at strata level in Gera Moist Evergreen Afromontane forest

| Carbon pools | Mean C and Biomass (Mg ha^{-1}) | | | |
| | Higher altitude (2328-2539 m a.s.l.) | | Lower altitude (1819-2268 m a.s.l.) | |
	Biomass	Carbon	Biomass	Carbon
AG	225.33 ± 160.69	112.66± 80.35	210.12± 188.61	105.6±94.3
BG	45.07± 32.14	22.53± 16.07	42.02± 37.72	21.01± 18.36
Litter	13.27± 4.31	6.64± 2.15	7.05± 6.62	3.52± 3.31
NTV	5.99± 23.94	2.99± 11.97	2.82± 2.14	1.41± 1.07
SOC	-	207.03± 94.35	-	138.62± 35.53

Interaction between carbon stocks andanthropogenic disturbance and aspect

AGC shows direct relationship with anthropogenic factors. It decreased with increasing disturbance level. On the other hand, highest AGC was recorded at east aspect and the lowest was at northeast aspect (Table 3). This may be related to the timing of sunlight that the vegetation can absorbed. That means the vegetation that have been grown in the east direction receive sunlight earlier than vegetation in west and other directions. Visible light or photosynthetically active radiation (PAR) is decreasing from morning to afternoon (Kunshan and Juntian, 2008). The clima diagram in study area shows that rainfall is not a limiting factor for plant growth. Therefore, growth factors which vegetation more competes for sunlight.

The vegetation grown in the east aspect can receive photosynthetic active radiation earlier than vegetation on the other aspects. The carbon stock variation based on these factors between sampling sites were not statistically significant (p-value > 0.005).

Table 3: The mean aboveground carbon (AGC), belowground carbon (BGC), non-tree vegetation carbon

(NTVC), litter carbon (LC) and soil organic carbon (SOC) stock estimated against aspect in Gera forest

The SOC showed increasing pattern with increasing anthropogenic disturbance level (Table 4). This may be related to high rate of decomposition of dead organic matter.

Aspect	Mean Carbon stocks (Mg ha^{-1}) in different carbon pools					
	AG	**BG**	**Litter**	**NTV**	**Soil**	**Total**
East	**174.12**	**34.82**	**13.59**	1.83	158.78	**383.14**
West	65.84	13.17	1.93	0.74	114.68	196.35
South	72.07	14.41	3.30	1.93	179.85	271.56
Southwest	146.65	29.33	4.63	3.28	**204.52**	388.41
North	81.99	16.40	4.89	3.69	140.19	247.15
Northwest	92.16	18.43	1.72	2.43	99.77	214.51
Northeast	58.95	11.79	2.59	**4.81**	153.42	231.56

That means during disturbance there is high amount of litters and wood debris lay on the ground. At the same time since canopy is opened high sunlight reach to the forest floor that accelerates the rate of decomposition.

On the other hand, the carbon stock in AG and BG carbon pools showed a reverse pattern. The carbon in the litter pool showed the same pattern with AGC and BGC. According to Zhu *et al.* (2010), when stand age of a forest increase after disturbance, AGC and SOC density tended to increase whereas litter and dead wood carbon density generally followed a U-shaped pattern. This means that exactly at the time of disturbance the amount of litter and dead wood at the forest floor becomes high and they decreased when they become decomposed. They again become increased when the forest gets matured.

Table 4: The estimated carbon stocks in Gera Moist Evergreen Afromontane forest in different carbon pools based on anthropogenic disturbance

Disturbance level	Mean Carbon stocks (Mg ha^{-1}) in different carbon pools					
	AG	BG	Litter	NTV	Soil	Total
Very high	74.75	14.95	2.91	2.11	218.85	313.58
High	100.52	20.10	6.87	2.68	187.63	317.81
Medium	103.07	20.61	2.77	1.90	152.69	281.05
Less	176.05	35.21	6.64	1.45	138.94	358.30

The total carbon stock (carbon density) of Gera Moist Evergreen Afromontane forest (the present study) is 345.09 (Mg ha^{-1}). Of which the carbon stock in the soil carbon pool was estimated as the largest carbon stock (172.62 Mg ha^{-1}). Similarly, Usuga *et al.* (2010) sated that more carbon in the terrestrial carbon pool is stored in soils, and forest stored majority of it. The average bulk

density of the soil in the Forest was 0.78 g cm^{-3}. The carbon stocks in previous studies (Belay Meles *et al.,* 2014; Adugna Feyissa *et al.,* 2013) which conducted in other forests types of the Ethiopia were 1.7 timesand 1.8 times greater than present study respectively (Appendix 2). This may be due to differences in allometric equations used for biomass estimation (Yitebitu Moges *et al.,* 2010), anthropogenic disturbance and other complex ecological factors. The tree parameters used to calculate the biomass of the forest in the present study were DBH, basic wood density and height. On the other side, the previous studies used only tree DBH to estimate the biomass of the cross ponding forests. The carbon stock of the forest in the present study has equivalent carbon stock with Mount Zequalla forest (Abel Girma *et al*., 2014). On the other hand, the current study was 3 times, 1.6 times, 1.2 times and 1.2 times greater than Hanang forest, Chilimo forest, Menagesha Suba State forest and Selected Church forests respectively (Appendix 2).

Conclusion and Recommendations

Different value of carbon stocks exist in different forest types and eco region depending on physical factors (precipitation regime, temperature, and soil type topography), biological factors (tree species composition, stand age, stand density) and anthropogenic factors (disturbance history, logging intensity). Associating a given area of deforestation with specific carbon stocks that is relevant to the location that is deforested or degraded will result in more accurate and precise estimates of carbon emissions. Therefore, it is worth to stratify forests based on the degree of human disturbance and other environmental variation, which affects the accumulation of biomass in a forest in order to lead to accurate and cost effective carbon emission estimates associated with a given area of deforestation or degradation.

Moreover, anthropogenic factors have paramount effects on the biomass of the given vegetation. The decreased tree carbon stock in a forest due to anthropogenic factors can either result in increased dead wood, increased wood products or immediate emissions of CO_2. The efficiency of carbon storage in organic matter reflects the quality of environmental conditions: climate, soil structure and nutrient availability. In the current study, anthropogenic factors were become the most degrading factors in biomass of the Forest.

Acknowledgments

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FOREST RESOURCES

IMPERATIVE PHYSICAL CHACARCTERSTICS AND POTENTIAL USES OF *Eucalyptus Pilularis, Eucalyptus Viminalis* and *Trichilia dregeana* Lumber Tree Species

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Abstract

Imperativetechnical information on lumber seasoning, moisture content (MC), density, mechanical, workability, anatomy, chemical characteristics and technologies of utilization would strongly determine rational utilization of each lumber species. A study was conducted on home-grown two *Eucalyptus* species *(Eucalyptus pilularis* and *Eucalyptus viminalis)* andindigenous *Trichilia dregeana*timbers with the main objective of determining some imperative seasoning and density characteristics of lumber that will indicate quality and proper utilization. Study species (*E. pilularis*, *E. viminalis* and *T. dregeana*) were harvested from Shashemene, Asella and Arjo-Jimma/Dedessa sites, respectively. The experimental design for seasoning and density was complete randomized design, a factorial experiment.The experiments were conducted using oven/microwave, air and kiln seasoning methods. The results indicated that the final mean MC for both air and kiln seasoning methods were 11.37%, 16.39 % and 11.61 %, respectively. Mean air seasoning for *E. pilularis, E. viminalis* and *T. dregeana* sawn boards of 3 cm thickness to reach to about 12 % MC was 100, 50 and 48 days, respectively. Mean kiln seasoning was 5, 4 and 6 days, respectively. Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber. Kiln seasoning 9 to 19 times faster than air seasoning.The three species were classified as very rapid seasoning timbers but *E. pilularis* had rapid air seasoning rate. When *E. pilularis, E. viminalis and T. dregeana* lumbers seasoned from green (48-66 %) to 12 % MC, mean shrinkage (%) characteristic values were: Tangential (6.31, 4.94 and 4.43 %), radial (3.4, 4.02 and 2.10 %), and volumetric (9.46, 8.6 and 6.37 %), respectively. Seasoning defects such as cup, bow, crook, end split, surface- and end-checks were observed, though the extent varies with species. The density of *E. pilulalris, E. viminalis and T. dregeana at* 12% MC was 780, 810 and 530 Kg/m^3, respectively.The one way analysis of variance indicated that there was significant difference (p > 0.001) in initial MC, final MC, density values at different MC and shrinkage characteristics. Lumber species *E. pilularis, E. viminalis* and *T. dregeana* revealed good lumber characteristics and qualities, comparable with many indigenous and home-grown exotic timber species in density, seasoning rate and shrinkage. They have multipurpose lumber products, non-timber forest products, and live tree cultural and ecological services. The species have to be well grown and managed, logs properly harvested and sawn, boards stacked and seasoned to less than 20% MC, preferable with kiln seasoning method that can help to minimize seasoning time, seasoning defects, shrinkage characteristics and increase quality.

Introduction

Human beings will be utilizing the renewable wood and bamboo products and services to contribute to their comfort and ever increasing demand.The demand and supply of forest products to industries, construction and energy sectors in Ethiopia has been highly exceeding the supply. The 2011/2012 forest products import amount in tone was 170721.3 with a value of about 3.2 billion Ethiopian birr. Based on annual incremental yield of forests demand, and supply for the year 2020 has been projected to 132,500,000 m^3 and 28,710,856 m^3 (CSA 2008/2009 and 2012; Habtemariam Kassa and Zeleke Ewnetu, 2014), respectively. Demand will exceed the supply by 103,789, 144 m^3 (4.6 times, > 460%). To satisfy the ever-increasing demand of consumers, large quantities of timber, panel and fiber products are being imported from different countries with hard currency.

Selection of limited tree species for every intended purpose paired with the low recovery rate of the saw mills and further processing industries as well as inappropriate utilization due to lack of lumber technical/ characteristics information and/or technologies on different wood properties (characteristics), and the rapid development of construction (industrial, commercial, and residential buildings) in the country, have resulted in the degradation of the existing forests both in quality as well as quantity.

There are more than 300 indigenous and home-grown exotic tree species whose quality, suitability and potential as lumber are not yet investigated and realized. This was not made possible due to lack of efficient technologies for alternative use of less utilized and potential forest resources. The quality and performance of wood and wood-based products have been seriously affected by the major factors, among which MC, inappropriate drying (here after, seasoning) and density are the preceding ones. More than 90 % of all the encounters related with wood and its rational utilization involves moisture amount, its influence, and fluctuation with time, environmental conditions and management (Hodaley, 1989; Simpson, 1991; Denig et al., 2000; FPL, 2010). About 75% of the manufacturing problems in furniture industries are related to inappropriate moisture content of lumber (Denig et al., 2000). Moisture content, density, mechanical characteristics, seasoning and shrinkage characteristics (tangential, radial, longitudinal volumetric), seasoning rates and defects, workability, anatomy, chemical composition and technologies of utilization indeed are among the major factors that determine the quality, suitability, rational utilization and service life of wood as round and sawn lumber (Hodaley, 1989; Simpson, 1991; Denig et al., 2000; Getachew Desalegn, 2006; FPL, 2010).

Increasing efficiency of utilization of forest products through product diversification, value addition and maximization of uses of wood and wood–based products, import substitution and export promotion will be possible in Ethiopia after determining the different characteristics, quality and suitability of each species. It is worth thus, to undertake integrated research on economically lesser known timber species (*E. pilularis*, *E. viminalis*and*T. dregeana*) that are not yet known by the development, processing and construction sectors, manufactures and end users in the lumber market of Ethiopia.

The hypotheses were:
- There is difference on MC, seasoning rate, shrinkage and density characteristics among *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers
- Seasoning methods can make difference on lumber quality
- *E. pilularis, E. viminalis* and *T. dregeana* sawn trees have quality and potential uses as lumber
- *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers could be alternative raw materials for forest industries and construction sectors.

The general objectives of this study were to investigate the different characteristics, generate technical information, appropriate utilization technologies, and assess potential uses of *E. pilularis, E. viminalis* and *T. dregeana* sawn timbers. Specific objectives were to: (i) evaluate seasoning methods for the timbers, (ii) determine appearance, moisture content, seasoning characteristics (seasoning rate, shrinkage characteristics, seasoning defects, possible remedies, handling techniques for seasoned lumber) and density of the timbers at different MC levels (iii) observe biodeterioration attack during and after seasoning, and (iv) assess potential uses of the timbers. Therefore, this technical report includes the results on imperative lumber seasoning and density characteristics, and potential uses of *E. pilularis E. viminalis* and *T. dregeana*lumber tree speciesgrown in Ethiopia.

Material and Methods

Study species

The tree species for this study were *Eucalyptus pilularis Sm.* [Family:Myrtaceae], *Eucalyptus viminalis* Labill. [Family:Myrtaceae]and *Trichilia dregeana* Sond [Family:Meliaceae]thathave fast growth, high yield (*E. viminalis* 10-20 m³/ha/year), good performance (height, diameter and clear bole), versatile timber and non-timber forest products, socio- economical/ cultural and ecological benefits and services, good site adaptability and coppice ability (*E. pilularis* and *E. viminalis*) in the country.

Eucalyptus pilularis (blackbutt, pilularis gum) is a very large tree up to 70 m tall, with bole up to 4.1 m in diameter (Brink, 2008a; Anonymous, 2012ab). In Ethiopia, *E. pilularis* isavailable at Suba, Shashemene (Figure 1), Asella, and Belete plantations of the former Forestry Research Center now Central Ethiopia Environment and Forest Research Center (CEE-FRC) trial stations.
E. pilularis iseucalyptus species without lignotuber. It has easy regeneration and quick growth ability (Anonymous, 2012ab). *E. viminalis* is an evergreen, large tree up to 50 (–90) m tall; bole up to 120(–150) cm in diameter (Brink, 2008b).In Ethiopia it is planted on well-drained, deep soils. *E. viminalis* is resistant to fire (Brink, 2008b). In Ethiopia, *E. viminalis*isavailable at Suba, Shashemene, Asella (Figure 2) and Belete plantations, former CEE-FRC trial stations. The *E. viminalis* seed source stand at Asella/Ellna has been affected may be by disease of which about 8% dead.

The tree T. *dregeana*attains a height of up to 35 m, the tall main stem assuming a relatively straight trunk dividing into large branches and sometimes buttressed habit up to 1.8 m in diameter (Azene et al., 1993; Thirakul, 1993). T. *dregeana* is an excellent feature plant that is fast-growing and provides great shading for coffee and other crops (Anonymous, 2009b). Vernacular names in Ethiopia: Bonga (Am), Desh (Gm), Luiya (Kf) Konu, Luya, Shego (Or.) (Wolde Michael Kelecha, 1987; Azene et al., 1993; Thirakul, 1993). In Arjio/Wollega area it is called Ambaressa (Or.) where, Gm- Gimirigna; Kf- Kefgna and Or- Oromugna and Sh- Gumuz (Wolde Michael Kelecha, 1987). Common (English) names:forest mahogany, forest natal mahogany, muchichiri, white mahogany, cape mahogany, thunder tree, Christmas bells, red ash (Eng.) (Anonymous, 2009a; Anonymous, 2009b).

Fig. 1a E. pilularis stand from   Fig. 1b E. viminalis Asella/ EIena CEF-FRC   Fig. 1c T. dregeana from at Jimma

T. *dregeana*available in Wellega (Arjo-Jimma/Dedessa), Illubabor (Yayu, Chora), Kefa (Bonga, Bebeka) regions and Teppi areas of Ethiopia (Hedberg and Edwards, 1989). Some harvested logs of *T. dregeana* heartwood (pith) along height were deep hollowed may be by red ants/ termites. Sample trees of *T. dregeana* were harvested from Abote Dedessa of river Dedessa area on the way Nekemt to Bedele.

Selection and harvesting of sample trees (Sampling techniques)

Matured trees (5-10 m^3 woods) representative of merchantable log size were selected from different sites with good morphological quality, straight and cylindrical stem, relatively free from visible defects. Trees were selected and harvested from natural and plantation forests taking into account the height ($\geq$ 10 m), breast height diameter ($\geq$ 20 cm) and quality of the tree bole. Trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 20 cm.

Study species *E. pilularis, E. viminalis* and *T. dregeana* were harvested from Shashemene/Hamulu, Asella/Elena and Arjo-Jimma/Abote Dedessa sites, respectively. The sample trees were harvested and tests conducted during three consecutive years 2012-2014, respectively. The sample trees of E. pilularis, E. viminalis and T. dregeana had mean height of 27, 36 and 15 m, respectively, and mean breast height diameter at 1.3 m above ground was 50, 39 and 210 cm, respectively.

Log sawing and sample preparation

Harvested logs while green (> 30% MC) were sized to 2.5 m and transported to WTRC for the preparation and testing of samples.Logs were sawn to 3 cm thick tangential boards at WTRC

mobile circular sawmill by applying through-and-through type of sawing method. This sawing method was used to obtain approximately equal proportions of sapwood and heartwood as well as to make the radial, tangential and longitudinal surfaces conspicuous.

Sawn logs were converted to appropriate dimensions and number of samples for each wood characteristic test. Samples were prepared and selected proportionally from each tree and log at 1 m interval along height and marked with identification codes using an indelible pencil or waterproof permanent ink.

In this study, the types, dimensions and number of specimens required to undertake the imperative wood characteristic tests were prepared following the ISO standards/protocols (ISO 3129, 1975; ISO 3130, 1975; ISO 3131, 1975); Burley and Wood, 1977; Lavers, 1983; Simpson, 1991; Denig et al., 2000; FPL, 2010.

From the sample trees felled per species, 10-18 defect- free sample boards per tree species with dimensions of 100 cm in length, 3 cm thickness and width equal to log-diameter were prepared. The samples were used for the following-up the seasoning process and determination of the characteristics. The green (initial) MC of each timber species were determined from the two small sections cross-cut 20 cm inwards from each sample board ends having 1.2 cm length and 3 cm thickness.

Defect-free specimens of each timber species (2x2x3 cm) (width, thickness and length, respectively) at green state were used to determine shrinkage characteristics (ISO/DIS 4469, 1975). The shrinkage samples and the measurements were also used to determine the density values of the species at different MC using mathematical formulas.

Stacking sawn boards

After sawing, boards were transported to the air drying (seasoning) yard (Figure 2) and compartment kiln-seasoning chamber (Figure 2) areas and air seasoned for a week to reduce kiln seasoning electric charge. Boards of each species were stacked at 3 cm spacing between successive boards. They were stacked horizontally in vertical alignments separated by well-seasoned, squared and standard stickers. To facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process long stickers with a dimension of 2.5x2.5x180 cm (width, thickness and length, respectively) were used to separate boards while the short strips (2.5x2.5x20 cm) placed up on the long stickers were used to easily access the control sample boards of each stack.

Top loading was applied to offset/minimize warping (Simpson, 1991; Denig et al., 2000; FPL, 2010). Based on the availability of the materials and nature of each test, in air and kiln seasoning, heavy stones weighing about 50 Kg/m^2 were loaded at a spacing of 0.5 m.

In each stack of the air and kiln seasoning, when clearly separated clearly separated, the heartwood boards, which have less moisture content, were placed in the middle while the sapwood boards were placed along the sides, top and bottom of the stacks since they have more MC than the heartwood. The ends of boards were made equal in both directions. The control sample boards were properly distributed and positioned in the pockets of the different layers of each stack each stack.

Figure 2: Air seasoning stacks of *E. pilularis*, *E. viminalis* and *T. dregeana* lumbers.

Boards for air seasoning were stacked under shed without direct interference of moisture, rainfall or sunshine. Boards were stacked on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4 m. The boards were aligned in a north-south direction where the ends were not exposed to the direction of the wind. The north-south direction alignment of boards was done to facilitate good air circulation and reduce the direct influence of fungi, temperature, wind and relative humidity. Boards for kiln seasoning were stacked out of the kiln on the transfer carriage having a dimension of 2.7x1.6x 0.30 m and placed in the kiln-seasoning chamber (Figure 3) and tested one species at a time.

Figure 3: Kiln seasoning stacks of *E. pilularis*, *E. viminalis* and *T. dregeana* lumbers.

Seasoning methods applied

Air seasoning

Natural air and artificial kiln seasoning methods were used for testing and determination of seasoning characteristics. Green weights and dimensions of all air seasoning samples were measured immediately after planing and cross-cutting using sensitive electrical balance and caliper, respectively. Weighing of initial MC samples at 4 hours interval was carried out as soon as samples were withdrawn from the oven drier to minimize moisture absorption and desorption (Desch, 1986). The process was continued until the difference between two successive weights of each specimen is between 0.1-0.2 g and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010).The control sample boards were weighed, re-placed into the stack, re-weighed and MC determined for the stack at one-week interval continuously until the average

final MC of the stack reached about 12 % MC, which is the equilibrium MC for in- and out-door purposes and standard for comparison within and between timber species.

Kiln seasoning

The conventional type of artificial kiln seasoning machine was used in this study. The machine is well insulated and has about 2.5 m^3 wood loading capacity room or chamber per kiln operation. It has controlled air circulation, temperature and humidity that can be adjusted according to each species characteristics using psychrometers (dry bulb and wet bulb thermometers) and has been equipped with fans to force air circulation, and air outlet at a temperature range of 40 -70 ºC.

The kiln seasoning schedules are steps/norms involving serious of temperature and relative humidity at different corresponding MC levels were selected based on the initial MC of timbers (Tack, 1969) adapted from England, Sweden and other schedules. While carrying out seasoning of each timber species independently, kiln seasoning schedule Ethiopia 3 was applied for *E. pilularis* and *E. viminalis,* and kiln schedule Ethiopia 8 for *T. dregeana.*

In kiln seasoning samples were weighed and the direction of the fan changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation and seasoning, control the seasoning process and maintain quality of the seasoned wood. The process was continued until the difference between two successive weights of each specimen is between 0.1-0.2 g and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010).

All air and kiln seasoning boards were gone under an initial air seasoning before stacking and commencing the regular air and kiln seasoning processes. This was done to reduce kiln charge since there will be no characteristics change above and up fiber saturation point (30% MC) (Haygreen and Bowyer, 1996; FPL, 2010).

Moisture content seasoning determination

MC was determined for both air and kiln seasoning stacks of the timbers. The oven- dry weight method of MC determination (the standard way) (Haygreen and Bowyer, 1996; Reed, 1997; FPL, 1999; Denig et al., 2000; MTC, 2002) was applied in this test since it is an indication of the amount of solid substance present. In both seasoning methods, the MC (%) was determined by the formula adapted from (FPL, 2010; Denig et al., 2000; Anonymous, 2002).

Rate of seasoning determination

Air and kiln seasoning rates of each timber species were estimated from the MC samples of each species. Seasoning rate (%/hour) = IMC-FMC (%)/Drying time (Hour) (Moya et al, 2013) where, IMC-initial moisture content and FMC- final moisture content. Air and kiln seasoning rates classification of timbers was done based on the adapted standard Longwood (1961) and Farmer (1987), respectively.

Shrinkage characteristics determination

The differential shrinkage characteristics caused by the differences in tangential, radial and longitudinal directions, outer and inner fibers are the major causes of warp (cup, bow, twist, crook/spring), distortion in and around knots, and other seasoning stresses (cracks and checks) (Denig et al., 2000; FPL, 2010).

Samples of the timbers with a dimension of 2x2x3 cm (Denig et al., 2000) were seasoned in the oven seasoning chamber to a constant dimension at a temperature of 105°c. Initial and current dimensions and weights of all the shrinkage samples were measured once per day. The measurements like MC tests were continued until the difference between the two successive weights of each specimen was constant i.e. between 0-0.2 g. Then, the final weights and dimensions were taken as oven dry weight and dimensions, respectively. Shrinkage rates of each specimen at tangential, radial, longitudinal direction and volumetric were determined from green (≥ 48 %) to 12 % MC and from green to 0 % MC, respectively.

Shrinkage characteristics (tangential, radial and longitudinal directions, and volumetric) of values the timbers were determined using the different formulas adapted from ISO/DIS 4469, 1975; ISO/DIS 4858, 1975; Chudnoff, 1984; Simpson, 1991; Reeb, 1997;Denig et al., 2000; Anonymous, 2002; FPL, 2010. Shrinkage values from green to oven dry were classified based on Chudnoff (1984) and Anonymous (2002) and Anonymous (2012d).

Seasoning defects determination

Initial and after seasoning defects of timbers including knots, cup, bow, twist, end split, end and surface checks were determined.

Storing and handling of seasoned lumber

Seasoned boards were properly piled in the air seasoning yard, board on board, without stickers and no top weighting as has been done in the lumber market, industries and construction sectors. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack. Follow-up of seasoned boards was done for more than six months and observations were recorded.

Density test

The density (specific gravity) values of timbers were determined, as prime indicator of wood quality, since it has strong influence on wood characteristics (seasoning rate, defects and possible remedies, shrinkage, physical and mechanical characteristics, etc.) and timber quality (SO 3131, 1975; Denig et al., 2000; MTC, 2002; FPL, 2012). Specific gravity is unit less and is the density of wood per density of water, numerically equal to density since an equal volume of water at 4°c has a density of 1 g/cm3 or 1000 Kg/m3 (Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002).

The samples (2x2x3 cm), procedures and measurements applied during shrinkage tests were used to determine the density values of each species using mathematical formulas at different MC and

sample volume conditions. Basic density was determined based on green volume and oven dry weight, since the two are relatively constant conditions (ISO/DIS 3131, 1975).

The dry density values have been converted to standard 12% equilibrium MC (Table 1) by applying the formula adapted from Haygreen and Bowyer, 1996; Denig et al., 2000; MTC, 2002 and classified based on the adapted standard classification (Framer, 1987).

Experimental design

The experimental design for seasoning and density characteristics was complete randomized design (CRD), a factorial experiment with 3 tree species, 3 positions along tree height, ≥ 10 samples per species and two main factors (three timber species and two seasoning methods).

Data collection and analysis

The measurements of dimension (length, width and thickness) and weight were helped to determine the followingparameters/characteristics: (i) moisture content (%) at green/initial, current and final, (ii) density (gm/cm^3) at green/initial and air dry conditions, (iii) rate of drying (%/day), (iv) shrinkage (%) from green to 12 % MC and green to 0 % MC in tangential, radial and longitudinal directions and volumetric, and (v) initial and seasoning defects (observation and measurements). The one-way analysis of variance (ANOVA) using SAS (2004) statistical software package was applied for the analysis of the collected data. Comparison was made within and between the timber species initial and final MC amounts, shrinkage characteristics, and density values.

Results and Discussion

Appearance

Heart wood of *E. pilularis* is yellowish brown to light brown (Figure 4a) (Anonymous, 2012b). Heart wood of *E. viminalis* is pale yellow or pink and is not clearly demarcated from sapwood

Fig. 4a   Fig. 4b   Fig. 4c

Figure 4b: (Brink, 2008).

Figure 4: Lumber pictures of study tree species (*a- E. pilularis* lumber, b-E. viminalis lumber, c-*T.dregeana* lumber).

The wood of *T. dregeana* was a pale pink *(*Figure 4c) (Anonymous, 2009a). The odor from *T.dregeana* lumber while planning and cross-cutting made all machine operators, other participating staff and daily workers of WTRC to vomit and become very dizzy for several days.

Moisture content

The results indicated that before air and kiln seasoning commenced, the mean initial MC for the three timber species were 48.25 %, 56.1 % and 65.45 %, while the final mean MC for both air and kiln seasoning were 11.37 %, 16.39 % and 11.61 %, respectively (Table 1). After seasoning, *E. pilularis* and *T. dregeana* attained 12 % mean MC. This means that 0.12 times the weight of wood substance occupied by moisture/water, while 88% was only wood substance. The one way analysis of variance indicated that there was significant difference ($p > 0.001$) in initial MC, final MC, density values at different MC and shrinkage characteristics.

Initial MC along height of timbers during air seasoning varies slightly. In case of *E. pilularis* bottom part had 63% to 75% MC; middle part had 69.52% MC, while top part had the least MC (43%). *E. viminalis* kiln seasoning stack had high initial MC (67.71%) for bottom part, middle part had 58.93% and top part 48.56 % MC. *T. dregeana* kiln seasoning lumber stack had 62.3% initial MC for bottom part, middle part had 65.40% and top part 69.11% MC. Initial MC increased along height of *T. dregeana* lumber since the bottom part changed to heartwood having less MC.

Rate of seasoning

Compared to air seasoning, kiln seasoning of *E. pilularis* lumber was 99.95 times faster (Table 1). In other words, air seasoning took extremely much time, i.e, it took more than 99.95 times greater than kiln seasoning.

Air seasoning rate of *E. pilularis* was0.36 %/day and that of *T. dregeana* lumber was 1.19 %/day. Kiln seasoning rate of *E. pilularis, E. viminalis and T. dregeana* lumber was 7 %/day, 9.15 %/day and 8.94 %/day, respectively (Table 1). Based on the adapted rate of seasoning categories (Longwood, 1961; Farmer, 1987), the three lumber species classified as rapid (77-119 days) to very rapid (< 77 days) in air seasoning methods and in kiln seasoning all classified as very rapid (< 10.5 days). *E. pilularis* took more air seasoning days (100 days) since it was long rainy season (June-August), while kiln seasoning took similar days (4-6 days) for the three timbers. According to Brink (2008a), *E. pilularis* has been indicated as slow seasoning.

Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber. Kiln seasoning 9 to 19 times faster than air seasoning. Controlling of environmental conditions and seasoning defects was less likely during the air seasoning process.

Table 1: Seasoning and density characteristics of *E. pilularis*, *E. viminalis* and *T. dregeana* lumber species.

Timber species studied	Air seasoning stacks MC (%) and rate of seasoning(%/day)			Kiln seasoning stacks MC (%) and rate of seasoning (%/day)			Density classification at 12% MC*			
	Initial MC of air seasoning	Final air Seasoning	No. of days in air and rate	Initial MC of kiln	Final kiln seasoning	No. of days in kiln and rate	Green /Initial	Basic density	At 12% MC	Density value (Kg/m³)at
E. pilularis	48.5	10.21	100 (0.36 %/day)	48	13	5 (7 %/day)	1000	670 (±19.27)	780 (±21.6)	Heavy
E. viminalis	59.13		50	53	16.39	4 (9.15 %/day)	990	820 (±13.02)	810 (±13.24)	*Very heavy*
T.dregeana	65.8	11.21	46 (1.19 %/day)	65.61	12	6 (8.94 %/day)	940	500 (±1.0)	530 (±10.5)	*Light*

*-SEM for density (basic and at 12% MC) are presented in bracket, respectively.

Shrinkage and swelling (Dimensional changes)

When lumber of *E. pilularis, E. viminalis and T. dregeana* timbers seasoned from green (48-66 %) to 12 % MC, the mean shrinkage percentage values were tangential (6.31, 4.94, 4.43 %), radial (3.4, 4.02, 2.10 %), and volumetric (9.46, 8.6, 6.37 %), respectively (Figure 5). Shrinkage

percentage values of *E. pilularis, E. viminalis and T. dregeana* timbers at 12% MC were classified tangential (Large, Medium, Medium), radial (Fairly large, Large, Small), and volumetric (Fairly large, fairly large, Small), respectively.

The maximum longitudinal shrinkage varies from 0.1 %-0.3 %; maximum radial shrinkage: 2.1-7.9 %; maximum Tangential shrinkage: 4.7-12.7 %. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage (Anonymous, 2012d).
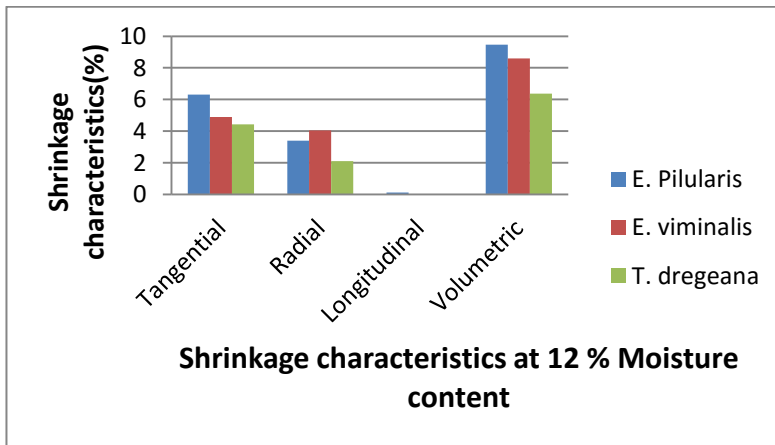
Figure 5: Mean shrinkage characteristics of *E. pilularis, E. viminalis and T. dregeana*lumber species at 12% MC.

The shrinkage characteristics of *E. pilularis, E. viminalis* and *T. dregeana*along height (bottom, middle and top parts) were not much significant when boards seasoned from green condition (47 %-62 % MC) to 12 % MC.Tangential shrinkage of *E. pilularis*, *E. viminalis* and *T. dregeana* were 1.86, 1.21 and 2.11 times greater than radial shrinkage, respectively. The shrinkage values of the lumbers up to oven dry (0 %) MC compared at 12 % MC was increased by about 1.66-1.68 times.

Tangential (4.94 %) and radial (4 %) shrinkage values of *E. viminalis* compared with similar study of Brink (2008), tangential (9.7-31 %) and radial shrinkage (5.2-13 %) was very low. *T. dregeana* had the least while *E. pilularis* the highest shrinkage characteristics. The lower the shrinkage value, the higher the quality of lumber for application. The respective mean tangential, radial, and volumetric swelling characteristics of *E. pilularis* (7.10, 3.63, 11.32 %), *E. viminalis* (5.34, 4.34, 10.06 %) and *T. dregeana* (4.48, 2.21, 4.86 %) lumbersat 12 % MC.

Seasoning defects and possible remedies
Seasoning defects such as cup, bow, twist, end split and checks were observed, though the extent varies with species (Table 2).

Table 2: Seasoning defects.

Timber species	Bow	Cup	Crook/ spring	End split	Surface check	End check	Knot
E. pilularis	x	x	x	x	x	x	
E. viminalis	x	x	x	x	x	x	x
T.dregeana	x	x			x	x	x dead knot

Preventions or remedies for seasoning defects indicated below: Bow and spring: Avoid seasoning low grade material with irregular grain, juvenile wood or reaction wood. Cup: Weights or adjustable strapping can minimize this defect. Distortion: Pile carefully with correct sticker spacing. Make sure sticker thickness is uniform. Support the ends of all boards. Careful control on the uniformity of the thickness of the boards being cut can reduce distortion. End splitting: Use end sealants or plastic end cleats. Stickers have to be placed up to the ends of the boards. Use timber shades if strong sunlight or warm winds are likely. Surface checks: Modify stacks to retard air circulation that can help to minimize checking. Internal checking: Use same measures as for end splits and surface checks. Twist: Avoid lumber with spiral, interlocked or irregular grain.

In brief, preventions or remedies for seasoning defects: Proper stacking using standard and well seasoned stickers, end sealants or plastic end cleats, top loading/ adjustable strapping …

Storing and handling of seasoned lumber
Seasoned boards were properly piled board on board foundation (under shed), without stickers and no top weighing. Boards were handled and conditioned well without direct access of moisture and sunshine to avoid dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack. Seasoned boards were inspected for more than six months and no infestation and biodegradation attack observed.

Density characteristics

Mean green (initial), basic and dry density of *E. pilularis, E. viminalis and T. dregeana* lumber speciesat 12 % MC were 780, 810 and 530 Kg/m^3, respectively (Table 1). The three lumber species in density at 12 % MC categorized light to very heavy. The density of *E. pilulalris* (780 kg/m^3) classified as heavy, *E. viminalis* (810 kg/m^3) classified as very heavyand the density of *T. dregeana* (530 kg/m^3) at 12 % MC, classified as light densitylumber species. The density of *E. pilulalris* was 740–960 kg/m³ at 12% MC (Brink, 2008a) while that of *E.viminalis* was 670–940 Kg/m³ (Brink, 2008b).

Comparable lumber species in density values at 12% MC with accuracy of ± 5% were selected with those same method and laboratory (WUARC, 1995; Getachew Desalegn et al., 2012). E. pilularis was comparable with*Celtis africana, Diospyros abyssinica, Eucalyptus globulus, Eucalyptus nitens, Syzygium guineense* and *Warburgia ugandensis. Lumber species Acacia decurrens, Eucalyptus paniculata, Olea welwitschii* were comparable with*E. viminalis* while

lumber species *Albizia schimperiana, Eucalyptus delegatensis, Grevillea robusta* and *Podocarpus falcatus* are comparable withT. *dregeana.*

Potential uses/applications of study timber species

E. pilularis, *E. viminalis* and *T. dregeana* timber species have versatile lumber and wood-based products, non-timber forest products and live tree uses/cultural aspects.Based on the results on seasoning, moisture content and density characteristics and references each timber species recommended for the different potential applications/uses accordingly.

E. pilularis potential uses/ applications

Lumber and wood-based products uses: Itis one of the main hardwoods of Australia, a significant commercial species. It is well regarded by foresters for the high quality of timber, easy regeneration and quick growth. The wood is moderately heavy, with a density of 740–960 kg/m³ at 12 % MC, strong, tough and moderately hard, not particularly difficult to work (Brink, 2008a). *E. pilularis* timber can be used as poles, posts, railway sleepers, flooring as used in the flooring of Parliament House (Canberra) panelling, construction, building framework, cladding, joinery, lining boards, furniture, veneer wood chipping and decking. It makes good charcoal and fuel wood (Brink, 2008a; Anonymous 2012a; Anonymous, 2012abc).

*E. viminalis*potential uses/ applications

Lumber and wood-based products uses:The wood can be used for poles, tool handles, shingles, indoor construction, flooring, boards, panelling, interior trim, joinery, ship and boat building, vehicle bodies, furniture, ladders, sporting goods, veneer, plywood, boxes, crates, particle board and fuel wood (Brink, 2008b).

E. viminalis as potential source of pulp for paper making compared to pulps from *E. globulus* and *E. grandis*, which are currently the main sources of *Eucalyptus* pulpwood, pulp from *E. viminalis* had a high strength, high opacity and low porosity, making it especially suited for wood free printing and writing papers and specialty papers (Brink, 2008b). When the wood is to be used for pulping, coppice rotations of 6–8 years are applied.The wood contained 44% cellulose, 22% glucuronoxylan and 29% lignin (Hills and Brown, 1978; Webb et al., 1984;Brink, 2008b).

Non-timber forest products: *E. viminalis* is bee forage. Branchlets have been used for weaving. A decoction of the leafy twigs is used in baths against rheumatism in the legs. In Ethiopia, leaves yield 0.8% essential oil, with main components 1, 8-cineole (50.9%), α-pinene (28.2%), globulol (5.1%) and limonene (4.3%). The essential oil content is highest in the summer season, when temperature and humidity are high (Brink, 2008b).

Live tree uses/ cultural aspects: The species is planted as an ornamental and shade tree, and in shelter belts and wind breaks. The trees coppices well. It is resistant to fire (Brink, 2008b).
Prospects:_E. viminalis_ suitable for regions where frost is common. It is considered as good alternative of *Eucalyptus glubulus* at higher altitudes. It has also good prospects for paper making and as source of cineole –rich essential oil (Brink, 2008a).

Trichilia dregeana **potential uses/ applications**
Lumber and wood-based products and uses: The wood easily worked making it very suitable for carving (Wyk et al, 2000 cited in Anonymous, 2009a). It is used for furniture and household implements, plywood and veneers, furniture, mortars, joinery, cabinetworks and interior decoration, construction and firewood (Azene et al, 1993; Thirakul, 1993*)*.

Non-timber forest products: The seeds are edible after removing seed coat and the seed arils are cooked as a vegetable or crushed to yield a milky juice taken as a drink or with side dishes (Wyk et al 2000, cited in Anonymous, 2009a). The seeds are also rich in fat. This fat being used in soaps, as body ointment and hair oil as well as for cooking (Von Breitenbach 1965 cited in Anonymous, 2009a). The species is also an important medicinal plant with the seed, oil, leaves, roots and bark being used for such purposes (Pooley, 1993, cited in Anonymous, 2009a).

Live tree uses/ cultural aspects: The forest mahogany, owing to its attractive nature and the fact that it makes an effective shade tree, is now a commonly cultivated species. *T. dregeana* is highly ornamental species with considerable cultural and ecological values. Flowers October to December and fruiting between January to May. Tree provides suitable nesting sites for a number of birds (Anonymous, 2009a).

Conclusion and Recommendations

Timber species revealed good lumber characteristics and qualities. These species were comparable with many indigenous and home-grown exotic timbers in density, seasoning rate and shrinkage. They have multipurpose lumber and wood-based products, non-timber forest products and live trees have ecological uses/ cultural aspects.

These lumber tree species *E. pilularis, E. viminalis* and *T. dregeana* have to be well grown and managed, timber properly sawn, stacked and seasoned to less than 20% MC. *E. pilularis, E. viminalis* and *T. dregeana* boards seasoned preferably with kiln seasoning method that can help to minimize seasoning time, seasoning defects and shrinkage characteristics thereby increase quality. Seasoned lumber of all study species have to be properly handled and rationally utilized at specified MC and density for intended construction and furniture purposes. Lumber species namely *E. pilularis, E. viminalis* and *T. dregeana*, to a certain extent can substitute accordingly comparable and endangered timber species in Ethiopia.

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ETHNOBOTANY OF WOODY MEDICINAL SPECIES IN YIGARCHEFE DISTRICT, SOUTHERN ETHIOPIA

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Abstract

In Ethiopia, indigenous knowledge about ethnomedicinal plants for the health care system of humans served up until early 19th century. The present study aimed at assessing and documentingwoody medicinal species commonly being used by Gedeo ethnic communities and traditional healers in Yirgachefe District of Gedeo Zone, southern Ethiopia. A total of 87 informants comprising 77 men and 10 women between the ages of 22 and 112 were selected. Data were collected using semi-structured interviews, guided field walk, discussions and field observations. A totalof 53 plant species belonging to 52 genera and 33 families were identified and documented. Family*Fabaceae*was represented by the highest number of species (9%), followed by *Rubiaceae* (8 %) and *Asteraceae* (7 %). Among all species, 62 % were applied for human ailments, 4 % were used for livestock ailments and 34% were both human and livestock ailments. *Croton macrostachyus* followed by *Albizia gummifera, Erythrina brucei* and *Brucea antidysenterica*were the most popular woody medicinal plant species. Stomach ache, Teeth illness, Gonorrhea, Cancer, malaria, Evil eye and many others were treated by different medicinal plant species. Gastrointestinal disorder and parasites infections had the highest Informant consensus factor (ICF) value, which accounted for 0.73, whereas *Bersema abyssinica, Celtis africana* and *Echinops longisetus* had the highest Fidelity level (FL) (100 %) in treating stomach ache in Yirgachefe District. Most of the traditional remedies were collected in fresh forms (91 %). Remedies were processedmainly through chewing, concoction and pounding and administered through orally (59.8 %) in estimated or fixed doses. Most of the traditional healers (81.6 %) in the study area had an experience of more than 20 years and they were more effective in administering the remedies. Under the Gedeo traditional Enset-Coffee based traditional homegardens Agroforestry system medicinal plant species plays a significant role for the farming households. Documenting woody medicinal plant species and associated indigenous knowledge can serve as a basis for future investigation of modern drugs as well as their conservation and sustainable use in Yirgachefe District.

Keywords*: Ailments, conservation, drugs, healers, threats

Introduction

Various medicinal plants were traditionally used as early as 5,000 to 4,000 B. C. in China and 1,600 B. C. by Assyrians, Babylonians, Hebrews and Egyptians (Hill, 1952). As a result, various woody medicinal species have been used as major source of medicine throughout the human history in traditional healthcare system. Accordingly, on the global basis, approximately 80% of the world population is believed to rely to some extent on medicinal plants for their medicinal applications (Cotton, 1996).

Likewise, in Ethiopia, more than 80% of the human population depends on traditional medicines for their health services (Dawit and Ahadu, 1993). Similarly, about 85% of livestock owners alternatively use both modern and traditional veterinary practices (Mesfine and Lemma, 2001). Thus, the demand and trade of woody medicinal species becomes increasing from time to time to alleviate health problems worldwide (Dawit, 2001). This is because of cultural acceptability, effectiveness, accessibility as well as economic affordability as a primary health care needs (Sofowora, 1982; Dawit and Ahadu, 1993). Despite this fact the contribution of ethnomedicinal plants in the traditional health care system has received very little attention in modern pharmacological research and drug development. This is because indigenous knowledge and the associated traditional medicinal practices of the local communities are not properly explored and documented.

Therefore, the present study was aimed at assessing and documentingwoody medicinal species commonly used by local community and traditional healers (practitioners) under Gedeo Agroforestry system in Yirgachefe District, southern Ethiopia. This helps to domesticate and promote them to improve the general health care system in the society and hence contribute for the proper utilization, management and conservation of these resources.

Material and Methods

Description of the study area

The study was conducted in Yirgachefe District, Gedeo Zone, Southern Nations, Nationalities and Peoples' Region (SNNPR) in southern Ethiopia. Yirgachefe District is bordered on the south by Kochere, on the west by the Oromia Region, on the north by WenagoDistrict, on the east by Bule, and on the southeast by Gedeb District (Fig. 1). Yirgachefe town, the capital of Yirgachefe District, is 395 km away from Addis Ababa. The study sites are located between latitudes 36N 067 41 19 8°50' and 9°10' north and longitudes UTM 067 86 99 39°45' and 40°10' east within an altitudinal range of 1931-2524 m a.s.l. The ethnic communities found in the District are mainly Gedeo ethnic communities. But other ethnic communities are also found in the District.Based on the 2007 Census conducted by the CSA, Yirgachafe District has a total population of 199,077, out of whom 99,421 are men and 99,656 women (CSA, 2008). The study *Kebeles* were located around Yirgachafe Town.
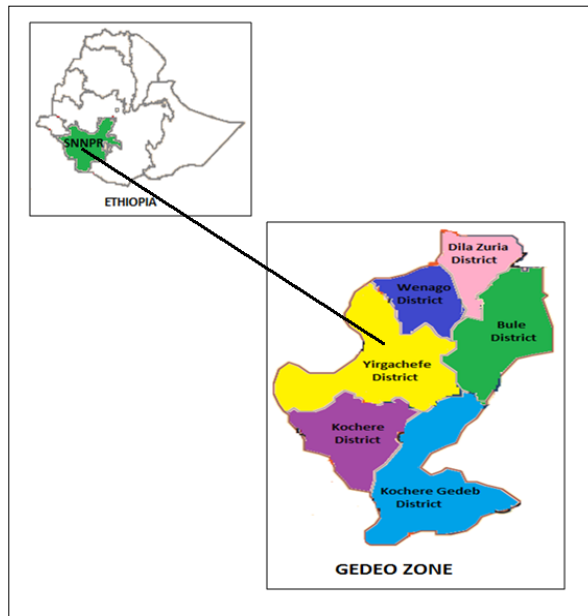
Figure 1: Map of Yirgachefe District of Gedeo Zone in SNNPR (source: UNOCHA, 2010)

Research methodology

Following a reconnaissance survey and pretest in Yirgachefe District between September, 2014 and June, 2015 nine sampled *Kebeles* (*Gerse, Bowicha, Wete, Haru, Beti Gotu, Hafursa Werabe, Wegida, Dumerso* and *Ila Tenecha)* were identified. During ethnobotanical study, 87 informants (77 men and 10 women) between the ages of 22 and 112 were selected for the assessment of woody medicinal species. Following the methods by Martin (1995), Cotton (1996) and Cunningham (2001), structured interview, guided field walk, individual and group discussions, direct researchers observation were applied to obtain indigenous knowledge of the local people and traditional healers on commonly used woody medicinal species. This ethnobotanical method was effectively applied by Tinsae et al. (2011), (2012), (2013) and (2015)

During data collection, basic information on woody medicinal species including their socioeconomic data (population demography), local names, plant use(s), growth habit and habitat, part(s) used such as leaves, root, fruit, seeds, bark, latex, etc., remedy used for human and/or livestock aliments, disease treated, method of preparation and ingredients added, route of administration, amount of dosages administered to the patience and associated side effects during taking the drug, sales price of the drug, method of collection and storage form used (fresh/dried), source of plant species (wild/cultivated), their conservation practice, indigenous knowledge transfer and management strategies, major threats and other related aspects were collected (Ermias et al., 2008 ; Haile et al., 2008; Tinsae, 2009). Voucher specimens collected under Gedeo Agroforestry system during the guided field walk were identified and approved at the National Herbarium, Addis Ababa University.

Data analysis

Collected ethnobotanical data were summarized using descriptive statistical methods such as graphs, tables and percentages. The Informant consensus factor (ICF) values were determined

following the method adopted by Tilahun et al. (2007), Fisseha et al. (2009) and Moa et al. (2013). The formula used to calculate ICF values was as follows:

$$ICF = \frac{nur - nt}{nur - 1}$$

Where, ICF = Informants Consensus Factor; nur = number of use citation in each category; and nt = Total number of species used.

Similarly, Fidelity level (FL) values were also determined following the method adopted by Haile et al. (2008) and Tilahun et al. (2007). It is used to identify the most important woody medicinal species used to treat a particular ailment in the study area. These values were calculated as:

$$FL\% = \frac{SF}{TF} x\ 100$$

Where, SF = frequency of citation of a species for a specific ailment; and TF = total number of citations of that species as a remedy to treat any given aliment.

Results and Discussion

Diversity of woody medicinal species and their medical application

An ethnobotanical study in Yirgachefe District showed that local communities and traditional healers use diverse woody medicinal species to treat various human, livestock or both types of ailments. Collected field data reported that a totalof 53woody medicinal species belonging to 52 genera and 33 families were identified and documented under Gedeo Agroforestry system (Fig. 2a). Family *Fabaceae* was represented by the highest number of species,i .*e*., 5 species (9%), followed by *Rubiaceae* with 4 species (8 %) and *Asteraceae* with 3 species (7 %) (Fig. 2b).
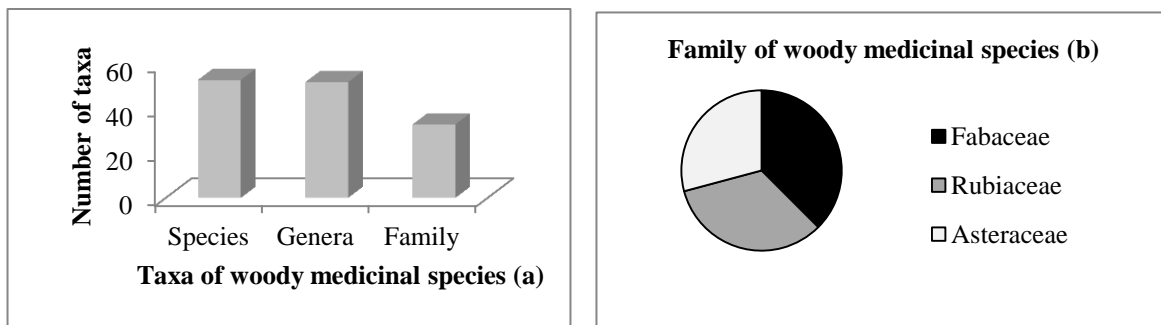
Figure 2: Taxa of woody medicinal species in Yirgachefe District

All the woody medicinal species collected under Gedeo Agroforestry systemwere reported by local names. Among these, 43 species (81.1 %) were reported by Gedeo language, 30 (56.6 %) by Amharic, 9 (17 %) by Afan Oromo as well as 10 (18.7 %) by multiple local names (two or more languages) only for this particular study. Others also named by the same local name but different languages. This suggests that there is a diverse exchange of information, language, culture and custom among different ethnic communities.

Among all species, 33 species (62 %) were applied for human ailments, 2 species (4 %) were used for livestock ailments and 18 species (34 %) were both human and livestock ailments (Fig. 3). Some of the woody medicinal species used to treat both human and livestock aliments were *Albizia gummifera, Apodytes dimidiat, Brucea antidysenterica, Croton macrostachyus, Diospyros mespiliformis, Pentas lanceolata, Pittosporum viridiflorum, Rhus vulgaris* and *Sida rhombifolia.* The presence of such a large number of medicinal plants indicates the high diversity of medicinal plants and the associated ethnomedicinal knowledge in the study area. The result of treated aliments analysis of medicinal species reported that they treat a variety of human, livestock or both aliments. Some of these were: Stomach ache, teeth illness, Gonorrhea, Cancer, intestinal parasites, liver disease, malaria, skin disease, blood pressure, evil eye, *Chife* and fibril illness (*Mitch beshita*). Of these woody medicinal species, *Croton macrostachyus*used to treat 31 different types of ailments (21.6 %)*; Albizia gummifera* and *Erythrina brucei* for 18 aliments, each and *Brucea antidysenterica* for 16 aliments.
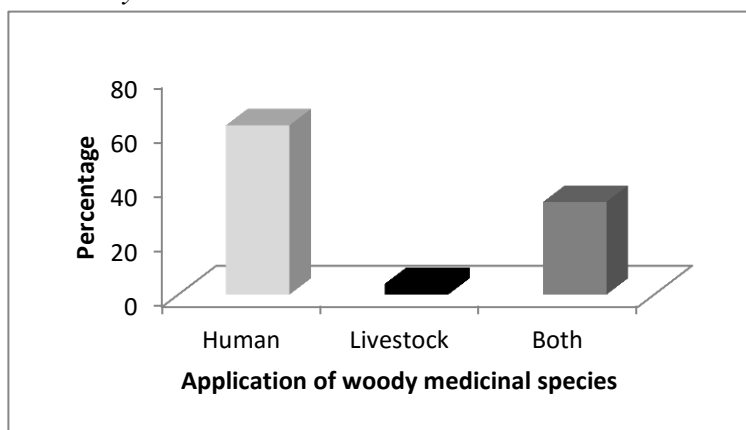
Figure 3: Application of woody medicinal species in Yirgachefe District

The most commonly reported growth forms of woody medicinal species were trees and shrubs, which accounted for 62.3 % (33 species) and 37.7 % (20 species), respectively. The application of leaves from 30 species (56.6 %), bark from 19 species (35.8 %) and roots from 12 species (22.6 %) were the most widely used plants parts for the preparation of traditional remedies for the treatment of different aliments (Fig. 4). On the other hand, most of the woody medicinal species preparations involved the use of a single plant part and mixing different species, which accounted for 98.1 and 1.9 %, respectively. In general, such diversity and various uses of medicinal species in YirgachefeDistrict suggests that the depth of indigenous knowledge and their application by the local people.
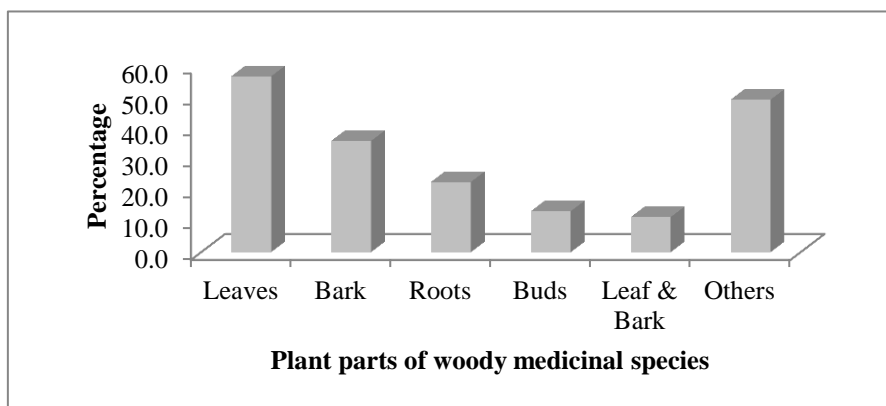
Figure 4: Various plant parts of woody medicinal species in Yirgachefe District

Socio-demographic characteristics of informants

In this study, a total of 87 informants or key informants were included between the ages of 22 and 112 from Yirgachefe District. Majority of the informants (20.7 %) were within the ranges of 31-40 and 61.70 ages, followed by 19.5 % within 51-60 ages (Fig. 5). All the selected informants during the ethnobotanical study belonged to the Gedeo ethnic community and speak Gedeo language only for this particular study. Of these, 40 % of the informants were illiterate, while 46 % of them were elementary in their educational background. This was followed by 13 % and 1 % of them attended secondary and diploma education, respectively.
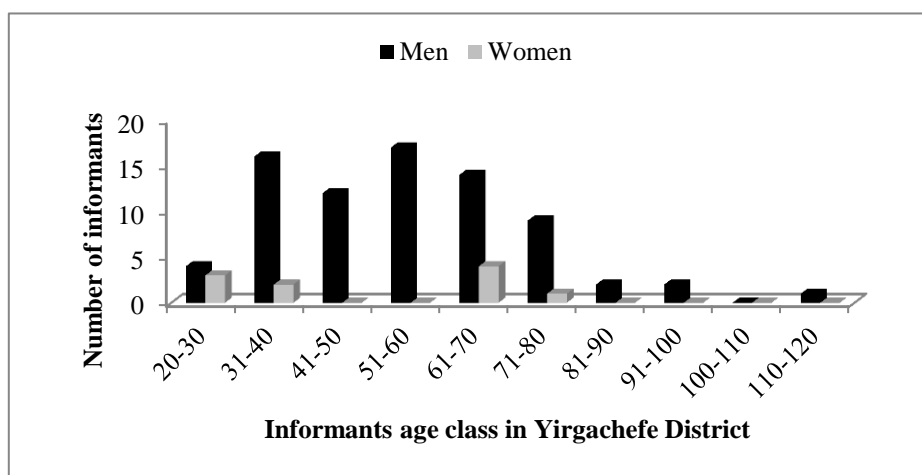
Figure 5: Distribution of informants among age classes in Yirgachefe District

Informants' role in the local communities indicated that 75.9 % were knowledgeable elders, 25.3 % religious leaders, 28.7 % *Kebele* Officials or representatives' and 12.6 % community members. Above 96% of the informants were indigenous to the area and they have lived from 18 to 112 years. Analysis of data reported that 99 % of the informants' main livelihood in Yirgachefe District is farming activity and 96.5 % of them are traditional healers.

Method of preparation, amount of doses, route of administration and side effects of woody medicinal species

Traditional healers claimed that most of the woody medicinal species were collected and stored in fresh forms (91 %) and 4 % either fresh or dried forms, while some species (6 %) were in dried forms. Similar finding was explored by Moa et al. (2013), for harvesting and preparation of plant parts. This is due to the fact that fresh plant parts are more effective in their healing power than the dried parts. This is because the chemical content of traditional remedies might be changed upon drying (Moa et al., 2013). After harvesting of plant parts, traditional remedies were processedmainly through chewing (32.8%), followed by concoction (29 %) and pounding (18.9 %) (Figure, 6). During the preparation of medicinal remedies, healers' added various ingredients or additives including butter, cosmetics, water, salt, honey and others. Finally, the processed remedies were mainly administered through orally, which accounted for 59.8 %. This was followed by dermal (30.8 %) and nasal (5.1 %) routes. This result also agreed with earlier studies of Haile et al. (2008), Fisseha et al.(2009) and Moa et al. (2013). Once the traditional remedies were prepared, majority of the prescriptions (87.7%) to traditional remedies had measured doses, whereas about 12 % of them were administered without doses. According to traditional healers report some of the traditional remedies (15.5 %) brought various side effects on patients. These were vomiting, stomachache, feels bitter taste and tiresome, diarrhea, body fever, body itching, headache and others.
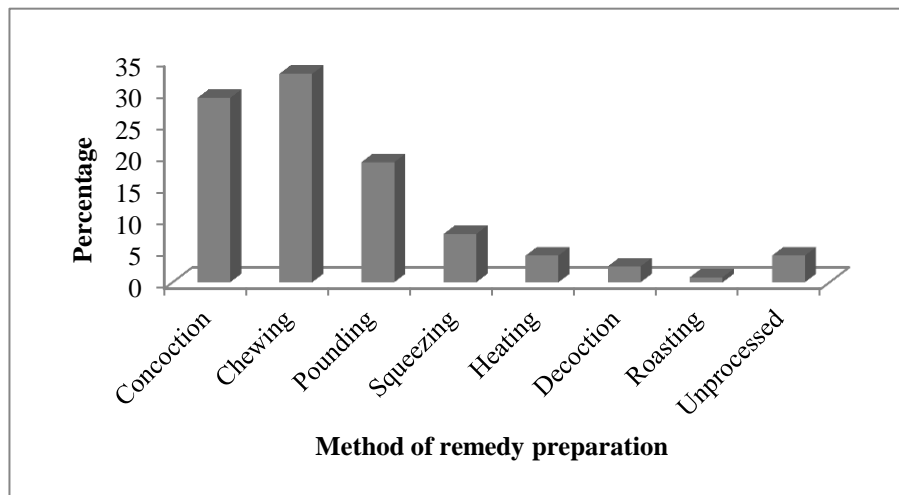
Figure 6: Method of traditional remedy preparation of woody medicinal species in Yirgachefe District

Informant consensus factor and species fidelity level values

In this study, a total of 48 different human, livestock or both ailments were managed with 53 woody medicinal species by traditional healers in Yirgachefe District. Among these the most frequently reported ailments were stomachache, which accounted for 23.8 %. This was followed by common cold (8.2 %), cancer (7.8 %) and body illness (*Qurtimat*) (7.4 %). All these ailments were grouped into ten major categories of aliments, which were managed by various traditional remedies. Of these, 70 % of the ailments had informant consensus of 0.40 and above. Woody

medicinal species that are effective in treating certain ailments and well known by community members also have higher Informant consensus factor(ICF) value (Tilahun et al., 2007, Fisseha et al.,2009, Moa et al., 2013). This revealed that the ailments are more common than those with the low ICF value (Fisseha et al., 2009). Gastrointestinal disorder and parasites infections had the highest ICF value, accounted for 0.73. This was followed by skin diseases, skin cut and wound as well as venereal diseases and impotence, with the informant consensus of 0.56 and 0.50, respectively. On the contrary, evil eye and bad sprit scored the least (0.13) ICF value indicated that the low degree of agreement among those healers in managing the ailments (Table 1). This further contributed for the knowledge differences among the traditional healers and the low prevalence of these diseases within the study area (Haile et al., 2008).

Table 1: Informant consensus factor (ICF) values of major category of ailments of woody medicinal species in Yirgachefe District.

No	Category of aliments	No. of species	Total % all species	No. of use citation	(%) all use citation	ICF value
1	Gastrointestinal disorder and parasites infections	21	39.6	74	28.8%	0.73
2	Skin diseases, skin cut and wound	16	30.2	35	13.6%	0.56
3	Venereal diseases and impotence	5	9.4%	9	3.5%	0.50
4	External organ diseases (ear, eye, teeth, nose & leg)	14	26.4	26	10.1%	0.48
5	Malaria, headache and fibril illness (*Mich Beshita*)	8	15.1	13	5.1%	0.42
6	Cancer and tumor	16	30.2	27	10.5%	0.42
7	Body illness and common cold	25	47.2	41	16%	0.40
8	Livestock aliments	11	20.8	15	5.8%	0.29
9	Internal diseases and respiratory infection	6	11.3	8	3.1%	0.29
10	Evil eye and bad sprit	8	15.1	9	3.5%	0.13
	Total	**53**		**257**		

In this study, *Bersema abyssinica, Celtis africana* and *Echinops longisetus* had the highest Fidelity level (FL) (100 %) in treating stomach ache in Yirgachefe District. Likewise, the same ailment was treated by *Albizia gummifera* with (72.2 %) FL value, *Erythrina brucei* with (65 %) and *Solanum schimperianum* with (50 %). In the same way other ailments were treated by one, two or more woody medicinal species in Yirgachefe District (Table 2).This suggests thatwoody medicinal species that are widely used by the local communities have higher FL values as compared to less popular species (Tilahun and Mirutse, 2007).

Table 2: Fidelity level values of woody medicinal species in Yirgachefe District

Woody medicinal species	Treated ailments	%FL
Acacia seyal Del.	Wound	100
Albizia gummifera (J. F. Gmel.) C. A. Sm.	Stomach ache (*Qurtet* (A))	72.2
Apodytes dimidiata E. Mey. Ex Am.	Diarrhea	100

Bersema abyssinica Fresen.	Stomach ache (*Qurtet* (A))	100
Canthium oligocarpum Hiern	Wist disease	100
Catha edulis (Vahl) Forssk. ex Endl.	Skin disease/Skin itching (Ikek (A))	100
Celtis africana Burm. f.	Stomach ache (*Qurtet* (A))	100
Coffea arabica L.	Wound	66.7
Dracaena steudneri Engl.	Common cold	100
Echinops longisetus A. Rich.	Stomach ache (*Qurtet* (A))	100
Embelia schimperi Vatke	Tapeworm	100
Erythrina brucei Schweinf.	Stomach ache (*Qurtet* (A))	65
Fagaropsis angolensis (Engl.) Dale	Stomach ache (*Qurtet* (A))	46.2
Ficus thonningii Blume	Teeth illness	100
Hagenia abyssinica (Bruce) J. F. Gmel.	Tapeworm	80
Hibiscus macranthus Hochst. ex A. *Rich.*	Cancer	50
Hibiscus macranthus Hochst. ex A. *Rich.*	Fire burn the body	50
Justicia schimperiana (Hochst. ex *Nees) T. Anders.*	Liver disease/*Yegubet Beshita* (A)	50
Nuxia congesta K. Br. ex *Fresen.*	Cancer	50
Nuxia congesta K. Br. ex *Fresen.*	Common cold	50
Ocimum lamiifolium Hochst. ex *Benth.*	Fibril illness (*Mich Beshita* (A))	75
Olea europaea L. subsp. cuspidata (Wall. ex G. Don) Cif.	Teeth illness	100
Olea welwitschii (Knobl.) Gilg & Schellenb.	Body illness (*Qurtimat* (A))	50
Olea welwitschii (Knobl.) Gilg & Schellenb.	Blood pressure	50
Phytolacca dodecandra L'Hérit.	Cancer	100
Pentas lanceolata (Forssk.) Defl.	Breast (*Tut* (A) (cattle)	50
Pentas lanceolata (Forssk.) Defl.	Cancer	50
Polyscias fulva (Hiern) Harms	Liver disease/*Yewof Beshita* (A)/*Bekeko* (G)	100
Pouteria adolfi-friederici (Engl.) Baehni	Teeth illness	60
Rhus vulgaris Meikle	Common cold	50
Rhus vulgaris Meikle	Evel eye	50
Rytigynia neglecta (Hiern) Robyns	Penis fails in sex (*Yebilit*/*Wosib Sinifet* (A))	100
Sida rhombifolia L.	Evil eye	100
Sideroxylon oxyacanthum Baill.	Malaria	100
Solanum schimperianum Hochst. ex A. Rich.	Stomach ache (*Qurtet* (A))	50
Solanum schimperianum Hochst. ex A. Rich.	Teeth illness	50
Urtica simensis Steudel	Ambiasis	50
Urtica simensis Steudel	Ascaris	50
Vernonia auriculifera Hiern.	Wound	62.5

Woody medicinal species and traditional healers' indigenous knowledge

During ethnobotanical study in the field, all of the informants (87 of them) reported that woody medicinal species are served as traditional medicine only if necessary. This means they go to the forest and collect the species for the particular ailment when the patients visited the healers. However, more than half percent of the informants additionally use the species throughout the whole year to treat various ailments. In turn, above 79 % of the informants described that they practice traditional medicine due to the lack of other choice, followed by 44.8 % as first aid and 20.7 % as a result of easy access to woody medicinal species. Regarding to indigenous knowledge, most of the informants (87 %) reported that the source of their information for the use of woody medicinal species to traditional medicine were older people such as their families (father, mother or grandparents) as well as close relatives. Some informants (17.2 %), in turn, stated that this source is from traditional healers. Analysis of field data reported that most of the traditional healers (81.6 %) in the study area had an experience of more than 20 yearsand they were more effective in utilizing and administering the traditional remedies. Furthermore, almost all of the informants (99 %) reported that they have a good access or chance to see people to collect various medicinal plants from their surrounding areas and treat different human and livestock ailments. Of these, 73.6 % of the healers that collect medicinal plants were men, while 32.2 % of them were women.

Woody medicinal species use diversity

Some of the surveyed woody medicinal species in the study area were found to have multi-purpose values in various ways. Analysis of field data under Gedeo Agroforestry systemreported that 46 species (86.8 %) of woody medicinal species have values other than their medicinal role. Seven species (13.2 %) are served only as medicinal species by traditional healers. This indicates that ethnomedicinal plants are being overexploited for various multi-purpose values other than their medicinal use (Ermias et al., 2008). These are wild edible and chewing, firewood consumption, charcoal making, livestock feed, house construction, logging and timber supply, beehive making and fencing to mention but a few. Of these, 81.1 % of the species were served for firewood consumption, followed by 41.5 % for charcoal making and 32.1% for house construction. Likewise, diverse uses of ethnomedicinal plants in construction, firewood and charcoal in Wonago District were reported by (Fisseha et al., 2009). Species with seven different uses other than medicinal values was *Erythrina brucei,* followed by *Croton macrostachyus with six use values.* Five other species had five various uses, each. Overall, under the Gedeo traditional enset-coffee based traditional homegardens Agroforestry system trees and shrubs plays a significant role for the farming households. They provide as coffee shade trees, firewood and fuel wood supply, house constriction, fencing, furniture, farm tools and household utensils, animal fodder, human food and bee forage. Similar finding was reported in earlier study by Tesfaye (2005) in Sidama administrative zone traditional homegardens Agroforestry system.

Threats to woody medicinal species and associated indigenous knowledge

Since the local communities typically have intimate relationships with their natural environment, they are familiar with the threats to woody medicinal species. During group and individual discussions as well as interview, researchers raised the issue and dealt in detail with informants and key informants about the issue. Accordingly, most of the informants (77 %) reported that

there is no main threat to woody medicinal species in the study area. This is due to the fact that local communities have an indigenous management system to conserve the resource. Of these, the proper conservation and management of their natural resources mainly focused in their traditional Agroforestry system and home gardens in Gedeo Zone. This is due to the proper management and intimate association of a multitude of cultivated crops, trees and shrubs as well as livestock (Tesfaye, 2005). On the other hand, 23 % of the informants accepted the depletion of woody medicinal species and they listed various causes for their threat. These included: deforestation for various purposes such as agricultural expansion, firewood and charcoal collection, forest fire or drought. Furthermore, over exploitation of medicinal plants further aggravates the depletion of the resource.

Conservation and management of woody medicinal species and associated indigenous knowledge

Local communities under Gedeo Agroforestry system have employed their untapped indigenous management strategies to sustainably utilize and conserve woody medicinal species. Based on this, about 45 % of the informants indicated that there are different indigenous management strategies commonly practiced by the local communities or the Government to properly manage and conserve woody medicinal species. Some of these strategies included plant seedlings, fencing and hoeing regularly; conserving and managing indigenous trees in the farmlands and homegardens as well as giving advice, education and raise their awareness to properly conserve the natural resources. Overall, domestication of woody medicinal species is a suitable option for optimizing their sustainable use and conservation, thereby reducing their overexploitation.

Conclusion and Recommendations

Indigenous people under Gedeo Agroforestry system and homegardens mainly depend on woody medicinal species to treat various human and/or livestock aliments. As a result, a totalof 53woody medicinal species belonging to 52 genera and 33 families were identified and documented in Yirgachefe District. Family*Fabaceae*was represented by the highest number of species, followed by *Rubiaceae* and *Asteraceae*.*Croton macrostachyus,* followed by *Albizia gummifera, Erythrina brucei* and *Brucea antidysenterica*were the most popular woody medicinal species. Stomach ache, teeth illness, Gonnoria, Cancer, malaria, evel eye and many others were treated by different medicinal species. Most of the traditional remedies were collected in fresh forms (91%); processedmainly through chewing, concoction and pounding and administered through orally (59.8%) in estimated or fixed doses. When the patents take the remedies various side effects might be seen such as vomiting, diarrhea, body fever, body itching, etc. Most of the traditional healers (81.6%) in the study area had an experience of more than 20 years and they were more effective in administering the remedies. Under the Gedeo traditional enset-coffee based traditional homegardens Agroforestry system medicinal species plays a significant role for the farming households. They provide as coffee shade trees, firewood and fuel wood supply, house constriction, fencing, furniture, farm tools and household utensils, animal fodder, human food and bee forage. Overall, the documented woody medicinal species can serve as a basis for future phytochemical and pharmacological studies and for further studies in the study area. Therefore, planting of medicinal plant species around homesteads and farmlands as well as public awareness on conservation and sustainable utilization of these species are recommended.

Acknowledgement

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ETHNOBOTANY OF WOODY MEDICINAL SPECIES IN SHEKO DISTRICT, SOUTHWEST ETHIOPIA

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Abstract

In Ethiopia, indigenous knowledge about ethnomedicinal plants for the health care system of humans served up until early 19th century. However, it is limited to a certain ethnic communities and not adequately documented. The present study aimed at assessing and documentingwoody medicinal species commonly being used by nine ethnic communities (Sheko, Sheka, Mejenger, Kefa, Bench, Menit, Amhara, Oromo and Wolayta) and traditional healers in Sheko District, Bench-Maji Zone, and southwest Ethiopia during September, 2014 and June, 2015. A total of 61 informants comprising 51 men and 10 women were identified using prior information. Data were collected using semi-structured interviews, guided field walk, discussions and field observations. A totalof 61 plant species belonging to 55 genera and 30 families were identified and documented. Family*Moraceae* was represented by the highest number of species (10%), followed by *Asteraceae* and *Fabaceae* with (8.3%), each. Among all species, 86.7% were applied for human ailments and 15% were used for livestock ailments. Different ailments such as toothache, gonorrhea, evil eye, rabies, snake bite, malaria, retained placenta and others were treated.External organ diseases had the highest informant consensus factor (ICF) value (0.72), while *Acacia seyal, Clerodendrum myricoides* and *Echinops kebericho*had the highest fidelity level (FL) (100%) in treating snake bite in Sheko District. Most of the traditional remedies were collected in fresh forms (57.1%), processedmainly through pounding, concoction and squeezing and administered through orally (63.1%) in estimated or fixed doses. Majority of the indigenous knowledge associated with woody medicinal species were transferred over generation via older people. Most of the traditional healers (57.4%) in the study area had an experience of more than 20 years and they were more effective in administering the remedies. Agricultural expansion, population pressure, cutting trees and settlement were threats of medicinal species in the study area. Documenting woody medicinal species and associated indigenous knowledge can serve as a basis for future investigation of modern drugs as well as species conservation and sustainable use in Sheko District.

Keywords: Ailments, conservation, drugs, healers, threats

Introduction

Various medicinal plants were traditionally used as early as 5,000 to 4,000 B. C. in China and 1,600 B. C. by Assyrians, Babylonians, Hebrews and Egyptians (Hill, 1952). As a result, various woody medicinal species have been used as a major source of medicine throughout the human

history in traditional healthcare system. Accordingly, on the global basis, approximately 80% of the world population is believed to rely to some extent on medicinal plants for their medicinal applications (Cotton, 1996).

Likewise, in Ethiopia, more than 80% of the human population depends on traditional medicines for their health services (Dawit and Ahadu, 1993). Similarly, about 85% of livestock owners alternatively use both modern and traditional veterinary practices (Mesfine and Lemma, 2001). Thus, the demand and trade of woody medicinal species becomes increasing from time to time to alleviate health problems worldwide (Dawit, 2001). This is because of cultural acceptability, effectiveness, accessibility as well as economic affordability as a primary health care needs (Sofowora, 1982, Dawit and Ahadu, 1993). Despite this fact the contribution of ethnomedicinal plants in the traditional health care system has received very little attention in modern pharmacological research and drug development. This is because indigenous knowledge and the associated traditional medicinal practices of the local communities are not properly explored and documented. Furthermore, it is limited to a certain ethnic communities in a particular area.

Therefore, the present study was aimed at assessing and documentingwoody medicinal species commonly used by local community and traditional healers (practitioners) in Sheko forest of the Sheko District, southwest Ethiopia. This will help to domesticate and promote them to improve the general health care system in the society and hence contribute for the proper utilization, management and conservation of these resources.

Material and Methods

Description of the study area

The study was conducted in Sheko District, Bench-Maji Zone, Southern Nations, Nationalities and Peoples' Region (SNNPR) in southwest Ethiopia during September, 2014 and June, 2015. Sheko District is bordered on the south by Debub Bench District, on the north by the Sheka Zone, on the northwest by the Gambela Region, on the east by Semien BenchDistrict as well as on the west by Guraferda District (Fig. 1).Sheko town, the capital of Sheko District, is 35 km and 646 km away from Teppi town and Addis Ababa, respectively. The study sites are located between 36N 076 43° 08'-36N 077 94° 30' and UTM 0678699-UTM 0787484 within an altitudinal ranges of 1000-1260 m a.s.l. The ethnic communities found in the District are Sheko, Kefa, Sheka, Mejenger, Bench, Menit, Amhara, Oromo, Wolayta and others.Based on the 2007 Census conducted by the CSA, Sheko District has a total population of 51,195, of whom 25,854 were men and 25,341 were women (CSA, 2008). The study Kebeles/sites were located around Sheko Town.

Research Methodology

Following a reconnaissance survey and pre-test in Sheko District between September, 2014 and June, 2015 five sampled *Kebeles (Bazhiqa, Giz Meret, Sanqa, Shayita and Shimi)* were identified. During ethnobotanical study, 61 informants (51 men and 10 women) between the age of 19 and 80 were selected for the assessment of woody medicinal species. Following the adapted methods from Martin (1995), Cotton (1996) and Cunningham (2001), structured

interview, guided field walk, individual and group discussions, direct researchers observations were applied to obtain indigenous knowledge of the local people and traditional healers on commonly used woody medicinal species. This ethnobotanical method was effectively applied according to Tinsae et al. (2011), (2012), (2013) and (2014).

During data collection, basic information on woody medicinal species including their socioeconomic data (population demography), local names, plant use(s), growth habit and habitat, part(s) used such as leaves, root, fruit, seeds, bark, latex, etc., remedy used for human and/or livestock aliments, disease treated, method of preparation and ingredients added, route of administration, amount of dosages administered to the patience and associated side effects during taking the drug were collected. Others data included were: sales price of the drug, method of collection and storage form used (fresh/dried), source of plant species (wild/cultivated), their conservation practice, indigenous knowledge transfer and management strategies, major threats and other related aspects (Ermias et al., 2008; Haile et al., 2008; Tinsae, 2009). Voucher specimens collected from Sheko forest during the guided field walk were identified and approved at the National Herbarium, Addis Ababa University.
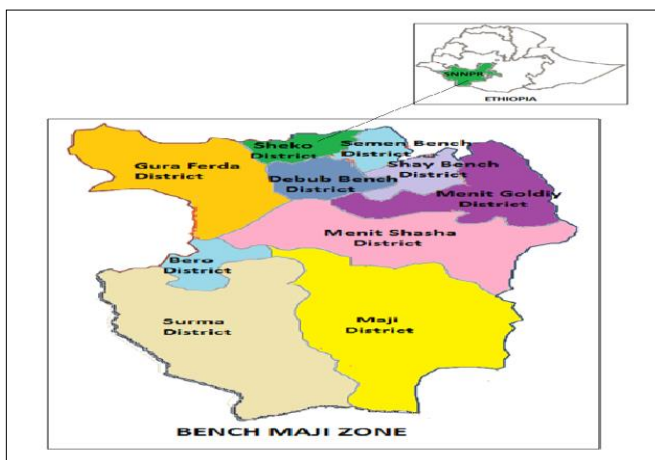
Figure 1: Map of Sheko District of Bench Maji Zone (source: UNOCHA, 2010).

Data analysis

Collected ethnobotanical data were summarized using descriptive statistical methods such as graphs, tables and percentages. The Informant consensus factor (ICF) values were determined following the method adopted by Tilahun et al. (2007), Fisseha et al. (2009) and Moa et al. (2013). The formula used to calculate ICF values was as follows:

$$\textbf{ICF} = \frac{\textbf{nur} - \textbf{nt}}{\textbf{nur} - \textbf{1}}$$

Where, ICF = Informants Consensus Factor; nur = number of use citation in each category; and nt = Total number of species used.

Similarly, Fidelity level (FL) values were also determined following the method adopted by Haile et al. (2008) and Tilahun et al. (2007). It is used to identify the most important woody medicinal species used to treat a particular ailment in the study area. These values were calculated as:

$$FL\% = \frac{SF}{TF} x\ 100$$

Where, SF = frequency of citation of a species for a specific ailment; and TF = total number of citations of that species as a remedy to treat any given aliment.

Results and Discussion

Diversity of woody medicinal species and their medical application

An ethnobotanical study in Sheko District showed that local communities and traditional healers used diverse woody medicinal species to treat various human, livestock and/or both types of ailments. Collected field data reported that a totalof 61 woody medicinal species belonging to 55 genera and 30 families were identified and documented in Sheko forest (Fig. 2a). Family *Moraceae* was represented by the highest number of species, *i.e*., 6 species (9.8 %), followed by *Asteraceae* and *Fabaceae* with 5 species (8.2 %) each and *Euphorbiaceae* with 4 species (6.6 %) (Fig. 2b).
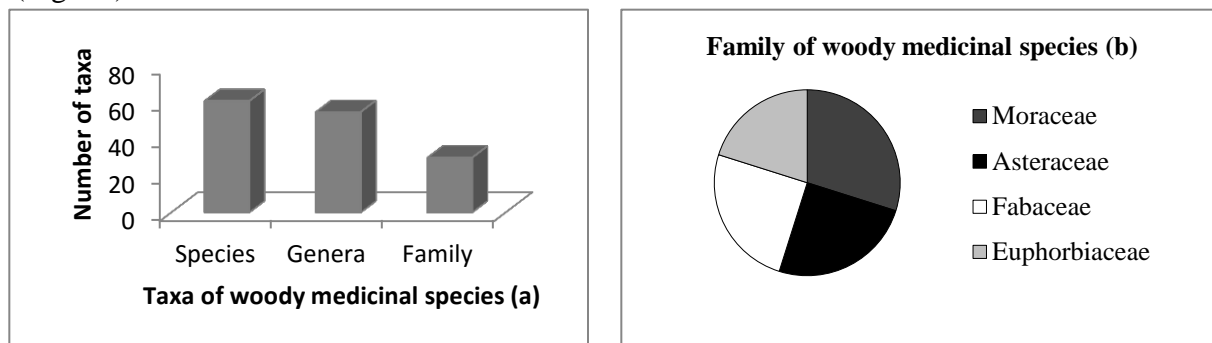
Figure 2: Taxa of woody medicinal species in Sheko District

All the woody medicinal species collected from Sheko forest were reported by local names. Of these, 42 species (68.9 %) were reported by Amharic language, 36 (59%) by Sheko, 20 (32.8 %) by Mejenger, 15 (24.6 %) by Menit, 14 (23 %) by Kefa, 11 (18 %) by Bench and 8 (13.1 %) by Afan Oromo only for this particular study. In contrast to this, 12 species (19.7 %) reported by multiple local names (two or more languages). Others also named by the same local name but different languages. This suggested that there has been a diverse exchange of information, language, culture and custom among different ethnic communities.

Among all species, 46 species (75.4 %) were applied for human ailments, 3 species (4.9 %) were used for livestock ailments and 12 (19.7 %) both human and livestock ailments (Fig. 3).The woody medicinal species used to treat both human and livestock aliments were *Chionanthus mildbraedii, C. myricoides, Croton macrostachyus, Dracaena steudneri, Fagaropsis angolensis, Gossypium hirsutum, Millettia ferruginea* subsp. *darassana, Ocimum lamiifolium* and*Vepris dainellii.* The presence of such a large number of medicinal plants indicated the high diversity of medicinal plants and the associated ethnomedicinal knowledge in the study area.

The results of treated aliments revealed that they treat a variety of human, livestock or both aliments. Snake bite; rabies; teeth illness; malaria; Gonoria; Stomach ache; retained placenta; common cold; intestinal parasites; skin disease; blood pressure, Evil eye and fibril illness (*Mitch Beshita*) were to mention but a few. Of these woody medicinal species, *C. macrostachyus* used to treat 16 different types of ailments (21.6 %), followed by *Antiaris toxicaria, Cordia africana* and *Phytolacca dodecandra*, each of them used to treat seven different types of ailments (9.5 %).
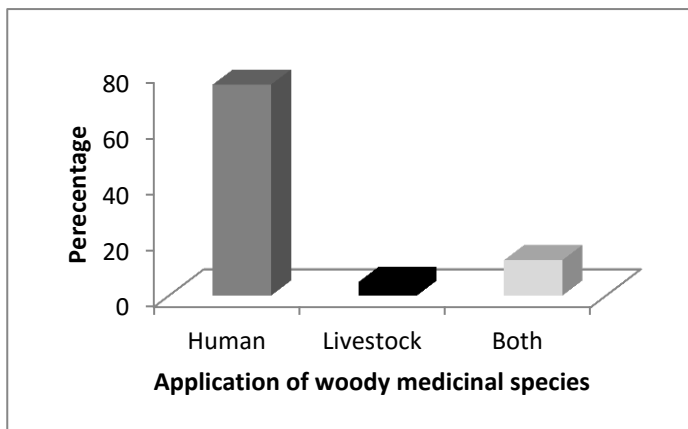
Figure 3: Application of woody medicinal species in Sheko District

The most commonly reported growth forms of woody medicinal species were trees and shrubs, which accounted for 72.1 % (44 species) and 27.9 % (17 species), respectively. The application of leaves from 29 species (47.5%), fruits from 19 species (31.1 %) and roots from 15 species (24.6 %) came as the most widely used plant parts for the preparation of traditional remedies for the treatment of different aliments (Fig. 4).
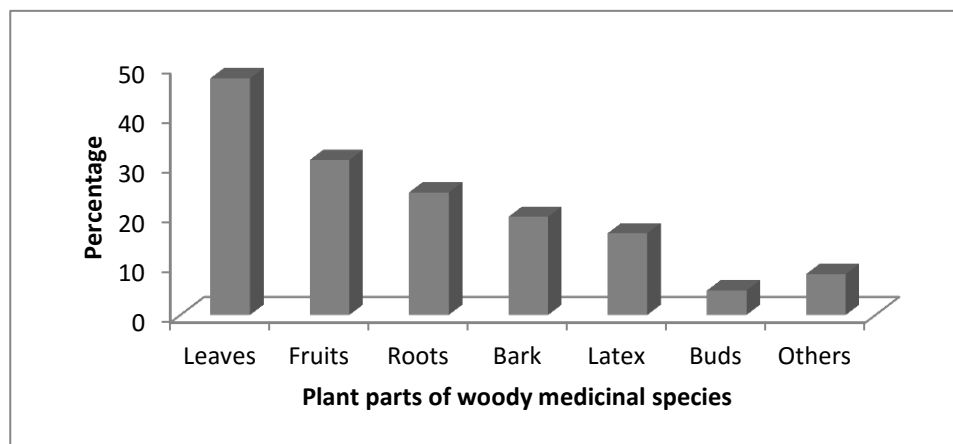
Figure 4: Various plant parts of woody medicinal species in Sheko District

On the other hand, most of the woody medicinal species preparations involved the use of a single plant part and mixing different species, which accounted for 98.1 and 1.9%, respectively. In general, such diversity and various uses of medicinal species in Sheko District suggested that the depth of indigenous knowledge and their application by the local people.

Socio-demographic characteristics of informants

In this study, a total of 61 informants were included between the ages of 19 and 80 from Sheko District. Majority of the informants (29.5 %) were within the ranges of 19-30 ages (Fig. 5). Among them 21 informants (34.4 %) belonged to the Sheko ethnic community, 9 (14.8%) from Mejenger, 7 (11.5%) from Bench and Amhara, each, 6 (9.8 %) from Kefa, 5 (8.2 %) from Menit, 4 (6.6) from Oromo and 1 (1.6 %) from Maji and Wolayta, each only for this particular study.
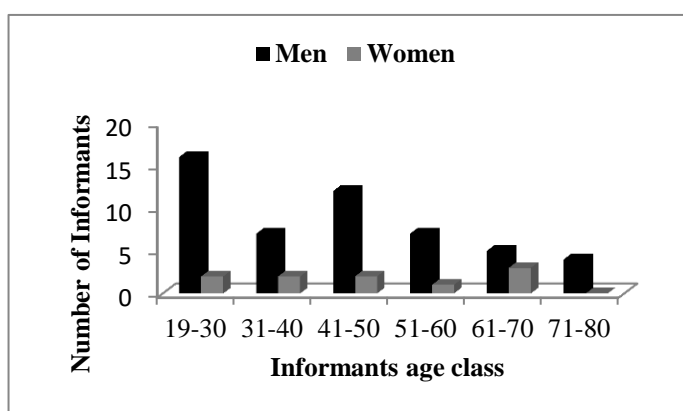
Figure 5: Distribution of informants among age classes in Sheko District

Analysis of field data showed that 62.3 % of the informants were elementary, while 26.2 % of them were illiterate in their educational background. This was followed by 11.5 % of them attended secondary education. Informants' role in the local communities indicated that 78.7 % were knowledgeable elders, 44.3 % *Kebele* Officials or representatives', 9.8 % religious leaders

and 6.6 % community members. About 87 % of the informants were indigenous to the area and they have lived from 20 to 78 years. Among them 59 % of the informants' main livelihood in Sheko District was both as farmers and traditional healers. On the other hand, 31.1 % were mainly farmers and 3.3 % are traditional healers.

Method of preparation, amount of doses, route of administration and side effects of woody medicinal species

Traditional healers claimed that most of the woody medicinal species were collected and stored in fresh forms (57.1 %) and either fresh or dried forms (6.4 %), while some species (4.9 %) were in dried forms. Similar finding was explored by Moa et al. (2013), for harvesting and preparation of plant parts. This was due to the fact that fresh plant parts are more effective in their healing power than the dried parts. This is because the chemical content of traditional remedies might be changed upon drying (Moa et al., 2013). After harvesting of plant parts, traditional remedies were processed mainly through pounding (17.9 %), followed by concoction (17.5 %) and squeezing (11.3 %). During the preparation of medicinal remedies, healers' added various ingredients or additives including water, salt, honey or milk and others.
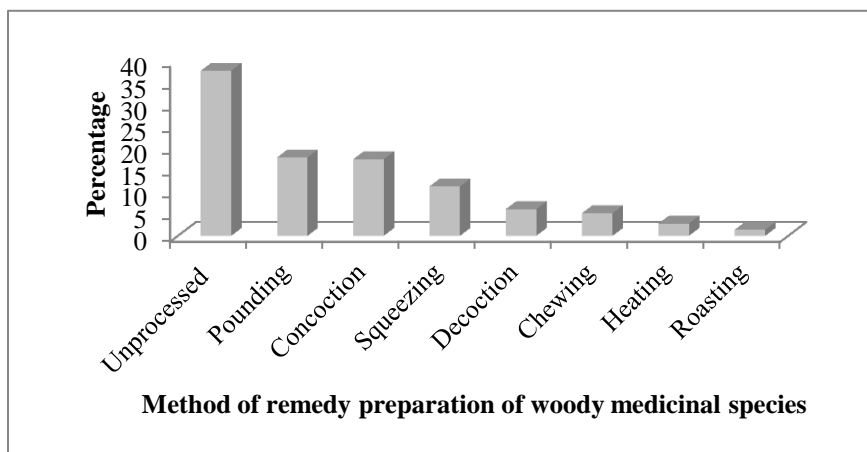
Method of remedy preparation of woody medicinal species

Figure 6: Method of traditional remedy preparation of woody medicinal species in Sheko District

Finally, the processed remedies were mainly administered through orally (63.1 %), followed by dermal (27.1 %) routes. These results were also agreed with earlier studies of Haile*et al.* (2008), Fisseha et al.(2009) and Moa et al. (2013) done in other part of the country. Once the traditional remedies were prepared, majority of the prescriptions (80.5 %) to traditional remedies had measured doses, whereas about 19.5 % of them were administered without doses. These units of measurement were cup, tea spoon, and size of index finger, liters, size of wound and others. For instance *Alstonia boonei* and *Antiaris toxicaria* were some of the ethnomedicinal plants used for the preparation of remedies in fixed or estimated dosage.According to traditional healers report some of the traditional remedies (28.9 %) brought various side effects on patients such as vomiting, diarrhea, body fever, over activation, body itching and headache just to mention but a few.

Informant consensus factor and species fidelity level values

A total of 74 different human, livestock or both ailments were managed with 61 woody medicinal species by traditional healers in Sheko District. Among these the most frequently reported ailments were toothache, which accounted for 45.9 %. This was followed by stomach ache (41.9 %) and fibril illness (17.6 %). All these ailments were grouped into nine major categories of aliments, which were managed by various traditional remedies. Of these, 80% of the ailments had informant consensus of 0.25 and above. Woody medicinal species that were effective in treating certain ailments and well known by community members also have higher informant consensus factor(ICF) value (Tilahun et al., 2007, Fisseha et al.,2009, Moa et al., 2013). This revealed that the ailments were more common than those with the low ICF value (Fisseha et al., 2009). From the nine major categories of aliments, external organ diseases had the highest ICF value, which accounted for 0.72. This was followed by skin diseases, skin cut and wound as well as gastrointestinal disorder, with the informant consensus values of 0.63 and 0.55, respectively (Table 1). On the other hand, the low ICF values (0) indicated that the low degree of agreement among those healers in managing the ailments. This further contributed for the knowledge differences among the traditional healers and the low prevalence of these diseases within the study area (Haile et al., 2008).

Table 1: Informant consensus factor values of major category of ailments of woody medicinal species in Sheko District.

No	Category of aliments	No. of species	Total % all species	No. of use citation	(%) all use citation	ICF value
1	External organ diseases (ear, eye, teeth, nose and leg)	13	22%	44	18%	0.72
2	Skin diseases, skin cut and wound	20	33%	52	21.2%	0.63
3	Gastrointestinal disorder and parasites infections	35	58%	77	31.4%	0.55
4	Livestock aliments	9	15%	16	6.5%	0.47
5	Malaria, headache and fibril illness	13	22%	23	9.4%	0.45
6	Internal diseases and respiratory infection	14	23%	21	8.6%	0.35
7	Venereal diseases and impotence	4	7%	5	2%	0.25
8	Body illness and common cold	4	7%	4	1.6%	0
9	Evil eye and bad sprit	3	5%	3	1.2%	0
	Total	**60**		**245**		

In this study, *A. seyal, C. myricoides* and *E. kebericho*had the highest fidelity level (FL) (100 %) in treating snake bite in Sheko District. Likewise, Ascaris, tapeworm, stomachache (*Qurtet*), fibril illness and other more ailments were treated by different woody medicinal species in Sheko District with the highest FL, which accounted for 100 % (Table 2).This suggested thatwoody medicinal species that were widely used by the local communities have higher FL values as compared to less popular species (Tilahun and Mirutse, 2007).

Table 2: Fidelity level values of woody medicinal species in Sheko District

Woody medicinal species	Treated ailments	%FL
Acacia seyal Del.	Snake bite	100
Albizia gummifera (J. F. Gmel.) C. A. Sm.	Ascaris	100
Alstonia boonei De Wild.	Toothache	84.6
Bersema abyssinica Fresen.	Diarrhea	50
Bersema abyssinica Fresen.	Stomachache (*Qurtet* (A))	50
Carica papaya L.	Malaria	100
Celtis africana Burm. f.	Ascaris	100
Celtis gomphophylla Bak.	Eye disease	100
Chionanthus mildbraedii (Gilg & Schellenb.) Stearn	Body favor (Human)	50
Chionanthus mildbraedii (Gilg & Schellenb.) Stearn	Improving milk in cows	50
Citrus aurantifolia (Christm.) Swingle	Who took poisonous drugs	100
Clerodendrum myricoides (Hochst.) Vatke	Snake bite	100
Deinbollia kilimandscharica Taub.	Stomachache (*Qurtet* (A))	100
Echinops kebericho Mesfin	Snake bite	100
Ehretia cymosa Thonn.	Fibril illness (*Mich Beshita* (A))	100
Erythrina brucei Schweinf.	Body cut by sharp tools (wound)	100
Eucalyptus globulus Labill.	Fibril illness (*Mich Beshita* (A))	50
Eucalyptus globulus Labill.	Vomiting	50
Fagaropsis angolensis (Engl.) Dale	Improving milk in cows	44.4
Ficus lutea Vahl.	Spider disease (Spider urine infection)	44.4
Garcinia buchananii Baker	Headache	50
Garcinia buchananii Baker	Stomachache (*Qurtet* (A))	50
Gossypium hirsutum L.	Common cold	50
Gossypium hirsutum L.	Stomachache (*Qurtet* (A))	50
Dracaena steudneri Engl.	Rabies	100
Juniperus procera Hochst. Ex Endl.	Stomachache (*Qurtet* (A))	100
Manilkara butugi Chiov.	Stomachache (*Qurtet* (A))	50
Millettia ferruginea (Hochst.) Bak. subsp. darassana (Cuf.) Gillett	Wound	44.4
Ocimum lamiifolium Hochst. ex Benth.	Fibril illness (*Mich Beshita* (A))	61.5
Olea capensis L. subsp. macrocarpa (C. H. Wright) Verde.	Ascaris	46.2
Premna resinosa (Hochst.) Schauer	Diarrhea	50
Premna resinosa (Hochst.) Schauer	Lose power	50
Phytolacca dodecandra L'Hérit.	Rabies	40
Pittosporum viridiflorum Sims	Diarrhea	50

Pittosporum viridiflorum Sims	Stomachache (*Qurtet* (A))	50
Pouteria adolfi-friederici (Engl.) Baehni	Bad sprit (*Yeseyitan Likifit* (A))	100
Psydrax schimperiana (A. Rich.) Bridson	Wrist illness/Backache	100
Pycnostachys abyssinica Fresen.	Headache	100
Ricinus communis L.	Hair loss in humans	100
Ritchiea albersii Gilg	Body swelling (*Ibach/Bigunji* (A))	100
Rothmannia urcelliformis (Hiern) Robyns	Malaria	100
Sapium ellipticum (Krauss) Pax	Tapeworm	100
Solanecio gigas (Vatke) C. Jeffrey	Body cut by sharp tools (wound)	100
Solannico mannii (Hook. f.) C. Jeffrey	Improving milk in cows	100
Syzygium guineense (Willd.) DC.	Stomachache (*Qurtet* (A))	100
Trichilia prieuriana A. Juss.	Tapeworm	100
Urtica simensis Steudel	Stomachache (*Qurtet* (A))	100
Vernonia auriculifera Hiern.	Ascaris	100
Vernonia amygdalina Del.	Skin disease/skin itching (*Ikek* (A))	40
Withania somnifera (L.) Dunal	Stomachache (*Qurtet* (A))	100
Zanha golungensis Hiern	Toothache	66.7

Woody medicinal species and healers' indigenous knowledge

During ethnobotanical study in the field, majority of the informants (88.5 %) reported that woody medicinal species were served as traditional medicine only if necessary. Every time, when the patients visited the healers, healers went to the forest and collect the species for the particular ailment. However, some informants (52.5 %) use the species throughout the whole year to treat various ailments. In turn, 65.6 % of the informants described that they practiced traditional medicine due to the lack of other choice such as health centers. This was followed by 52.5 % as first aid.

Regarding to indigenous knowledge, most of the informants (80.3 %) reported that the source of their information for the use of woody medicinal species *to* traditional medicine were older people such as their families as well as close relatives. Some informants (24.6%), in turn, stated that this source was from traditional healers. Analysis of field data indicated that most of the traditional healers (57.4 %) in the study area had an experience of more than 20 yearsand they were more effective in utilizing and administering the traditional remedies. The remaining 27.9 % were practiced between 10 and 20 years. Furthermore, *m*ost of the informants (90.2 %) reported that they have a good access or chance to see people to collect various medicinal plants from their surrounding areas and treat different human and livestock ailments. Of these, 60.7 % of the healers that collect medicinal plants were men, while 26.2 % of them were women.

Woody medicinal species use diversity

Some of the surveyed woody medicinal species in the study area were found to have multi-purpose values in various ways. Analysis of field data in Sheko forestreported that 46 species (75.4 %) of woody medicinal species have values other than their medicinal role. Fourteen species (23 %) were served only as medicinal plants by traditional healers. This indicated that

medicinal species were being overexploited for various multi-purpose values other than their medicinal use (Ermias et al., 2008). These were wild edible, firewood consumption, charcoal making, livestock feed, house construction and timber supply, honey production (nectar) and beehive hanging, washing clothes and household utensils, fishing activity, oil production, toothbrush and others. Of these, 18.3 % of the species were served for house construction, followed by 17.7 % for charcoal making and 16 % for livestock feed. Species with eight different uses other than medicinal values were *Alstonia boonei, C. africana* and *F. angolensis.*

Threats to woody medicinal species and associated indigenous knowledge

Since the local communities typically have intimate relationships with their natural environment, they are familiar with the threats to woody medicinal species. During group and individual discussions as well as interview, researchers raised the issue and dealt in detail with informants and key informants about the issue. Accordingly, most of the informants (72.1 %) reported that there was no main threat to woody medicinal species in the study area. This has been because of two main reasons. Firstly, local communities have an indigenous management system to conserve the resource. Some of these management and conservation strategies were planting seedlings, hoeing and fencing as well as awareness raising to manage medicinal species. Secondly, the government give due attention to conserve the forest in various ways and hence to control human impact on the forest. Participatory forest management and wild coffee conservation programmes, awareness raising, education and training for the local communities, conservation and supervision works as well as carrying out various researches on the forest were among a few. On the other hand, 27.9 % of the informants accepted the depletion of medicinal plants and they listed various causes for their threat. Among these were: population pressure, human settlement and agricultural expansion. In turn, over exploitation of medicinal plants further aggravated the depletion of the resource.

Conservation and management of woody medicinal species and associated indigenous knowledge

Local communities in Sheko District have employed their untapped indigenous management strategies to sustainably conserve and utilize woody medicinal species. Based on this, about 72 % of the informants indicated that there were different indigenous management strategies commonly practiced by the local communities or the Government to properly manage and conserve medicinal plants. Some of these strategies included planting seedlings, fencing and hoeing regularly; properly conserving and managing the forest; controlling cutting trees, forest degradation and agricultural expansion as well as giving advice, training and education and raise their awareness to properly conserve the forest. In addition, Participatory Forest Management (PFM) and Wild Coffee Conservation (WCC) programmes initiated by the government, awareness raising, education and training for the local communities, conservation and supervision works as well as carrying out various researches on the forest were among a few. Overall, domestication of woody medicinal species will be a suitable option for optimizing their sustainable use and conservation, thereby reducing their overexploitation.

Conclusion and Recommendations

Indigenous people mainly depend on woody medicinal species in Sheko forest to treat various human and/or livestock aliments. As a result, a totalof 61species belonging to 55 genera and 30 families were identified and documented in Sheko forest. Family*Moraceae* was represented by the highest number of species, followed by *Asteraceae*, *Fabaceae* and *Euphorbiaceae.Croton macrostachyus,* followed by *A. toxicaria, C. africana* and *P. dodecandra*were the most popular woody medicinal species. Malaria, Gonnoria, Teeth illness, Snake bite and others were treated by different species. Most of the traditional remedies were collected in fresh forms (57.1%), processedmainly through pounding, concoction and squeezing and administered through orally (63.1%) in estimated or fixed doses. When the patients took the remedies various side effects were seen such as vomiting, diarrhea, body fever, body itching, etc. Most of the traditional healers (57.4%) in the study area had an experience of more than 20 years and they were more effective in administering the remedies. Woody medicinal species have multipurpose uses in the study areas. This has been more important if it is interlinked with modern medical treatment. Despite major threats of woody medicinal species in the study area, local communities have developed various proper conservation and management strategies in Sheko forest. Overall, planting of medicinal plant species around homesteads and farmlands as well as public awareness on conservation and sustainable utilization of these species are recommended.

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EFFECTS OF PROVENANCE ON SEED GERMINATION, EARLY SURVIVAL AND GROWTH PERFORMANCE OF ZIZIPHUS SPINA-CHRISTI (L.) DESF. A MULTIPURPOSE WILD FRUIT SPECIES IN ETHIOPIA

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Abstract

Effects of provenance on seed germination, early survival and growth performance of *Ziziphus spina-christi* (L.) Desf. in Ethiopia was evaluated. Seeds were collected from Dello Mena, Bati, Guba and Habru Districts of Ethiopia. In this study, seed pre-sowing and light/dark treatments on seed germination as well as effects of provenance on early survival and growth performance of *Z. spina-christi* seedlings were tested in CEE-FRC. There were 11,686-24,103 seeds contained within 1kg of *Z. spina-christi* seeds with 82-95% pure seeds among the four provenances.From 1 kg of pure *Z. spina-christi* seeds 6,800-12,811 seedlings were raised in the laboratory. Nicked seeds showed the highest germination of 94% compared to other treatments with 10 months of storage in cold room having 6.9% to 8.6% moisture content.There was a highly statistical significant difference (p <0.001) among treatments (nicking, soaking the seeds in cold water (19°c) for 24 hours and Control). Dello Mena provenance had the highest germination percentage (94%) as compared to other provenances. Percentage germination showed highly statistical significant differences (*p <0.001*) among the four provenances.Germination was significantly improved in dark treatment (68%) compared to light treatment (65%). The highest survival percentage (about 80%) of seedlings was recorded on Bati provenance, followed by Guba provenance (73 Habru provenance had the highest mean values of seedlings' shoot length (30.85 cm), RCD (0.40 mm), tap root length (19.50 cm), fresh shoot (2.33$\pm$1.15 g) and dry shoot (0.76$\pm$0.36 g), root fresh weight (2.84$\pm$1.71 g) as well as root dry weight (1.27$\pm$0.71 g). Bati provenance had the largest number of leaves on the stems, while Guba provenance had the largest number of secondary roots. This implies that Habru, followed by Bati provenances has been preferable for raising *Z. spina-christi* seedlings in the Green House. This research outputs provide an evidence of the variation among *Z. spina-christi* provenances and hence the potential for future tree improvement and domestication programme.

Key words*: Domestication, nicking, tree improvement*

Introduction

Ziziphus spina-christi (L.) Desf. has diverse uses and values including fuel wood (firewood and charcoal), timber, posts and poles, tool handles and farm implements, medicinal uses, edible (fruits), livestock fodder, erosion control as well as soil improvement (Thulin, 1989, Orwa et al., 2009, Nkafamiyaet al., 2013).

Despite this fact depletion of forest resources due to various human and natural factors such as agricultural expansion and human settlement, overgrazing, forest fire, deforestation for construction and energy supply, environmental degradation and global climatic change are major challenges. As a result, many plant species are declining from their natural habitats and even some species are endangered and others are near to extinct (IUCN, 2012). Furthermore, poor seed storage characteristics and hence low seed viability, vigour of the seeds and germination capability; limited availability of seeds and seedlings, difficulty in seed collection, transportation, handing and processing; as well as flowering at longer intervals are some of the practical problems in wild fruit trees for large-scale propagation and plantation using seeds (FAO, 1985, Tinsae Bahru et al., 2012, 2014 and 2015). Secondly, there is no latest information or little efforts have been made to explore on seed pre-sowing and light/dark treatments on seed germination as well as effects of provenance on seed germination, early survival and growth performance to promote the large scale propagation and plantation establishment as well as domestication under agroforestry system. Therefore, the current study aimed to investigate the effects of provenance on seed germination, early survival and growth performance of *Z. spina-christi* species in Ethiopia, which is socio-economically important and an ecologically feasible species.

Material and Methods

Seed collection, handling and processing

Ziziphus spina-christi is a multipurpose species belonging to the family *Rhamnaceae* (Thulin, 1989, Orwa *et al*., 2009). It has various local names in different languages including *Qwrqwra/ Qurqura/Geba*in Amarigna; *Qurqura* in Afan Oromo; *Geba* in Tigrigna; *Lang* in Anuwakigna; *Bow* in Nuyerigna; *Atsoda* in Bertagna; *Geb* in Somaligna and Christ's thorn in English (Thulin, 1989; Azene, 2007). It is a shrub or tree growing up to a height of 10 m (Thulin, 1989) and a diameter of 60 cm (Orwa et al., 2009). In Ethiopia, it is widely distributed in wooded grassland on limestone slopes, *Acacia* bushland on alluvial soils, in and along dry riverbeds, edges of cultivations and gardens of Afar, Tigray, Gonder, Welo, Shewa, Gojam, Bale and Harerge regions within an altitudinal ranges of 0-1,900 (2,400) m above sea level (Thulin, 1989).

Fruits of *Z. spina-christi* were collected from Bati and Habru Districts, Amhara Regional State; Guba District, Benishangul-Gumuz Regional State as well as Dello Mena District, Oromia Regional State, Ethiopia. To ensure maximum genetic diversity, fruits were collected from 10-20 selected mother trees at a distance of 100 m apartbetween them (FAO, 1975). Fruits were transported, extracted and cleaned in CEE-FRC seed processing laboratory, following the procedures by FAO (1985). Then seeds were separated from fruits by cracking the fruit walls. Finally, seeds were placed in perforated plastic bags and stored in cold room at +5°c and the experiment was started soon.

Determination of purity, moisture content and seed weight

Purity, moisture content and seed weight per kg of *Z. spina-christi* were determined in the CEE-FRC laboratory, following the methods adapted from FAO (1985).

Pre-sowing seed treatments

Effects of seed pre-sowing treatments on the germination of *Z. spina-christi* seeds was assessed by conducting three major pre-sowing treatments. Accordingly, seeds were subjected to nicking; soaking the seeds in cold water (19°c) for 24 hours and Control (without treatment or intact seeds) treatments in order to improve the rate and germination of seeds (Tinsae et al., 2014). To investigate the effect of nicking on germination of seeds, a small portion of the seed coat was carefully removed at the side of the Hilum using the sharp edge of a Scissor until a small hole was remained for imbibitions of water and oxygen. Great care was taken to avoid/not to damage seed embryo and the emerging radicle as well. This method was followed based on Tinsae et al. (2014).

Light/dark treatment

In this test, the effect of light or darkness on germination of seeds was tested by sowing seeds in light and under dark conditions. Based on this, for light treatment nicked seeds were sowed and enclosed in Petri-dishes on moist filter paper. On dark treatment, seeds were sowed and enclosed in Petri-dishes on moist filter paper and immediately wrapped with Aluminum Foil to avoid exposure of seeds to light. Finally, the Petri-dishes of both treatments were placed on a table at room temperature ($21 – 22^{0}$c) and the light treatment exposed to light from florescent tubes. This method was followed based on Tinsae et al. (2014) and (2015).

Effects of storage period on seed longevity

Seeds of *Z. spina-christi* were stored for 0, 180 and 360 days in cold room at $+5^{o}$c and the seed germination tests were carried out to assess the seed viability during storage, following the method adapted from Tinsae et al. (2014) and Tinsae et al. (2015).

Daily germination assessment of seeds

All germination tests were conducted in such a way that all treatments had 100 seeds in 4 replicates of 25 seeds each. The filter paper was kept moist with distilled water as much as possible throughout the entire experimental period. Seeds were inspected everyday starting from the 2nd day after sowing except those seeds incubated in the dark. All germinated seeds were counted and removed daily in order to avoid the double counting of seeds. A seed was considered as germinated when the radicle was penetrated out from the seed coat and clearly appeared visually. The daily germination count was continued until no more seeds had been germinated (28 days). This method was adapted from Baskin and Baskin (2001), Tinsae et al. (2012), (2014) and (2015).

Seedling raising in the laboratory and transplanting on polyethylene pots

Treated (*i.e*., nicked) *Z. spina-christi* seeds with best germination were sowed in the laboratory on plastic Petri-dishes, where sand used as a substrate. Following this, 100 polyethylene pots having 10 cm height and 8 cm diameter for each provenance were filled with 2 hand sand and 1 hand forest soil mix (2:1 Ratio) to raise the seedlings. Accordingly, using a completely randomized design (CRD), 100 polyethylene pots in 5 replications of 20 polyethylene pots each were designed at Green House. Hundred germinated seedlings having 2-4 leaves were transplanted to polyethylene pots at Green House from three different provenances (*i.e*., Bati, Habru and Guba Districts). Dello Mena provenance was not included due to the shortage of seeds. This method was adapted from Tinsae et al. (2014).

Seedlings survival was supervised until two weeks and the dead seedlings were replaced by other normal seedlings. Watering and weeding was done regularly (morning and evening) when it is necessary. Finally, data on early survival and mortality rate as well as growth performance of seedlings were carried out at five months after the completion of transplanting in the polyethylene pots. This method was followed based on Tinsae et al. (2014).

Early survival rate and growth performance of seedlings

Early survival and mortality rate of *Z. spina-christi* seedlings were counted among the three provenances. Shoot length/height of each *Z. spina-christi* seedling was measured using ruler in cm, while root-collar diameter (RCD) was measured using seed caliper in mm among the three provenances, following the method adapted from Tinsae et al. (2014). In line with this, the number of leaves and number of branches of each seedling were counted.

Seedlings' leaf, stem and root fresh and dry weight estimation

Once the necessary data on survived seedlings, seedling shoot length and RCD recorded, 30 seedlings were randomly sampled from each provenance for the experiment to estimate seedlings' leaf, stem and root fresh and dry weight. Accordingly, each seedling was uprooted one by one and the tap-root length was measured using ruler in cm. The number of secondary roots associated with the tap root was counted. Then each seedling's leaf was separated from the stem and branches. Likewise, the stem was cut from root at the soil level and all parts put separately in to the coded Manila Envelope (*Kaki Wereket)* (Amharic)).

Fresh weight of each seedling's leaf, stem and root was measured using sensitive analytical balance in gram (g). Following this, each seedling's leaf, stem and root with their respective envelopes placed in to the dry-oven at a temperature of $73 \pm 2^{o}c$ for 24 hours. Finally, envelops were removed out from the dry-oven and each seedling's leaf, stem and root dry weight was measured separately soon not to absorb moisture and affect the weight. The process was continued in the same way until insignificant weight difference was observed between dry weights by measuring randomly drawn samples. This method was followed based on Tinsae et al. (2014).

Data analysis

Germination data were first arcsine transformed before statistical analysis to fulfill normality (Gomez and Gomez, 1984; Baskin and Baskin, 2001). Collected data were analyzed and evaluated by using percentages, figures and tables. In addition, the statistical significance difference was determined by one-way Analysis of variance (ANOVA) test at 95 %, 99 % or 99.9 % confidence interval and multiple comparison of Least Significance Difference (LSD) to show real significance difference among the treatments using SPSS Version 20.0 Computer Software Programme.

Results and Discussion

Purity, moisture content and seed weight

The results indicated that the purity analysis of *Z. spina-christi* seeds ranged from 82-95 % among the four provenances. Hence, the seeds could be classified as pure seeds (Tinsae et al., 2014 and 2015). Bati provenance had the highest purity percentage (95 %) among the provenances, while Habru provenance had the least (91 %). Its percentage moisture content from the average of the two samples found to be 6.9- 8.6 % for storage in cold room at $+5^0$C among the four provenances (Table 1).

Table 1: Purity, moisture content and seed weight of *Z. spina-christi* seeds

Provenance	Purity (%)	Moisture content (%)	seed weight/kg	Mean 1,000 seed weight (g)	No of seedlings/kg
Dello Mena	82	6.89-8.58	11,686	86	9,008
Bati	95	7.31	24,080	42	12,811
Guba	92	7.88	22,998	44	11,002
Habru	91	8.05	24,103	42	6,800

The hard and woody shell (fruit) of *Z. spina-christi* species contains 1-3seeds and the fruit is cracked with Morsa or Hammer to leave the seeds. The overall seed weight test after purity analysis indicated that there were 11,686-24,103 seeds contained in one kg of pure *Z. spina-christi* seeds. This, in turn, has a mean thousand seed weight of 42-86 g. Therefore, from one kg of pure *Z. spina-christi*seeds 6,800-12,811 seedlings are raised at Laboratory.

Pre-sowing seed treatment

Germination of *Z. spina-christi* seeds recorded at the end of the experiment ranged between 0 % and 94 % within 10 months of storage in cold room within 8.6-6.9 % of moisture content. Thus, the seeds had longer viability as well as survival value and hence stored for longer periods. This showed that *Z. spina-christi* seeds have Orthodox seed storage behavior as also reported by Orwa et al. (2009). Nicked seeds showed the best germination (94 %) (Figure 1). The statistical test of one-way ANOVA also showed that there was a statistical significant difference (p <0.001) among treatments.
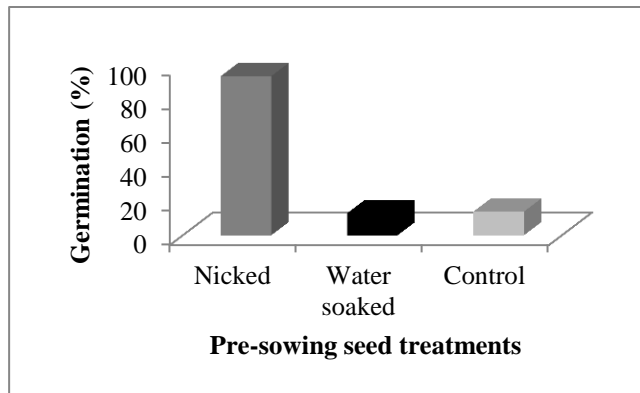
Figure 1: Pre-sowing seed treatments of *Z. spina-christi* seeds

Germination was fastest and uniform in nicked seeds than the rest treatments. This showed that *Z. spina-christi* seeds require a proper seed pre-sowing treatment for better germination of seeds. This result was similarly reported by earlier study of Aboutalebi et al. (2012), where treated seeds with stratification showed the best germination (78.8 %).Similarly, nicked seeds also successfully improve the germination of seeds in different species as also described by Tilahun and Legesse (1999) and Tinsae et al. (2014).

Effects of storage period on seed longevity

Germination of *Z. spina-christi* seeds were 63, 80 and 94 %, respectively for 0, 180 and 360 days of storage in cold room at + 5°c. Germination ofseeds steeply increased over the entire storage periods (Fig. 2).
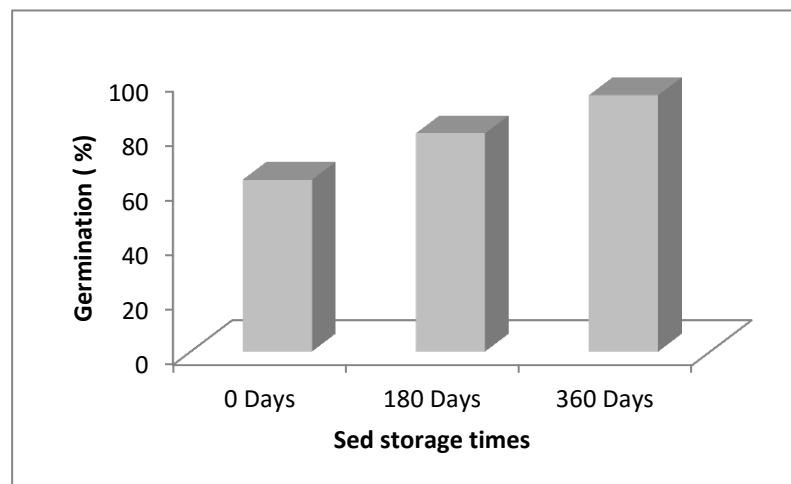
Figure 2: Effects of storage period on *Z. spina-christi* seed longevity

This indicated that storage time had no effect on *Z. spina-christi* seed germination. Thus, the seeds maintain its viability over the entire storage periods, *i.e.*, until 360 days of storage. However, this result was totally disagree from earlier findings were reported by Demelash *et al.* (2012), Demel (1994), Baskin and Baskin (2001) and Tinsae et al. (2015). This might be attributed by lower storage temperature of *Z. spina-christi* seed in cold room at $+5^{o}c$.

Effects of provenance on seed germination

The results of *Z. spina-christi* seed germination in the laboratory indicated that Dello Mena provenance had the highest germination (94 %) in producing potential viable seeds (Fig. 3). Bati and Guba also had better germination than Habru provenance. The statistical test also showed that there was a significant difference ($p < 0.001$) among provenances.
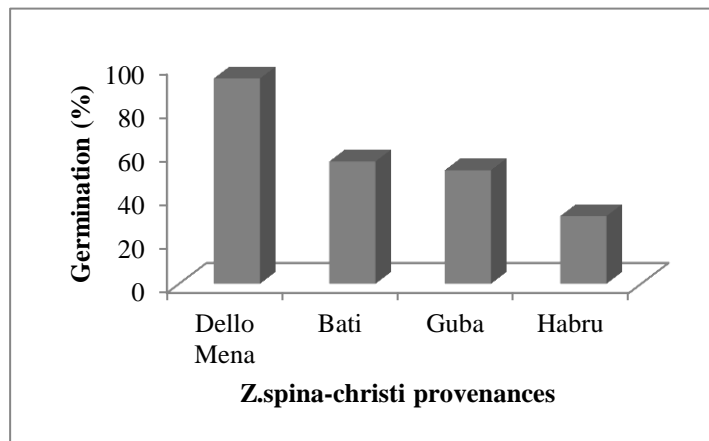
Figure 3: Effects of provenance on *Z. spina-christi* seeds germination

According to Florence (1996) species with a broad geographic distribution generally show provenance variation in both morphological and physiological attributes. Therefore, Dello Mena, followed by Bati and Guba provenances recommended in producing viable seeds and hence a potential as a seed source.

Light/dark treatment

Dark treatment showed a slightly higher germination (68 %) than the light treatment (65 %) (Fig. 4). But, the statistical test showed no significant difference ($p < 0.05$) between treatments.
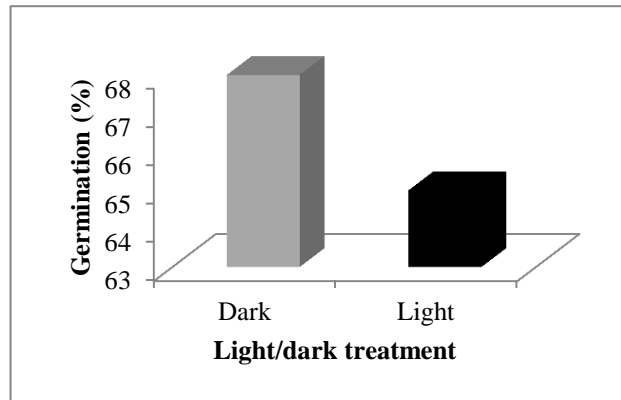
Figure 4: Effect of light or dark treatment on *Z. spina-christi* seed germination

This is because light can prevent the germination of negatively photoblastic (light inhibited) seeds (Baskin and Baskin, 2001). Consequently, light is not a limiting factor for the germination of these seeds (Demel, 1994).

Seedlings' survival and mortality rate determination

The results of *Z. spina-christi* seedlings survival count in the Green House reported that the survival percentage of the seedlings among the three provenances were different. The highest survival percentage of seedlings was recorded for Bati provenance, which accounted about 80, %. In contrast, the Habru provenance was characterized by the highest mortality rate (50 %) of seedlings (Fig. 5).

According to Florence (1996) species with a broad geographic distribution generally show provenance variation in both morphological and physiological attributes. In turn, variation in physiological attributes may enhance both the survival and growth potential of trees within local populations.
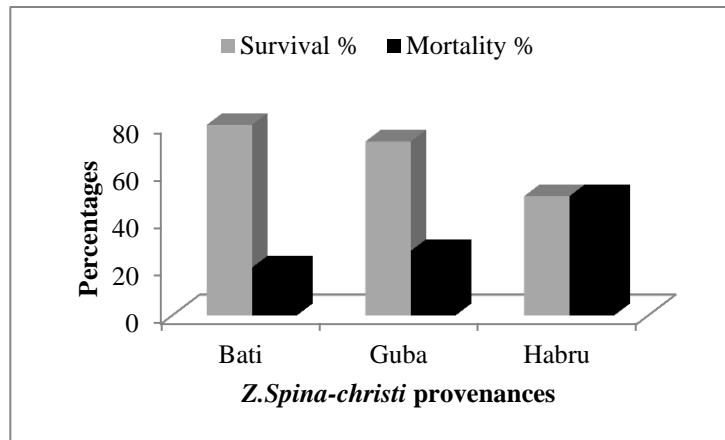
Figure 5: Seedlings' survival and mortality rate of *Z. spina-christi* provenances

This revealed that the long-term yield of plantation per unit area can be affected by the mortality or survival rate of seedlings (Girma et al., 2012; Negash and Mebrate, 2005). This might be due to various environmental factors such as the size and effect of polyethylene pots, soil, moisture and temperature in the green house, availability of water, insect and pest and other determinant factors. Therefore, Bati provenance is more recommended for raising large number of *Z. spina-christi* seedlings in the green house with the best survival potential.

Seedlings growth performance determination

The statistical test of One-way ANOVA showed that there was a significant difference ($p < 0.01$) among provenances for the mean values of seedlings' shoot length, RCD, tap root length and number of leaves. Habru provenance had the highest mean values of seedlings' shoot length (30.85 cm), RCD (0.40 mm) and tap root length (19.50 cm) (Table 2). This indicated that Habru provenance had the highest growth performance and adaptation capacity than the two provenances. Similarly, Bati provenance scored the largest number of leaves (35.51 cm) on the stems and branches of seedlings.

On the other hand, Guba provenance had the largest number of secondary roots (62) associated with the primary roots, while Bati provenance had the least number of secondary roots (47). However, the statistical test showed no significant differences ($p < 0.05$) among the three provenances for the mean values of secondary roots.

Table 2: Mean values of seedlings growth performance parameters assessed for *Z. spina-christi* among the three provenances (n=30 or 100, mean $\pm$ Standard deviation (SD))

Provenance	Shoot length (cm), n=100	RCD (mm), n=100	Tap root length (cm), n=30	No of secondary roots, n=30	No of leaves, n=100
Bati	25.88 $\pm$ 5.30	0.32 $\pm$ 0.13	15.27 $\pm$ 3.72	46.47 $\pm$ 20.54	35.51 $\pm$ 13.19
Guba	28.75 $\pm$ 6.46	0.34 $\pm$ 0.10	17.77 $\pm$ 6.10	61.47 $\pm$ 27.79	27.86 $\pm$ 11.07
Habru	30.85 $\pm$ 9.34	0.40 $\pm$ 0.12	19.50 $\pm$ 5.54	54.43 $\pm$ 25.15	31.90 $\pm$ 19.17
P in ANOVA (f)	8.476	7.037	4.991	2.776	5.504
Sig. levels	0.000	0.001	0.009	0.068	0.005

In general, the seedlings longer tap root length and higher number of secondary roots might increase the surface area for efficient absorption of water and nutrients from the soil and provides physical support of the plant (Silvana, 1998; Shiferaw et al., 2010). Higher shoot length and RCD values were also important for better survival rate and higher growth performance with better adaptation capacity of the seedlings at field conditions. In turn, a large number of seedlings' leaves might contribute to a higher rate of photosynthesis, which in turn resulted in a higher growth rate (Shiferaw et al., 2010).

Seedlings' fresh and dry shoot and root weight (Biomass) estimation

As presented in Table 5, in all the mean values of fresh and dry weight seedlings' parameters, Habru provenance had the highest weight values, followed by Guba provenance. On the other hand, Bati provenance had the least mean values for all the parameters. Likewise, the seedlings root/shoot ratio showed a similar trend in all the seedlings' fresh and dry weight parameters (Table 3).

Table 3: Mean values of seedlings' fresh and dry shoot and root weight assessed for *Z. spina-christi* among the three provenances (n=30, mean $\pm$ Standard deviation (SD))

Prove nance	Leaf fresh weight (g)	Stem fresh weight (g)	Root fresh weight (g)	Root/shoot Ratio	Leaf dry weight (g)	Stem dry weight (g)	Root dry weigh t (g)	Root/sh oot Rat io
Bati	1.66 $\pm$ 0.66	1.00 $\pm$ 0.38	1.81 $\pm$ 1.10	0.68	0.52 $\pm$ 0.20	0.43 $\pm$ 0.15	0.83 $\pm$ 0.47	0.87
Guba	1.82 $\pm$ 0.78	1.21 $\pm$ 0.71	2.19 $\pm$ 1.27	0.72	0.62 $\pm$ 0.24	0.57 $\pm$ 0.29	1.08 $\pm$ 0.56	0.91
Habru	2.33 $\pm$ 1.15	1.31 $\pm$ 0.74	2.84 $\pm$ 1.71	0.78	0.76 $\pm$ 0.36	0.58 $\pm$ 0.31	1.27 $\pm$ 0.71	0.95
P in ANOV A (f)	4.593	1.894	4.206		5.789	2.976	4.173	
Sig.	0.013	0.157	0.018		0.004	0.056	0.019	

But, the statistical test showed that only the fresh and dry leaf weight values had significant differences (p < 0.01) among the three provenances. Overall, biomass allocation, *i.e.*, root to shoot ratio had a great impact on survival rate and early growth performance (height, RCD, number of leaves, tap root length and number of secondary roots) among *Z. spina-christi* provenances. This result was also similarly reported by earlier study of Sileshi et al. (2007) on *Uapaca kirkiana* Müell Arg; an African fruit tree.

Conclusion and Recommendations

The present study indicated that the hard seed coat of *Z. spina-christi* seeds prevents the imbibitions of water and oxygen and hence inhibits the germination of seeds. In order to get high, rapid and uniform germination of seeds, seeds require appropriate seed pre-sowing treatment methods. As a result, nicked seeds (94 %) greatly improved seed germination as compared to other treatments and recommended as good treatment. The effect of provenance on seed germination further revealed that Dello Mena provenance had the highest germination in producing viable seeds, which indicated its potential as a seed source.

On the other hand, *Z. spina-christi* seedlings' survival and growth performance in the Green House reported that Bati provenance had the highest survival rate (80 %). Habru provenance had the highest mean values of seedlings' shoot length, RCD, tap root length as well as the fresh and

dry shoot and root weight. Bati provenance had the largest number of leaves on the stems and branches of seedlings. On the other hand, Guba provenance had the largest number of secondary roots associated with the primary roots. This implies that Habru, followed by Bati provenances has been preferable for raising *Z. spina-christi* seedlings in the Green House.

Acknowledgments

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EFFECTS OF PROVENANCE AND STORAGE TIME ON SEED GERMINATION CAPACITY OF *ACACIA SEYAL DEL. VAR. SEYAL.* A SOURCE OF COMMERCIAL GUM TALHA BEARING SPECIES IN ETHIOPIA

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Abstract

*Acacia seyal Del. var. seyal*is a multipurpose species that produce high value commercial product known as gum talha. Despite its socio-economic and ecological values, there is scarcity of knowledge, among others, on the storage and germination behavior of this species. In this study, various seed pre-sowing treatments, effects of dry and moist heat, effect of provenances and storage times, and light/dark treatments on seed germination were tested at Central Ethiopia Environment and Forest Research Center (CEE-FRC). Seeds of *A. seyal*were collected from Guba District, Metekel Zone and Metema District, North Gonder Zone. Seedswere collected from selected 10-20 mother trees standing at a distance of 100 m apart between them. There were 17,952 seeds contained in 1 kg of*A. seyal* seeds with 96 % pure seeds. From 1 kg of pure seed, 17,234 seedlings were raised in the laboratory. Analysis of germination data reported that nicked *A. seyal*seeds showed the best germination of 100%. Its germination was significantly (p < 0.001) varied among treatments, which ranged between 6 and 100%. Germination ofseeds steeply increased until 240 days (100 %) and slightly declined thereafter, suggesting that length of storage time had slightly a negative impact on germination of *A. seyal*seeds. Provenances of *A. seyal* seeds were significantly (p < 0.01) varied, where Metema provenancehad higher germination capacity (95 %) than Guba provenance (73 %).This showed that Metema provenance could serve as better potential seed source. Proper dry and moist heat treatments further trigger the germination of *A. seyal*seeds. There was significant variation ($p < 0.001$) among the dry and moist heat treatments. Dark treatment of *A. seyal*seeds had higher germination (100 %) than light treatment (95 %) and showed significant variation (p < 0.05) between treatments. Therefore, storing of collected *A. seyal* seeds from Metema provenance for not more than 240 days and sowing nicked seeds in the laboratory were recommended for raising and effective large scale plantation establishment of seedlings. Further study on Guba and other provenances of *A. seyal*seeds should be carried out to serve as a baseline data to select potential seed source in the country.

Key words*:* Light, Guba, Mettema, nicked, treatments.

Introduction

Acacia seyal Del. var. *seyal* is the source of Gum Talha, which has an international trade value (FAO, 1993; Orwa et al., 2009). Its price is about 33 % that of gum Arabic (FAO, 1993). According to Orwa et al. (2009), despite its darker and inferior quality than Gum Arabic from *A.senegal*, talha gum forms 10 % of the Sudanese gum exported to India and Europe. Furthermore, itis a multipurpose tree having various uses including livestock feed (leaves and pods), timber, fuel wood (firewood and charcoal), posts and poles, tool handles and farm implements, edible (gum), medicinal uses (bark and gum) and red dye (bark), shade and fencing (Thulin, 1989 ; Fichtl and Admasu, 1994; Arbonnier, 2004; Azene, 2007; Orwa et al., 2009). It is also important in soil and water conservation, nitrogen fixation as well as wind break under agroforestry systems (Thulin, 1989; Azene, 2007).

Despite diverse socio-economic and ecological importance, depletion of forest resources due to various human and natural factors such as agricultural expansion and human settlement, overgrazing, forest fire, deforestation for construction and energy supply, environmental degradation and global climatic change are major challenges. As a result, many plant species including species of *Acacia seyal* are declining from their natural habitats and even some species are endangered and others are near to extinct (IUCN, 2012). Furthermore, poor seed storage characteristics and hence low seed viability, vigour of the seeds and germination capability; limited availability of seeds and seedlings, difficulty in seed collection, transportation, handing and processing; as well as flowering at longer intervals are some of the practical problems in tree seeds for large-scale propagation and plantation using seeds (FAO, 1985; Tinsae Bahru et al., 2012, 2014 and 2015). Secondly, there is no latest information or little efforts have been made to explore on the effects of provenance and storage times on seed germination to promote the large scale propagation and plantation establishment as well as domestication under agroforestry system. Therefore, the current study is aimed at investigating the effects of provenance and storage times on seed germination of *A. seyal*species in Ethiopia.

Material and Methods

Seed collection, handling and processing

Acacia seyal is an indigenous plant belonging to the family *Fabaceae* (Thulin, 1989). It has various local names in different languages including *Adiqento/Makani* in Afarigna; *Wachu* in Amarigna or Afan Oromo; *Cea* in Tigrigna; *Jiq* in Somaligna; *Fundukiya* in Wolaytigna and white whistling thorn in English (Thulin, 1989; Fichtl and Admasu, 1994; Azene, 2007; Orwa et al., 2009). It is a small to medium-sized tree growing to a height of 9(17) m and a diameter of 60 cm with usually flattened crown and white to greenish yellow or orange red bark (Thulin, 1989, Orwa et al., 2009). The spines are all slender and inflated spines are absent (Thulin, 1989). In Ethiopia, it is widely distributed in woodland and wooded grasslands of Tigray, Welo, Gonder, Gojam, Shewa, Arsi, Harerge, Ilubabor, Kefa and Sidamo regions within altitudinal ranges of 1,200-2,100 m above sea level (Thulin, 1989). It grows with a mean annual temperature of 18-28°c and a mean annual rainfall of 250-1,000 mm. *A. seyal* normally prefers heavy, clayey soils, stony gravely alluvial soils or humic soils (Orwa et al., 2009).

Seeds of *A. seyal* var. *seyal*were collected from Guba District in Benishangul-Gumuz Regional State and Metema District in Amhara Regional State, Ethiopia. To ensure maximum genetic

diversity, seeds were collected from 10-20 selected mother trees standing at a distance of 100 m apartamong them (FAO, 1975). Seeds were transported, extracted and cleaned in CEE-FRC seed processing laboratory, following the procedures by FAO (1985). Finally, seeds were placed in perforated plastic bags and stored in cold room and the experiment was started soon.

Determination of purity, moisture content and seed weight

Purity, moisture content and seed weight per kg of *A. seyal* seeds were determined at CEE-FRC laboratory, following the methods by FAO (1985) and Tinsae et al. (2015).

Pre-sowing seed treatments

The effects of various seed pre-sowing treatment on the germination of *A. seyal* seeds were assessed. Accordingly, seeds were subjected to nicking, seeds soaked in cold water (19 ^{o}c) for 24 hours and control (without treatment or intact seeds), following the method adapted from Tinsae et al. (2014) and (2015). To investigate the effect of nicking on germination of seeds, a small portion of the seed coat was carefully removed at the side of the Hilum using sharp scissor until a small hole was remained for imbibitions of water and oxygen. Great care was taken to avoid/not to damage seed embryo and the emerging radicle as well.

Dry and moist heat treatments

Seeds were treated with dry and moist heat in dry oven at a range of different temperatures (60, 80 and 100 ^{o}c) and duration (15, 30 and 60 min) for each range of temperature, following the method adapted from Tinsae et al. (2014) and (2015). Moist heat was similar to dry heat, the only difference was in moist heat, seeds were placed in Glass Bottle containing water and treated in dry oven. The test had also a control (without heat treatment) with the same number of seeds and replications.

Light/dark treatment

The effect of light or darkness on the germination of *A. seyal* seeds were tested by sowing seeds in light and under dark condition. For light treatment control seeds were sowed and enclosed in Petri-dishes on moist filter paper. On dark treatment, seeds were sowed and enclosed in Petri-dishes on moist filter paper and immediately wrapped with Aluminum Foil to avoid exposure of seeds to light. Finally, the Petri-dishes of both treatments were placed on a table at room temperature (21-22 ^{o}c) and the light treatment exposed to light from florescent tubes. This method was followed based on Tinsae et al. (2014) and (2015).

Effects of storage period on seed longevity

Seeds of *A. seyal* were stored for 0, 120, 240 and 300 days in cold room at room temperature (21-22 ^{o}c) and the seed germination tests were carried out to assess the seed viability during storage, following the method adapted from Tinsae et al. (2014) and (2015).

Daily germination assessment of seeds

All germination tests were conducted in such a way that all treatments had 100 seeds in 4 replicates of 25 seeds each. The filter paper was kept moist with distilled water as much as possible throughout the entire experimental period. Seeds were inspected everyday starting from the second day after sowing except those seeds incubated in the dark. All germinated seeds were counted and removed daily in order to avoid the double counting of seeds. A seed was considered as germinated when the radicle was penetrated out from the seed coat and clearly appeared visually. The daily germination count was continued until no more seeds had been germinated (28 days). This method was adapted from Baskin and Baskin (2001), Tinsae et al. (2012), Tinsae et al. (2014) and (2015).

Data analysis

Germination percentage data were first arcsine transformed before statistical analysis to fulfill normality (Gomez and Gomez, 1984; Baskin and Baskin, 2001). Data were analyzed and evaluated by using descriptive statistics such as percentages, tables and figures. In addition, the statistical significance difference between and within treatments was determined by one-way Analysis of variance (ANOVA)at 95 %, 99 % or 99.9 % confidence intervals and multiple comparison of Least Significance Difference (LSD) using SPSS Version 20.0 Computer Software Programme.

Results and Discussion

Purity, moisture content and seed weight

Purity analysis of *A. seyal* seeds indicated the presence of high purity level (96 %) purity (Table 1). Hence, the seeds could be classified as pure seeds (Tinsae et al., 2014and 2015). Its moisture content from the average of the two samples was found to be 3.8 to 4 % for storage in cold room. Thus, in desiccation tolerant seeds, 4 to 6 % moisture content has been favorable for prolonged seed storage (Hartmann and Kester, 1983).

Table 1: Determination of purity, moisture content seed weight and number of seedlings of *A. seyal* seeds

Species	Purity analysis	Moisture content	Seed weight/kg	Mean 1000 seed weight	Number of seedlings/kg
A. seyal seeds	96 %	3.8-4 %	17,952		17,234

The overall seed weight test after purity analysis indicated that there were 17,952 seeds contained in one kilogram (kg) of pure *A. seyal* seeds. This, in turn, has a mean thousand seed weight of 55.7g. Therefore, from one kg of pure *A. seyal* seeds, 17,234 seedlings were raised at CEE-FRC laboratory.

Pre-sowing seed treatment

Germination of *A. seyal* seeds were significantly (p < 0.001) varied among treatments (nicking, soaked seeds in cold water (19 °c) for 24 hours and control), which ranged between 6 and 100 %. The best germination (100 %) was recorded by nicking. Similar result was reported by earlier study of Bahru et al. (2014) for the *Tamarindus indica* L. seeds. In this treatment, most of the germination (93 %) was completed within the 1st and 5th days after sowing. Hence, germination was fastest and uniform in nicked seeds. On the other hand, seeds soaked in cold water for 24 hours had the least germination (6%) (Fig. 1).
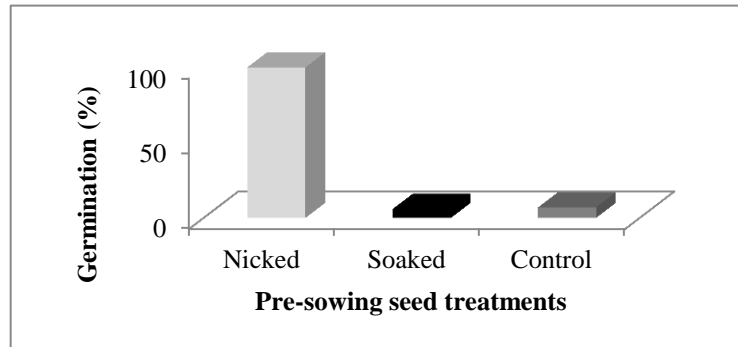
Figure 1: Pre-sowing seed treatments of *A. seyal* seeds

Effects of storage period on seed longevity

Germination of *A. seyal* seeds were 95, 98, 99 and 93 %, respectively for 0, 120, 240 and 300 days of storage in cold room at room temperature (21 - 22 ^{0}C). Germination ofseeds steeply increased until 240 days and slightly declined thereafter (Fig. 2).
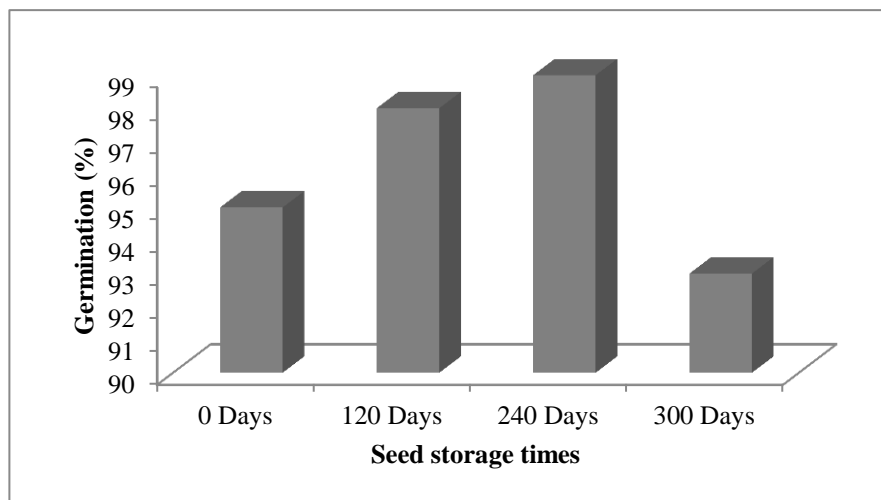
Figure 2: Effects of storage period on *A. seyal* seed longevity

This indicated that storage time had a negative impact on seed germination. Similar earlier findings were reported by Demelash et al. (2012) and Tinsae et al. (2015). Hence, as the seed storage time increased, there is a gradual decrease in seed viability and/or an increase in seed

dormancy. This result was similarly reported by earlier studies of Demel (1994), Baskin and Baskin (2001) and Tinsae et al. (2015). Such viability loss of seeds might be associated with the relatively higher storage temperature (21 - 22 oc) of the cold room. Therefore, to determine the storage behavior of *A. seyal* seeds, the seeds should be further stored at +5 ^{0}c or lower temperature in cold room and the germination test will be carried out.

Effects of provenance on seed germination

Provenances of *A. seyal* seeds were significantly (p <0.01) varied between treatments, where Metema provenancehad higher germination (95 %) than Guba provenance (73%) (Fig. 3). Therefore, the Metema provenance had the potential in producing viable seeds and recommended for raising seedlings in the laboratory for large scale plantation of *A. seyal*. Seedlings.
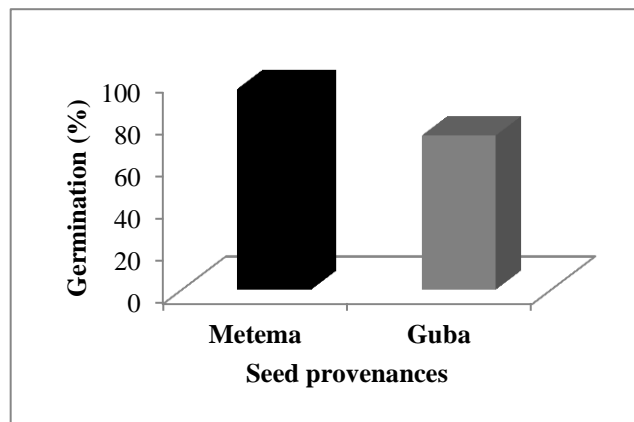
Figure 3: Effect of provenances on *A. seyal* seeds germination

Nevertheless, Guba provenance can also serve as a good seed source in the absence of Metema provenance. According to Florence (1996) species with a broad geographic distribution generally show provenance variation in both morphological and physiological attributes. In turn, variation in physiological attributes may enhance both the survival and growth potential of trees within local populations.

Dry heat treatment

In dry heat tests, *A. seyal* seeds were significantly (p< 0.001) varied among treatments, with a highest mean value of 55.69 $\pm$ 5.28 % at 80 ^{o}c for 60 minutes. On the contrary, the least germination (4 %) was recorded at 60 ^{o}c for 60 minutes. Overall, germination of *A. seyal*seeds was steeply increased from 4% germination at 60 ^{o}c to 68 % germination at 80 ^{o}c but declined to 58 % germination at 100 ^{o}c with increasing time (Fig. 5). Baskin and Baskin (2001) reported that dry heat at temperature of 60-100 ^{o}c causes seeds of many species to become permeable to water. This revealed that appropriate dry heat treatments trigger the germination of *A. seyal*seeds.
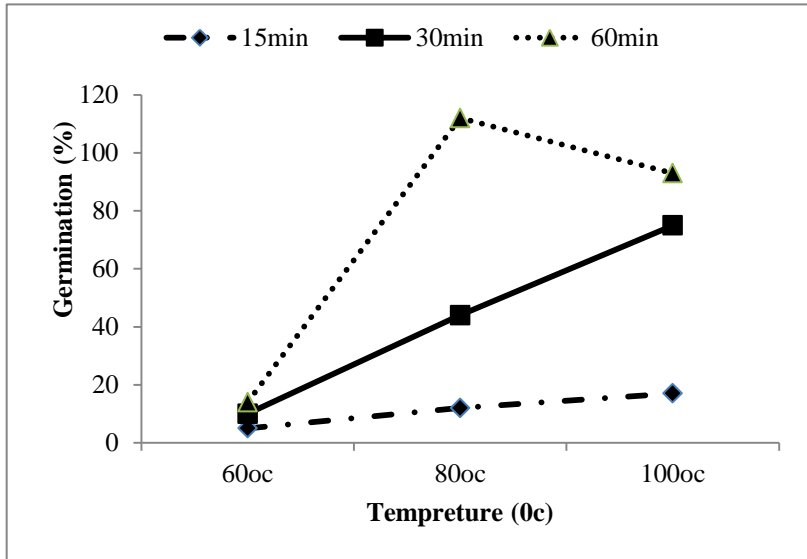
Figure 4: Effects of dry heat treatment on *A. seyal* seed germination

Therefore, heat generated from forest fire in dryland areas act as one of the factors stimulating seed germination. This result was also similarly reported by earlier studies of Martin et al. (1975), Demel (1996), Baskin and Baskin (2001), Tinsae et al. (2014) and Tinsae et al. (2015).

Moist heat treatment

In moist heat treatment, the highest germination of *A. seyal* seeds was recorded (20 %) at 100 ^{0}c for 60 minutes and the least germination (3 %) was at 60 ^{0}c for 15 and 60 minutes. According to Martin et al. (1975) moist heat exposure for 4 min in the range of 90 ^{0}c to 110 ^{0}c appears to be lethal to all seed tested. The statistical test also indicated that there was a significant difference ($p < 0.001$) among the moist heat treatments. This showed that appropriate moist heat treatments trigger the germination of *A. seyal* seeds.
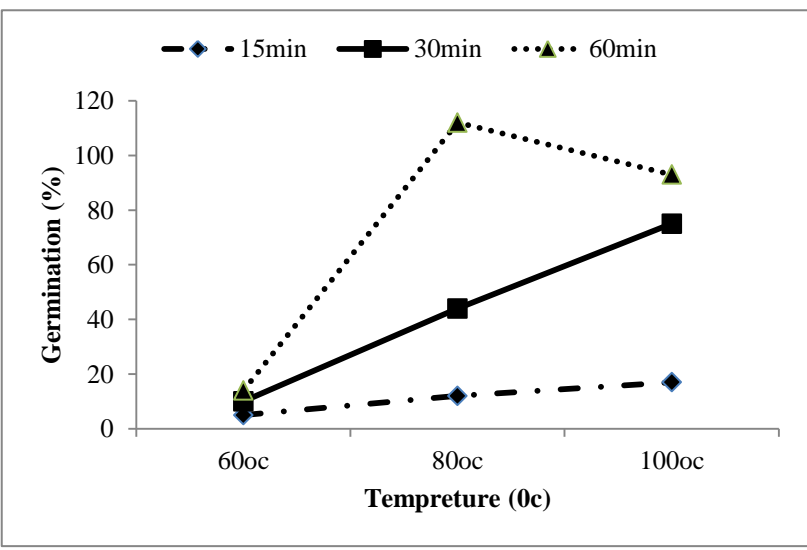
Figure 5: Effects of moist heat treatment on *A. seyal* seed germination

Therefore, moisture generated from forest fire in dryland areas serve as a favourable environmental condition to break seed dormancy and stimulate seed germination. This result was in line with earlier studies (Martin et al., 1975; Demel, 1996; Baskin and Baskin, 2001, Tinsae et al., 2014 and 2015).

Light/dark treatment

Germination of seeds significantly ($p < 0.05$) varied between treatments, where the dark treatment showed a slightly higher germination (100 %) than the light treatment (95 %) (Fig. 6).
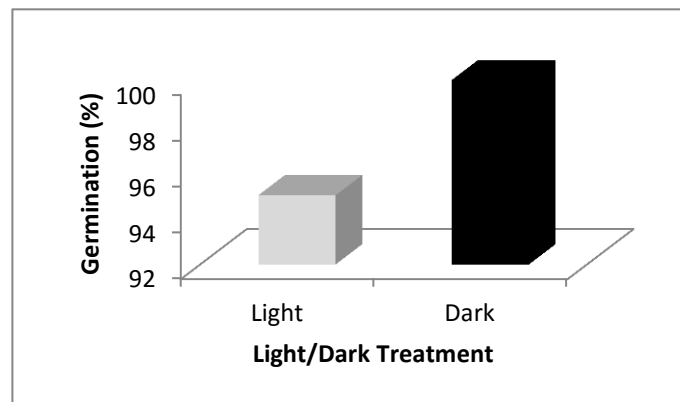
Figure 6: Effect of light or dark treatment on *A. seyal* seed germination

This is because light can prevent the germination of negatively photoblastic (light inhibited) seeds Baskin and Baskin, 2001). Consequently, light is not a limiting factor for the germination of these seeds (Demel, 1994).

Conclusion and Recommendations

The present study indicated that the hard seed coat of *A. seyal* seeds prevented the imbibitions of water and oxygen and hence inhibits seed germination. In order to get high, rapid and uniform seed germination; appropriate seed pre-sowing treatments are required. Therefore, nicked seeds (100 %) significantly improved seed germination compared with other treatments. Metema provenancehad higher germination than Guba indicating that the Metema provenancehad potential as seed source. Proper dry and moist heat treatments further trigger the germination of *A. seyal* seeds. Dark treatment of *A. seyal* seeds had higher germination than light treatment. In general, storing collected *A. seyal* seeds from Metema provenance until 240 days and sowing nicked seeds in the laboratory are recommended for rising of seedlings and effective large scale plantation establishment.

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EFFECTS OF TRADITIONAL STORAGE MEDIA, FRUIT PROCESSING METHODS AND STORAGE TIME ON SEED GERMINATION OF *BORASSUS AETHIOPUM* MART.: AN INDIGENOUS AFRICAN PALM TREE IN SOUTHWEST ETHIOPIA

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Abstract

Borassus aethiopum Mart. is an indigenous palm tree in tropical Africa belonging to the family *Arecaceae* or *Palmae*. In Ethiopia, its local name is commonly called *Zembaba*in Amharic. A study was conducted to determine the effects of traditional storage media, fruit processing methods and storage time on *B. aethiopum* seed germination. Fruits of *B. aethiopum* were collected from 10-20 selected mother trees at a distance of 100 m apart between themin February, 2012 from Guba District of Benishangul-Gumuz Regional State. *Borassus aethiopum* seed germination test had completely randomized design (CRD) in a three factor experiment involving three traditional storage media (jute sacks, perforated plastic bags and *Jerican*/plastic *Roto*), two fruit processing methods (processed and unprocessed) and three storage time levels (90, 270 and 740 days after storage) with five replications. The results revealed that control seeds of *B. aethiopum* showed the best germination of 98 %. Analysis of Generalized Linear Model (GLM) reported that there was a highly statistical significant difference (p < 0.001) among storage times on germination of *B. aethopium* seeds. However, no significant difference (p <0.05) was observed among traditional storage media and between fruit processingmethods. Germination of *B. aethoipum* seeds were reduced from 70 % after 90 days of storage to 0 % after 740 days. Among the storage media, the best germination was recorded in perforated plastic bags (70 %), followed by *Jerican* (60 %). Unprocessed seeds had better overall germination capacity (70 %) than processed seeds (30 %). Therefore, storing unprocessed seeds of *B. aethopium* in perforated plastic bags for less than 270 days was better in maintaining the viability of the seeds.

Keywords*:* Guba, palm tree, treatment

Introduction

Borassus aethiopum Mart. is an economically and ecologically important indigenous palm tree species in tropical Africa. It is a multipurpose tree species which is used in construction, household articles, bridges, boards for making floors, walls and roofs, beehive gutters (Sambou et al., 1992, Arbonnier, 2004). Fruits are edible and leaves are used for making thatch, mats, rugs and baskets (Sambou et al., 1992).

Despite this fact depletion of forest resources due to various human and natural factors such as agricultural expansion and human settlement, overgrazing, forest fire, deforestation for construction and energy supply, environmental degradation and global climatic change are major challenges. As a result, many plant species are declining from their natural habitats and even some species are endangered and others are near to extinct (IUCN, 2012). In addition, *B. aethopium* fruits are rapidly deteriorating and lost under hot (32-38^{0}c) and humid (70-90% relative humidity) climatic conditions after their collection from mother trees (Tchiegang et al., 2010) during harvesting season. The viability losses during longer storage are associated with inappropriate fruit storage and seed processing methods (Tchiegang et al., 2010). Furthermore, poor seed storage characteristics and hence short viability as well as limited availability of seeds are the practical problems in *B. aethiopum* large-scale propagation using seeds (Sanon and Sacande, 2007). Secondly, there is no latest information or little efforts have been made to explore on effects of traditional storage media, fruit processing and storage time on germination capacity of *B. aethiopum* seeds to promote the large scale plantation establishment and domestication under agroforestry system. Therefore, the present study aimed at investigating effects of traditional storage media, fruit processing and storage time on germination capacity of *B. aethiopum* seeds for proper*ex situ* conservation of its genetic base.

Material and Methods

Seed collection, handling and processing

Borassus aethiopum is an indigenous palm tree species to tropical Africa belonging to the family *Arecaceae or Palmae* (Edwards and Tewolde Berhan, 1997; Arbonnier, 2004). It is known by different local names including *Zembaba*in Amarigna; *Uduai*in Anuwakigna and African fan palm/*Borassus* palm/*Deleb* palm in English(Edwards and Tewolde Berhan, 1997; Azene, 2007).*Borassus aethiopum* is a large palm tree growing up to a height of 20 - 30 m (Edwards and Tewolde Berhan, 1997) and a diameter of 30 - 40 (- 60) cm (Arbonnier, 2004). It develops a swallowing or bulge up to 80 cm across above the middle usually after about 25 years growth. In Ethiopia, it is found in Gojam, Ilubabor and Sidamo Regions at the edge of semi-deciduous lowland forest by forming stands in depressions in *Terminalia* woodland and along streams at the altitudes ranging from 400-950 m (to 1200 m in east Africa) above sea level (Edwards and Tewolde Berhan, 1997).

Fruits of *B. aethiopium* were collected in February, 2014 from Gublak Kebele, Guba Wereda, Metekel Zone of Benishangul-Gumuz Regional State, Ethiopia. To ensure maximum genetic diversity, fruits were collected from 10-20 selected different mother trees at a distance of 100 m apartbetween them (FAO, 1975; Moussa et al., 1998). The collected fresh fruits were put into jute sacks and safely transported to CEE-FRC/EEFRI, Addis Ababa. Then, fruits were extracted and cleaned in seed processing laboratory following the procedures by FAO (1985). Accordingly, seeds were separated from each fruit by cutting with machete. Seeds which had been attacked by insects or decayed were excluded. Following this seeds were air-dried under shade in seed processing room.

Application of seed treatments

Seed germination test had completely randomized design (CRD) in a three factor experiment involving three traditional storage media (jute sacks, perforated plastic/polyethylene bags and *Jerican*/plastic *Roto*), two fruit processing methods (processed and unprocessed) and three storage time levels (90, 270 and 740 days after storage in cold room) in five replications. Following this, seeds were grouped into two: processed and unprocessed seeds. In processed seeds, both the exocarp and mesocarp was totally removed and only the bare endocarp was left. For unprocessed seeds, seeds left with both the exocarp and mesocarp, *i.e.*, with its dried edible flesh and many longitudinal fibers. Then, seeds were placed in three different traditional seed storage media: jute sacks, perforated plastic or polyethylene bags and *Jerican*/plastic *Roto*). During initial seed germination test, two seed pre-sowing treatments were applied. These were: control seeds (seeds without treatment) and treated seeds. In treated seeds, all the three layers of pericarp (*i.e.*, exocarp, mesocarp and the endocarp) were totally removed with a machete without damaging the nut, *i.e.*, the bare nut (endosperm) remained. Then the nut was soaked in cold water (19 ^{o}c) for 48 hours. Moussa et al. (1998) also applied bare nut and soaking in water treatments for *Hyphaene thebaica* Mart. seeds. But, after initial germination test, subsequent tests were carried out only with treated seeds. Finally, after initial germination test, the seeds were stored at room temperature (21 - 22 ^{0}c) and the experiment was started soon as also partially applied by Baskin and Baskin (2001).

Initial germination test

Seeds were randomly drawn from the total bulk seed lot after thoroughly mixing the bulk seed lot. Following this, 100 seeds were treated, while 100 of them were control seeds. Finally, the germination capacity was assessed in the laboratory. After taking initial germination test, sample seeds were drawn randomly from each traditional storage media and tested for germination capacity at 90, 270 and 740 days interval since seed storage.

Daily germination assessment of seeds

For initial seed germination, treatments had 50 seeds in 5 replicates of 10 seeds each. Germination test was conducted in such a way that all treatments had 10 seeds in 5 replicates of 2 seeds each. Seeds were sowed on plastic petri-dishes with sand as a germination medium and covered with polyethylene bags. The sand was kept moist with distilled water as much as possible throughout the entire experimental period. Seeds were inspected everyday starting from the 2nd day after sowing. All germinated seeds were counted and discarded daily in order to avoid the double counting of seeds. A seed was considered as germinated when the radicle was penetrated out from the nut and clearly appeared visually. The daily germination count was continued until no more seeds had been germinated, *i.e.*, 90 germination days. This method was applied following Baskin and Baskin (2001), Tinsae et al. (2012), (2014) and (2015).

Data analysis

Germination data were first arcsine transformed before statistical analysis to fulfill the normality assumption (Gomez and Gomez, 1984; Baskin and Baskin, 2001). Data were analyzed and evaluated by using descriptive statistics such as percentages, graphs and figures. In addition, the generalized linear model (GLM) was employed for the analysis of dry heat and moist heat datausing SPSS Version 20.0 Computer Software Programme. Whereas all the remaining data

were determined by one-way Analysis of variance (ANOVA) test at 95 % or 99.9 % confidence interval to test the statistical significance difference. Multiple comparison of using Least Significance Difference (LSD) was also applied to show significance difference among the treatments.

Results and Discussion

Initial germination test

Germination of *B. aethiopum* seeds recorded at the end of the experiment ranged between 0 and 94 % (Fig. 1). Treated seeds showed rapid and uniform germination, which accounted 94 %. On the other hand, control or untreated seeds had no germination (0 %). Hence, germination data reported that out of the total 50 *B. aethiopum* sowed seeds in the laboratory, the germination capacity was 94 %. Germination began 23 days after sowing and completed within 90 days.

Figure 1: Pre-sowing seed treatments of *B. aethiopum* seeds

Eighty-two percent of germinated seeds were recorded within 42 days. Out of the total germination (94 %), 12 % of germinated seeds were recorded after 80 days of sowing. The entire seed germination test lasted 90 days. This result was almost similar to Moussa et al. (1998), where *Hyphaene thebaica* Mart. seed germination test lasted 100 days.

Effects of storage media, fruit processing and storage time on seed germination

Analysis of GLM reported that there was a highly statistical significant difference (p <0.001) among storage times on germination of *B. aethopium* seeds. However, nosignificant difference (p <0.05) was observed among traditional storage media and between fruit processingmethods.The highest germination was recorded in unprocessed seeds stored in perforated plastic bags after 90 days, which accounted for 70 %. This was followed by *Jerican* (60 % germination), while sacks had the least germination (20 %) (Fig. 2).

Figure 2: Germination of unprocessed *B. aethiopum* seeds

Similarly, the overall trend was more or less the same for processed seeds except germination was lower than unprocessed seeds (Fig.3). Accordingly, after 90 days of storage seeds stored both in sack and *Jerican* scored higher germination (30 %), while perforated plastic bags had the least (20 %). But after 270 days of storage, seeds stored both in sack and perforated plastic bags the germination was reduced by 10 %, whereas germination of seeds that stored in *Jerican* abruptly declined to 0 %.

Figure 3: Germination capacity of processed *B. aethiopum* seeds

On the other hand, after 90 days of storage, unprocessed seeds stored in perforated plastic bags and *Jirican* had higher germination, *i.e*., 70 and 60 %, respectively than processed seeds. In contrast, processed seeds stored in sack had higher germination (30 %) than unprocessed seeds (Fig. 4).
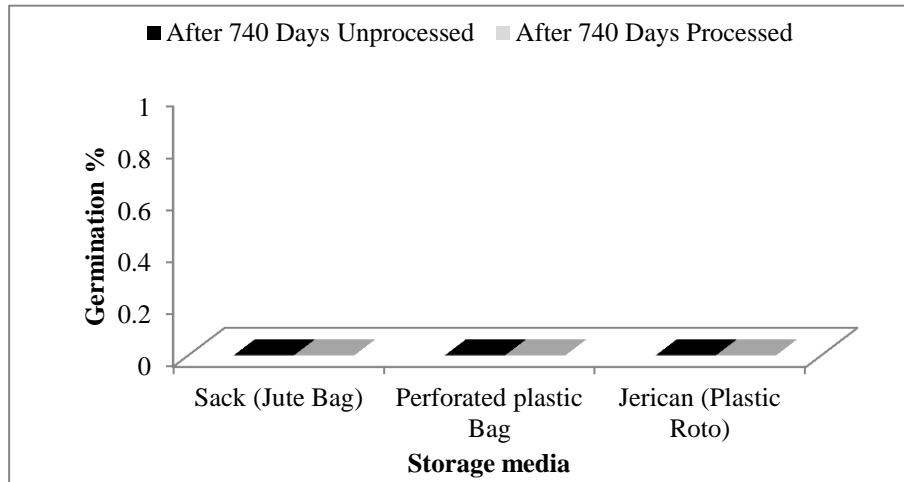

Figure 4: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 90 Days.

After 270 days of storage times, both unprocessed seeds stored in perforated plastic bags and processed seeds in sack scored higher germination (20 %). But processed seeds stored in perforated plastic bags had 10 % germination, while unprocessed seeds stored in sacks and *Jerican* as well as processed seeds in *Jerican* all scored no germination (0 %) (Fig. 5).

Figure 5: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 270 Days

After 740 days of storage times, both processed and unprocessed seeds stored in all storage media had no germination. However, seeds stored in *Jerican* and plastic bags were totally developed moisture in the media and started to decompose within 90 days and totally decayed in the 270 days. On the other hand, after 740 days of storage time, only seeds stored in Jute bags, *i.e.*, both processed and unprocessed seeds were remained (Fig. 6). In addition, in processed seeds, their endocarp and mesocarp was break down and peeling away leaving the dead embryo and endosperm? Overall, unprocessed seeds (70 %) had better germination capacity than processed seeds (30 %).

Figure 6: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 740 Days

Therefore, it is possible to conclude from this result that processing *B. aethoipum* seeds during storage is not necessary as it causes the loss of viability of seeds. In addition, from the practical aspect storing and sowing unprocessed seeds is more useful to save human power, time and resource. This result was in line with a study conducted by Demelash et al. (2012) for the lowland Bamboo (*Oxytenanthera abyssinica* (A. Rich.) Munro), where the germination of seeds declined with time and varied in different seed storage media.

Conclusion and Recommendations

Borassus aethiopum is an indigenous palm tree in tropical Africa belonging to the family Arecaceae or Palmae. The results on effects of traditional storage media, fruit processing methods and storage time on seed germination revealed that control seeds of *B. aethiopum* showed the best germination of 98 %, while treated seeds had 94 %. Analysis of Generalized Linear Model (GLM) reported that there was a highly statistical significant difference (p <0.001) among storage times on germination of *B. aethopium* seeds. However, no significant difference (p < 0.05) was observed among traditional storage media and between fruit processingmethods. Germination of *B. aethoipum* seeds were reduced from 70 % after 90 days of storage to 0 % after 740 days. Among the storage media, the best germination was recorded in perforated plastic bags (70 %), followed by *Jerican* (60 %). Unprocessed seeds had better overall germination (70 %)

than processed seeds (30 %). Therefore, storing unprocessed *B. aethopium* seeds in perforated plastic bags for less than 270 days was better in maintaining the viability of the seeds.

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EFFECTS OF TRADITIONAL STORAGE MEDIA, FRUIT PROCESSING METHODS AND STORAGE TIME ON SEED GERMINATION OF *BORASSUS AETHIPIA*

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Abstract

Borassus aethiopum Mart. is an indigenous palm tree in tropical Africa belonging to the family *Arecaceae* or *Palmae*. In Ethiopia, its local name is commonly called *Zembaba*in Amharic. A study was conducted to determine the effects of traditional storage media, fruit processing methods and storage time on *B. aethiopum* seed germination. Fruits of *B. aethiopum* were collected from 10-20 selected mother trees at a distance of 100 m apart between themin February, 2012 from Guba District of Benishangul-Gumuz Regional State. *Borassus aethiopum* seed germination test had completely randomized design (CRD) in a three factor experiment involving three traditional storage media (jute sacks, perforated plastic bags and *Jerican*/plastic *Roto*), two fruit processing methods (processed and unprocessed) and three storage time levels (90, 270 and 740 days after storage) with five replications. The results revealed that control seeds of *B. aethiopum* showed the best germination of 98%. Analysis of Generalized Linear Model (GLM) reported that there was a highly statistical significant difference ($p < 0.001$) among storage times on germination of *B. aethopium* seeds. However, no significant difference ($p < 0.05$) was observed among traditional storage media and between fruit processingmethods. Germination of *B. aethoipum* seeds were reduced from 70% after 90 days of storage to 0% after 740 days. Among the storage media, the best germination was recorded in perforated plastic bags (70 %), followed by *Jerican* (60 %). Unprocessed seeds had better overall germination capacity (70 %) than processed seeds (30 %). Therefore, storing unprocessed seeds of *B. aethopium* in perforated plastic bags for less than 270 days was better in maintaining the viability of the seeds.

Key words*:* Guba, palm tree, treatment

Introduction

Borassus aethiopum Mart. is an economically and ecologically important indigenous palm tree species in tropical Africa. It is a multipurpose tree species which is used in construction, household articles, bridges, boards for making floors, walls and roofs, beehive gutters (Sambou et al., 1992 ;Arbonnier, 2004). Fruits are edible and leaves are used for making thatch, mats, rugs and baskets (Sambou et al., 1992).

Despite this fact depletion of forest resources due to various human and natural factors such as agricultural expansion and human settlement, overgrazing, forest fire, deforestation for

construction and energy supply, environmental degradation and global climatic change are major challenges. As a result, many plant species are declining from their natural habitats and even some species are endangered and others are near to extinct (IUCN, 2012). In addition, *B. aethopium* fruits are rapidly deteriorating and lost under hot (32-38 ^{0}c) and humid (70-90 % relative humidity) climatic conditions after their collection from mother trees (Tchiegang et al., 2010) during harvesting season. The viability losses during longer storage are associated with inappropriate fruit storage and seed processing methods (Tchiegang et al., 2010). Furthermore, poor seed storage characteristics and hence short viability as well as limited availability of seeds are the practical problems in *B. aethiopum* large-scale propagation using seeds (Sanon and Sacande, 2007). Secondly, there is no latest information or little efforts have been made to explore on effects of traditional storage media, fruit processing and storage time on germination capacity of *B. aethiopum* seeds to promote the large scale plantation establishment and domestication under agroforestry system. Therefore, the present study aimed at investigating effects of traditional storage media, fruit processing and storage time on germination capacity of *B. aethiopum* seeds for proper*ex situ* conservation of its genetic base.

Material and Methods

Seed collection, handling and processing

Borassus aethiopum is an indigenous palm tree species to tropical Africa belonging to the family *Arecaceae or Palmae* (Edwards and Tewolde Berhan, 1997, Arbonnier, 2004). It is known by different local names including *Zembaba*in Amarigna; *Udua*in Anuwakigna and African fan palm/*Borassus* palm/*Deleb* palm in English (Edwards and Tewolde Berhan, 1997; Azene, 2007). *Borassus aethiopum* is a large palm tree growing up to a height of 20-30 m (Edwards and Tewolde Berhan, 1997) and a diameter of 30–40 (- 60) cm (Arbonnier, 2004). It develops a swallowing or bulge up to 80 cm across above the middle usually after about 25 years growth. In Ethiopia, it is found in Gojam, Ilubabor and Sidamo Regions at the edge of semi-deciduous lowland forest by forming stands in depressions in *Terminalia* woodland and along streams at the altitudes ranging from 400-950 m (to 1200 m in east Africa) above sea level (Edwards and Tewolde Berhan, 1997).

Fruits of *B. aethiopium* were collected in February, 2014 from Gublak Kebele, Guba Wereda, and Metekel Zone of Benishangul-Gumuz Regional State, Ethiopia. To ensure maximum genetic diversity, fruits were collected from 10-20 selected different mother trees at a distance of 100 m apartbetween them (FAO, 1975; Moussa et al., 1998). The collected fresh fruits were put into jute sacks and safely transported to CEE-FRC/EEFRI, Addis Ababa. Then, fruits were extracted and cleaned in seed processing laboratory following the procedures by FAO (1985). Accordingly, seeds were separated from each fruit by cutting with machete. Seeds which had been attacked by insects or decayed were excluded. Following this seeds were air-dried under shade in seed processing room.

Application of seed treatments

Seed germination test had completely randomized design (CRD) in a three factor experiment involving three traditional storage media (jute sacks, perforated plastic/polyethylene bags and *Jerican*/plastic *Roto*), two fruit processing methods (processed and unprocessed) and three storage time levels (90, 270 and 740 days after storage in cold room) in five replications. Following this, seeds were grouped into two: processed and unprocessed seeds. In processed seeds, both the exocarp and mesocarp was totally removed and only the bare endocarp was left. For unprocessed seeds, seeds left with both the exocarp and mesocarp, *i.e.*, with its dried edible flesh and many longitudinal fibers. Then, seeds were placed in three different traditional seed storage media: jute sacks, perforated plastic or polyethylene bags and *Jerican*/plastic *Roto*). During initial seed germination test, two seed pre-sowing treatments were applied. These were: control seeds (seeds without treatment) and treated seeds. In treated seeds, all the three layers of pericarp (*i.e.*, exocarp, mesocarp and the endocarp) were totally removed with a machete without damaging the nut, *i.e.*, the bare nut (endosperm) remained. Then the nut was soaked in cold water (19 ^{o}c) for 48 hours. Moussa et al. (1998) also applied bare nut and soaking in water treatments for *Hyphaene thebaica* Mart. seeds. But, after initial germination test, subsequent tests were carried out only with treated seeds. Finally, after initial germination test, the seeds were stored at room temperature (21-22 ^{0}c) and the experiment was started soon as also partially applied by Baskin and Baskin (2001).

Initial germination test

Seeds were randomly drawn from the total bulk seed lot after thoroughly mixing the bulk seed lot. Following this, 100 seeds were treated, while 100 of them were control seeds. Finally, the germination capacity was assessed in the laboratory. After taking initial germination test, sample seeds were drawn randomly from each traditional storage media and tested for germination capacity at 90, 270 and 740 days interval since seed storage.

Daily germination assessment of seeds

For initial seed germination, treatments had 50 seeds in 5 replicates of 10 seeds each. Germination test was conducted in such a way that all treatments had 10 seeds in 5 replicates of 2 seeds each. Seeds were sowed on plastic petri-dishes with sand as a germination medium and covered with polyethylene bags. The sand was kept moist with distilled water as much as possible throughout the entire experimental period. Seeds were inspected everyday starting from the 2nd day after sowing. All germinated seeds were counted and discarded daily in order to avoid the double counting of seeds. A seed was considered as germinated when the radicle was penetrated out from the nut and clearly appeared visually. The daily germination count was continued until no more seeds had been germinated, *i.e.*, 90 germination days. This method was applied following Baskin and Baskin (2001), Tinsae et al. (2012), (2014) and (2015).

Data analysis

Germination data were first arcsine transformed before statistical analysis to fulfill the normality assumption (Gomez and Gomez, 1984; Baskin and Baskin, 2001). Data were analyzed and evaluated by using descriptive statistics such as percentages, graphs and figures. In addition, the generalized linear model (GLM) was employed for the analysis of dry heat and moist heat data using SPSS Version 20.0 Computer Software Programme. Whereas all the remaining data were

determined by one-way Analysis of variance (ANOVA) test at 95 % or 99.9 % confidence interval to test the statistical significance difference. Multiple comparison of using Least Significance Difference (LSD) was also applied to show significance difference among the treatments.

Results and Discussion

Initial germination test

Germination of *B. aethiopum* seeds recorded at the end of the experiment ranged between 0 and 94 % (Fig. 1). Treated seeds showed rapid and uniform germination, which accounted 94 %. On the other hand, control or untreated seeds had no germination (0 %). Hence, germination data reported that out of the total 50 *B. aethiopum* sowed seeds in the laboratory, the germination capacity was 94 %. Germination began 23 days after sowing and completed within 90 days.

Figure 1: Pre-sowing seed treatments of *B. aethiopum* seeds

Eighty-two percent of germinated seeds were recorded within 42 days. Out of the total germination (94 %), 12 % of germinated seeds were recorded after 80 days of sowing. The entire seed germination test lasted 90 days. This result was almost similar to Moussa et al. (1998), where *Hyphaene thebaica* Mart. seed germination test lasted 100 days.

Effects of storage media, fruit processing and storage time on seed germination

Analysis of GLM reported that there was a highly statistical significant difference (p < 0.001) among storage times on germination of *B. aethopium* seeds. However, nosignificant difference (p < 0.05) was observed among traditional storage media and between fruit processingmethods.The highest germination was recorded in unprocessed seeds stored in perforated plastic bags after 90 days, which accounted for 70 %. This was followed by *Jerican* (60 % germination), while sacks had the least germination (20 %) (Fig. 2).
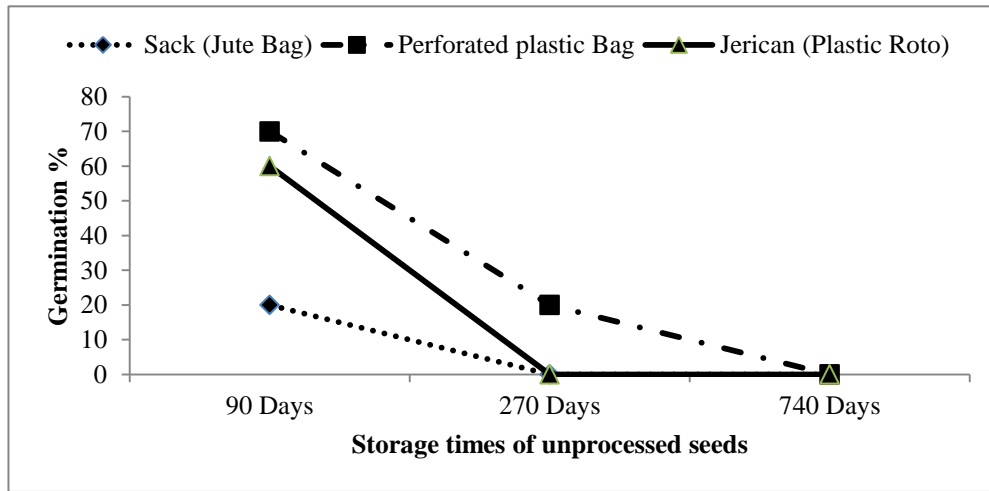
Figure 2: Germination of unprocessed *B. aethiopum* seeds

Similarly, the overall trend was more or less the same for processed seeds except germination was lower than unprocessed seeds (Fig.3). Accordingly, after 90 days of storage seeds stored both in sack and *Jerican* scored higher germination (30 %), while perforated plastic bags had the least (20 %). But after 270 days of storage, seeds stored both in sack and perforated plastic bags the germination was reduced by 10 %, whereas germination of seeds that stored in *Jerican* abruptly declined to 0%.

Figure 3: Germination capacity of processed *B. aethiopum* seeds

On the other hand, after 90 days of storage, unprocessed seeds stored in perforated plastic bags and *Jirican* had higher germination, *i.e.*, 70 and 60 %, respectively than processed seeds. In contrast, processed seeds stored in sack had higher germination (30 %) than unprocessed seeds (Fig. 4).
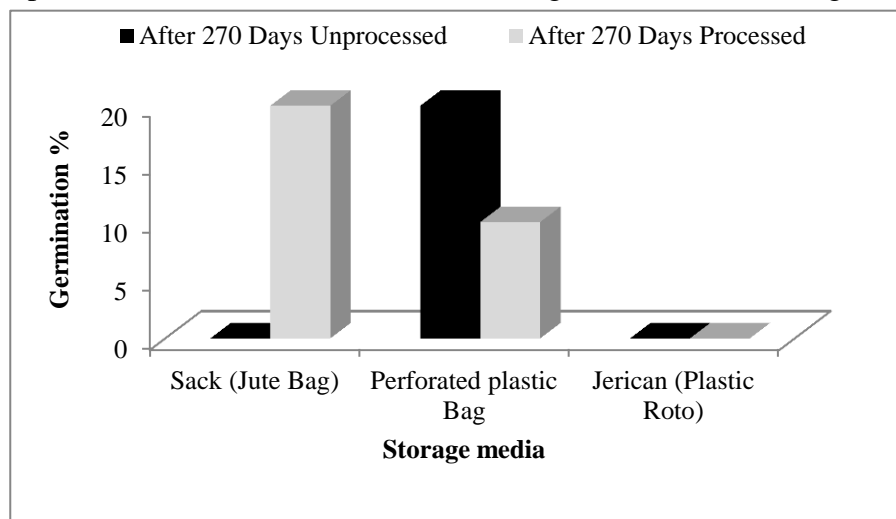
Figure 4: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 90 Days

After 270 days of storage times, both unprocessed seeds stored in perforated plastic bags and processed seeds in sack scored higher germination (20 %). But processed seeds stored in perforated plastic bags had 10 % germination, while unprocessed seeds stored in sacks and *Jerican* as well as processed seeds in *Jerican* all scored no germination (0 %) (Fig. 5).

Figure 5: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 270 Days

After 740 days of storage times, both processed and unprocessed seeds stored in all storage media had no germination. However, seeds stored in *Jerican* and plastic bags were totally developed moisture in the media and started to decompose within 90 days and totally decayed in the 270 days. On the other hand, after 740 days of storage time, only seeds stored in Jute bags, *i.e.*, both processed and unprocessed seeds were remained (Fig. 6). In addition, in processed seeds, their endocarp and mesocarp was break down and peeling away leaving the dead embryo

and endosperm? Overall, unprocessed seeds (70 %) had better germination capacity than processed seeds (30 %).
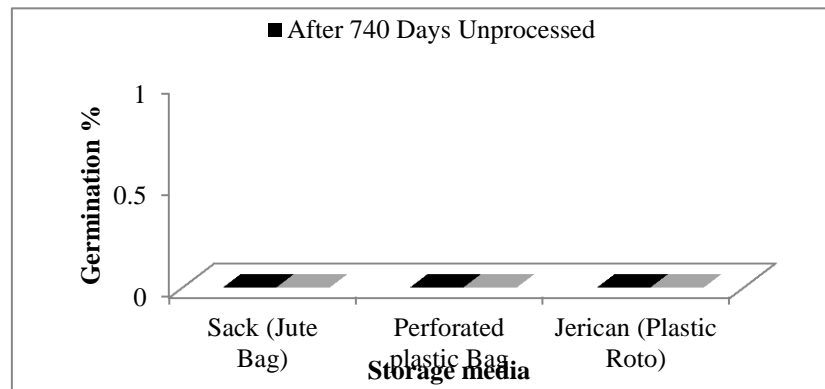

Figure 6: Effects ofseed storage media and fruit processing on germination of *B. aethopium* seeds after 740 Days.

Therefore, it is possible to conclude from this result that processing *B. aethoipum* seeds during storage is not necessary as it causes the loss of viability of seeds. In addition, from the practical aspect storing and sowing unprocessed seeds is more useful to save human power, time and resource. This result was in line with a study conducted by Demelash et al. (2012) for the lowland Bamboo (*Oxytenanthera abyssinica* (A. Rich.) Munro), where the germination of seeds declined with time and varied in different seed storage media.

Conclusion and Recommendations

Borassus aethiopum is an indigenous palm tree in tropical Africa belonging to the family Arecaceae or Palmae. The results on effects of traditional storage media, fruit processing methods and storage time on seed germination revealed that control seeds of *B. aethiopum* showed the best germination of 98 %, while treated seeds had 94 %. Analysis of Generalized Linear Model (GLM) reported that there was a highly statistical significant difference (p <0.001) among storage times on germination of *B. aethopium* seeds. However, no significant difference (p <0.05) was observed among traditional storage media and between fruit processingmethods. Germination of *B. aethoipum* seeds were reduced from 70% after 90 days of storage to 0% after 740 days. Among the storage media, the best germination was recorded in perforated plastic bags (70 %), followed by *Jerican* (60 %). Unprocessed seeds had better overall germination (70 %) than processed seeds (30 %). Therefore, storing unprocessed *B. aethopium* seeds in perforated plastic bags for less than 270 days was better in maintaining the viability of the seeds.

Acknowledegments

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ADAPTABILITY AND GROWTH PERFORMANCE OF DIFFERENT INTRODUCED BAMBOO SPECIES IN ETHIOPIA

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Abstract

Six different bamboo species were introduced in Ethiopia starting from 2008 and tested in different agro-ecologies to evaluate their adaptability and performance. The testing sites were Jimma (Southwestern Ethiopia), Chagni (Northwestern Ethiopia) and Gambo (Central Ethiopia). A simple randomized complete block design was used in the experiment. Parameters like number of culm, culm height, diameter at breast height (DBH), number of shoot sprouts per clump, shoot sprouts height, root collar diameter and biomass was measured. SPSS software was used and subjected for analysis using descriptive statistics.*Dendrocalamous hamiltonii* at Jimma showed best growth performance than others in culm height (10.58 m), diameter of culm and root collar diameter (3.4, 4.3 cm), respectively.*Bambusa vulgaris var. green* had the greatest number of culms/clump, number of shoot sprout per clump and shoot sprout height (66+5, 19+0.6, 87.5+2.4 cm), respectively. Among the four species, *D. hamiltonii* showed the highest total biomass accumulation of 82.16 + 0.94 kg/clump. However, at Chagni *D.asper* showed higher number of total biomass accumulation which was 131.2+3.3 kg/clump (82 ton/ha) followed by *D. hamiltonii* which has103.47+0.52kg/clump (65 t/ha). From the five species planted at Gambo*, D. hamiltonii* showed the highest score in shoot sprout height followed by *D. asper* and *B. vulgaris* (5.4+0.1 cm, 3.47+0.07 cm, 2.49+0.01 cm), respectively. *B. balcoa* had the highest number of shoot sprout (66+1) followed by *G. amplexifolia* and *D. hamiltonii*. At PAwe *D. membranaceus* and *B. vulgaris var. green* had showed greater performance in number of shoot sprouts per clump and *D. asper* had showed higher performance in shoot sprout height and shoot diameter. The number of new sprouts produced showed high fluctuation from dry season to rainy season and their number was lower in dry season in all bamboo species at all sites. Amongthe species, *D. hamiltonii* showed faster growth performance at Jimma and Gambo and *D. membranaceus* the second fastest at Jimma*. D. asper* showed higher performance and *D. hamiltinii* the second fastest at Pawe. The results indicated that *D. hamiltonii, D. asper, D. membranaceus* and *B. balco* were having good potential bamboo species for cultivation in Ethiopia

Keywords: Bamboo, growth performance, species, testing sites.

Introduction

Bamboo is a fast growing and high yielding perennial plant with a considerable potential to the socio-economic development and environmental protection (Baghel *et al.*, 1998; Kumar *et al.*, 1998). It is becoming so increasingly important in the world's forest economy, because (i) it is a superior wood substitute, (ii) it is cheap and efficient, (iii) it is environmentally friendly i.e. it has high potential for environmental protection and wide ecological adaptation (iv) the world forest is shrinking. Globally, one billion people live in bamboo houses; the economy of 2.5 billion people comes from bamboo. According to Maxim (2005), annual trade earns 5-7 billion USD from bamboo (tropical timber earns 8 billion USD).

There are about 1500 bamboo species in the world (Zhaohua, 2004); Africa alone has 43 species (Kigomo, 1993). Ethiopia has narrow genetic diversity in this resource; it has only two indigenous species namely *Yushania alpina* and *Oxytenantera abyssinica* (Kassahun, 2000). These two species are restricted to limited agro ecologel regions; many agro ecological sites are not suitable for the available two species. With these limited species; it is very difficult to sustainably supply bamboo raw material and products. Besides, due to mysterious death of bamboo rhizomes after flowering and seed setting, some areas that were covered with bamboo are currently devoid of the species.

Among the various measures that should be taken in averting these problems, widening the genetic base of the resource is indispensable. These will require introduction and evaluation of potential species from different parts of the world to establish bamboo plantations in areas where indigenous species could not grow. So that the overall aim of this study is to evaluate adaptability and growth performance of different introduced bamboo species in different agro-ecologies of the country.

Material and Methods

Study site

These researches were conducted in three different agro ecologies of Ethiopia namely Gambo (Central Ethiopia), Jimma (Southwestern Ethiopia) and Pawe (North western Ethiopia). The altitude range of Gambo was between 1610-1680 meter above sea level and annual rainfall was between 500-835 mm. Jimma were found at 1753 meters above sea level and have maximum of 26.2^0C and minimum of $11.3\ ^0$C temperature and received 1529.5 mm average rainfall per annual.

Treatments

The five potential introduced bamboo species namely *Bambusa vulgaris*var. green, *Guadua amplexifolia, Dendrocalamus hamiltonii, Dendrocalamus membranaceus*, *Dendrocalamus asper, Bambusa balcoa* were raised at Debre Zeit Agricultural Research Center, Central Ethiopia Environment and Forest Research Center and Holetta Agricultural Research Center, tree nursery site for the purpose of planting. Then, seedlings were out planted at Jimma Agricultural Research Center, Pawe Agricultural Research Centre and Arsi Negele filed planting sites to evaluate their adaptability and performance of the species. For reason of lack of planting material treatments were different at each site of seedlings planted. At Jimma species *B. vulgaris*var. green, *G.*

amplexifolia, D. hamiltonii and *D. membranaceus* were planted, at Pawe *B. vulgaris*var. green*, G. amplexifolia, D. hamiltonii, D. membranaceus*, *D. asper and B. balcoa* were planted, and at Gambo *B. vulgaris*var. green*, G. amplexifolia, D. hamiltonii, D. asper and B. balcoa* were planted.

A simple randomized complete block design was used in the experiment. There were four replicates in the trial plot. Each replicate consisted of alternate single line of each four commercial species mentioned earlier assigned with 16 holes per line with a spacing of 4*4 m at Jimma. At Pawe there were three replicates in the trial plot where each replicate consisted of alternate single line of each six species which were mentioned earlier assigned with 16 plants per plot with a spacing of 2*2 m and at Gambo there were three replicates in the trial plot where each replicate consisted of alternate single line of each five species which were mentioned earlier assigned 16 plants per plot with a spacing of 2*3 m.

Data collection

The parameters measured were number of culm, culm height, diameter at breast height (DBH), number of shoot sprouts per clump, shoot sprouts height, root collar diameter, biomass and adaptability of species.

Data analysis

Growth study

The diameter was measured at breast height by using digital caliper and the height was taken from the tip of the culm by using a 20 m graduated pole. For all the data's recorded measurement were taken on average. The data on the performance of bamboo was summarized using SPSS software and subjected for analysis using descriptive statistics.

Biomass estimation

In order to estimate the total biomass, four plots/clumps were selected randomly from each block. For reasons of economy, time and labour, the rhizome was excavated only from one clump/plot for all species. After felling, the clumps were subdivided into leaves, branches, stems and rhizome and grouped into three age classes: < 1 year, 1-2 years, and > 2 years. Fresh weight of the components was estimated in the field and sub samples from each component were brought to the laboratory in plastic bags.

The culm was divided into three parts: bottom, middle, and top. Sub samples were taken from the four plots randomly: 200 g of culm from the second internodes of the bottom, middle and top parts. Hundred g of branch and 100 g of leaf were taken in each of the age class from the field immediately after felling and dried in an electric oven at 85℃ until constant weight was reached. With these data, the ratio of dry weight to fresh weight was obtained for each sample; this ratio was used to obtain the values of dry matter (DM) for each component of the species.

From the oven-dry weight of the samples, the total grand total biomass of each clump group was calculated by multiplying the average number of the bamboos of each clump with the average

dry weight of the sample, following (Shanmughavel et al., 1995). Total above ground dry weight of the culm and clump was obtained from the sum of the dry weight of the components, that is dry weight of stem + dry weight of branch + dry weight of leaf. Overall biomass of the species was obtained from the sum of the dry weight of all the components.

Results and Discussion

Growth studies

Number of culms per clump

The number of culms produced from 4 years old clumps for each species at Jimma was counted and are presented in Table 1. Maximum number of culms per clump was observed under *B.vulgaris* variety green *(66±5)* followed by *D. membranaceus* (42±3) and *D. hamiltonii* (26±2), whereas *G. amplexifolia* showed lower number of culms per clump (7±1) at Jimma. The growth of new culms that develop from a clump varies by species, soil, climate conditions and size of clump-culm relationship (Anonymous, 1960). The season plays a very important role in rooting and sprouting of shoots in many bamboos. Our study also showed that there was a difference in species performance for growth development.

Culm height

Significantly higher culm height (m) was observed under *D. hamiltonii (*10.58±0.47) followed by *D. membranaceus* (7.208±0.304) and *B. Vulgaris variety* green (6.77±0.264), where as lowest culm height was observed under *G. Amplexifolia* (3.167±0.20). *D. hamiltonii* measured higher value on average height (10.58±0.47 m) as compared to the finding of Bharat Rai and Bijay Kumar Mallik (2013) of 8±4 m (Table 1).

Table 1: Biomass allocations of introduced bamboo species in clump base at Jimma**.**

Age (years)	Species name	Biomass (Kg/Clump)			Total above ground biomass (Kg)/clump	Rhizome (Kg)/clump	Total grand biomass (Kg)/clump
		Stem /kg/clump	Branch/kg/clump	Leaf /kg/clump			
4	*Dendrocalamus hamiltonii*	41.34±0.6	13.78±0.26	16.64±0.26	71.76±1.12	10.40±0.88	82.16±0.94
	Bambusa vulgaris variety green	36.3±1.2	15.84±0.35	18.48±0.8	70.62±2.10	6.6±0.75	77.22±2.15
	Dendrocalamus membranaceus	31.50±1.32	15.54±0.3	29.74±0.48	66.78±1.95	8.4±0.06	75.18±1.95
	Guadua amplexifolia	2.24±0.14	2.24±0.15	2.03±0.16	6.51±0.38	5.39± 0.67	11.90±0.45

Diameter at breast height

Significantly higher culm diameter (DBH in cm) was observed under *D. hamiltonii*(3.44+0.21) followed by *G. amplexifolia (*2.83+0.19) and *D. membranaceus (*2.716+0.15)*,*where as *B. Vulgaris* variety green showed lower culm diameter *(*1.9+0.92). Our results showed lower performance in DBH at breast height, compared to the findingofBharat Rai and Bijay Kumar Mallik (2013) on a six year old *Melocanna baccifera* plantation with value of 7 cm on average (Table 1).

Shoot root collar diameter

Significantly higher shoot root diameter *(SRCD)* was observed under *D. hamiltonii (*4.3+0.28 cm) followed by *D. Membranaceus* (3.56+0.1 cm) and *G.amplexifolia (*3.35+0.17 cm),where as*B. vulgaris*variety green showed lower culm diameter (2.43+0.93 cm) at Jimma.However*,* at Chagni *D. asper* had showed higher performance in shoot diameter (30.5+2.6 cm) followed by *D. hamiltonii* (23.63+2.6 cm) (Table 1and 2).

Table 2: Characteristics of introduced bamboo species at Gambo.

Age	Species	Average number of shoot sprout /clump	Average shoot sprout Height (cm)/clump
	Dendrocalamus hamiltonii	**31+ 1**	**540+ 0.1**
	Bambusa vulgaris	**25 +1**	**249 +0.01**
4	*Guadua amplexifolia*	**34 +1**	**76.7+ 0.01**
	Dendrocalamus asper	**25+ 1**	**347.0+0.07**
	Bambusa balco	**66 +1**	**218 +0.02**

Shoot sprout height and number of shoot sprout per clump

From the five species planted at Gambo, *D. hamiltonii* showed the highest score in shoot sprout height (cm) per clump followed by *D. asper* and *B. vulgaris var. greeen* (5.4+0.1 cm, 3.47+0.07 cm, 2.49+0.01 cm), respectively. However, seedlings of *B. balcoa* and *G. amplexifolia* performed least in the site in terms of number of shoot sprouts height. While in number of shoot sprouts per clump *B. balcoa* had showed higher number followed by *G. amplexifolia and D. hamiltonii* (66+1, 34+1, 13+1), respectively. But *D. asper* and *B. vulgaris* var. green had shown lower performance in terms of number of new sprout produced per clump. At Chagni *D. membranaceus* and *B. vulgaris* var. green had shown greater performance in number o shoot sprout per clump (21+2 and 22+2), respectively followed by *D. hamiltonii* (13+2). However, *B. balco* had shown lower number of shoot sprout per clum (2+2). *D. asper* had showed higher performance in shoot sprout height and shoot diameter (406.32+28 cm, 30.5+2.6 cm), respectively followed by *D. hamiltonii* (332.33+28 cm, 23.63+2.6 cm), respectively. At Jimma *B. vulgaris* var. green had showed higher performance in terms of number of shoot sprout per clump and average shoot sprout height (19+1, 87.5+2.4 cm), respectively followed by *D. membranaceus* (13+1, 86.76+2.5 cm), while *G. amplexifolia* showed lower performances in terms of number of shoot sprout per clump and average number of shoot sprout height (6+1, 22.19+4.3 cm), respectively (Table 1, 2 and 3).

Table 3: Characteristics of introduced bamboo species at Chagni.

Age	Species	Average number of shoot /clump	Average shoot sprout Height (cm)/clump	Average number of shoot root collar diameter (cm)
4	*Dendrocalamus hamiltonii*	13± 2	332.33± 28	23.68± 2.6
	Bambusa vulgaris	22± 2	295.35± 28	14.39± 2.6
	Dendrocalamus membranaceus	21± 2	254.80± 28	17.95± 2.6
	Guadua amplexifolia	11± 2	184.54± 28	19.55±2.6
	Dendrocalamus asper	10±2	406.31± 28	30.5 ±2.6
	Bambusa balco	2+2	121.49±28	13.39± 2.6

The number of new sprouts produced showed high fluctuation from dry season to rainy season and their number was lower in dry season in all bamboo species at all sites. Early rains plus the irrigation treatments probably provided substantial moisture to the soil, which initiated early shoot emergence. Our findings were in line with Fernandez etal. (2003) that bamboo shoots usually emerge during the onset of the rainy season and very few shoots arise during the dry season when soil moisture is at its lowest. The availability of soil moisture and the decrease in temperature during rainy months influenced the emergence of shoots. In general, shoot emergence and its duration were affected by monthly rainfall (Virtucio and Roxas, 2003). Shoot emergence started in early June, peaked in late July, tapered off in August and ended in late September or early October, depending on precipitation (Bamboo information network, 2011). Indeed, precipitation influenced shoot production as practically no shoots emerged during drier months. It generally took 2 months for shoots to grow to full height although for some culms it took only 1 month. Based on observation, precipitation also enhanced the rate of culm elongation. Our results indicated that shoots elongated fastest 3–5 weeks after shoot emergence and the quickest rate was 37 cm/day (Figure 1, 2, and 3).
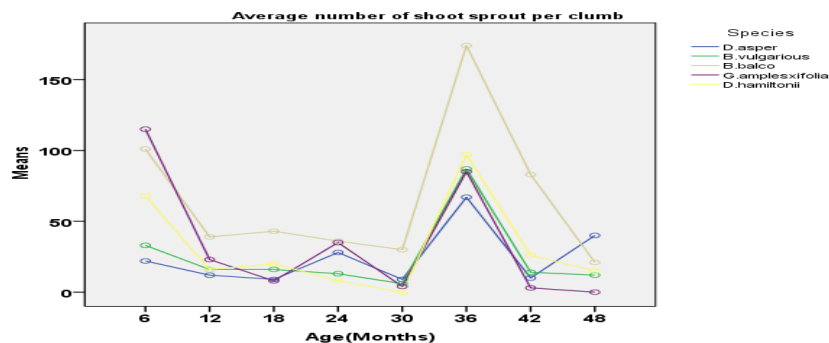

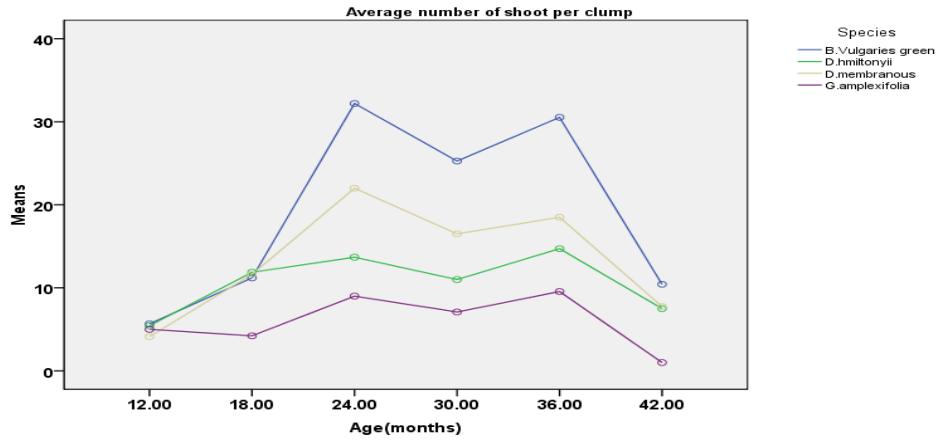**Figure 1A**: Average number of shoot sprout per clump at Gambo

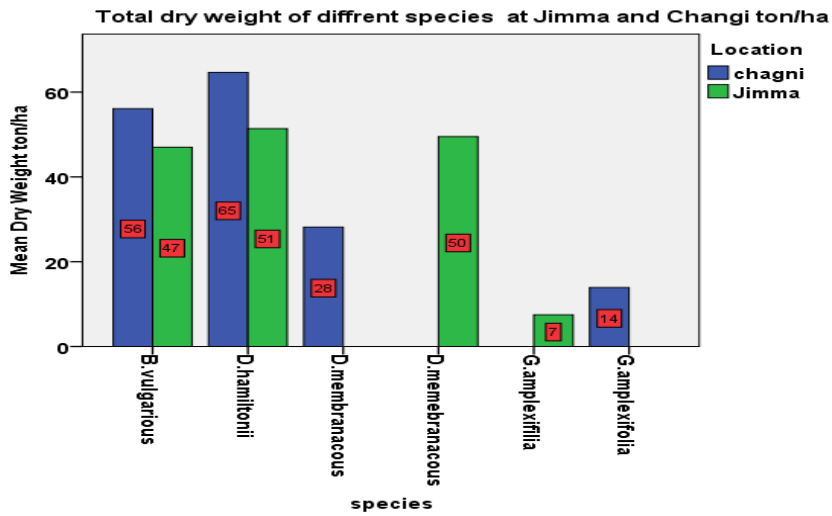**Figure 2:** Average number of shoot sprout per clump base at Chagni

Figure 3: Average number of shoot sprout per clump at Jimma

Biomass study

Biomass production in clump basis

It is seen in Table 4 that at Jimma the total biomass accumulation of *D. hamiltonii, B.vulgaris, D. Membranaceus*and *G.amplexifolia* per clump were 82.16±0.94, 77.22±2.15, 75.18±1.95 and 11.90±0.45 kg, respectively. For stem/culm, branch, leaf and rhizome the average dry weight per clump for *D. hamiltonii* was 41.34±0.6, 13.78±0.26, 16.64±0.26, and 10.40±0.88 kg, respectively. *B. vulgaris, D. membranaceus and G. amplexifolia* had 36.3±1.2, 31.50±1.32, 2.24±0.14 kg; 15.84±0.35, 15.54±0.3, 2.24±0.15 kg; 18.48±0.8, 29.74±0.48, 2.03±0.16 kg; 6.6±0.75, 8.4±0.06, 5.39± 0.67 kg of culms, branches, leaves and rhizomes, respectively. At Chagni the total biomass accumulation of *D. asper, D. membranaceus, G. amplexifolia, B. vulgaris, B. balco* and *D. hamiltonii* were131.2±3.3, 45.07±2.16, 22.27±1.6, 89.73±0.4, 8.27±0.4, 103.47±0.52 kg, respectively. For stem, branch, leaf and rhizome the average dry weight per clump for *D. asper* was42±1.5, 10.8±0.5, 10.27±0.2, 68.14 ±1.1 kg, respectively (Table 4 and 6).

Table 4: Comparison of different bamboo species at Jimma and Chagni

Ag	Species	*Dendrocalamus hamiltonii*	*Bambusa vulgaris*	*Dendrocalamus membranaceus*	*Guadua amplexifolia*
4	Average number of Culm /clump	26±2	66±5	42±3	7±1
	Average Height (m)/clump	10.58±0.47	6.77±0.264	7.208±0.304	3.167±0.20
	Average DBH(Cm)/clump	3.44±0.213	1.9±0.92	2.716±0.145	2.83±0.189
	Average number of shoot /clump	11±1	19±1	13±1	6±1
	Average shoot sprout Height (cm)/clump	75.5±2.4	87.5±2.4	86.76±2.5	22.19±4.3

Percentage contribution of biomass components

With regard to contribution of different plant components to total shoot weight (total above ground biomass) the culm contributes maximum in the entire clumps at Jimma (50.32, 47.02, 35.14, and 18.82) % for *D. hamiltonii, B. vulgaris, D. membranaceus and G. amplexifolia* but at Changi the rhizome contribution is higher as compared to other components for the species *D. asper, D. hamiltonii and G.amplexifolia* 51.92, 34.40 and 54.40 %, respectively.   The contributions of branch, leaf and rhizome biomass were shown Table 5 and 7.

Table 5: Percentage contribution of each component for individual species at Jimma.

Species name	Culm biomass %	Branch biomass %	Leaf biomass%	Rhizome biomass %
Dendrocalamus hamiltonii	50.32	16.77	20.25	12.66
Bambusa vulgaris	47.02	20.51	23.93	8.54
Dendrocalamus membranaceus	35.14	22.14	27.68	15.02
Guadua amplexifolia	18.82	18.82	17.06	45.30

Table 6: Biomass allocation of introduced bamboo species in clump base at Chagni.

Species name	Biomass Kg/clump Culm kg/clump	Branch kg/clump	Leaf kg/clump	Total above ground biomass kg/clump	Rhizome kg/clump	Total dry weight kg/clump
D. membranacous	17.87±1.1	5.73±0.2	7.33±0.26	30.93±1.56	14.14 ± 0.6	45.07±2.16
G. amplexifolia	4.67± 1.1	3.07 ±0.1	2.4±0.2	10.13 ±1.4	12.14 ±0.2	22.27±1.6
D. asper	42±1.5	10.8±0.5	10.27±0.2	63.07 ±2.2	68.14±1.1	131.2±3.3
B.Vulgarious green	39.47±0.1	11.2±0.1	9.73 ±0.1	60.4±0.3	29.33±0.1	89.73±0.4
B. balco	3.73±0.1	1.2±0.1	0.9±0.1	4.93±0.1	3.33±0.1	8.27±0.4
D. hamiltonii	31.6±0.12	18.67±0.1	17.6±0.2	67.87 ±0.42	35.6±0.1	103.47± 0.52

Table 7: Percentage contribution of each component for individual species at Chagni.

Species name	Culm biomass %	Branch biomass %	Leaf biomass%	Rhizome biomass %

D.membranacous	39.70	12.70	16.25	31.35
G.amplexifolia	21.01	13.82	10.77	54.40
D.asper	32.01	8.24	7.84	51.92
B.Vulgarious green	44	12.48	10.83	32.62
B.balco	44.15	13.56	3	39.29
D.hamiltonii	30.54	18.05	17.01	34.40

The grand total biomass of the species was calculated on the basis of the average number of culms/clump multiplied by the average total biomass of sample culm. Accordingly the grand total biomass for the species *D. hamiltonii, B. vulgaris, D. membranaceus* and *G. amplexifolia* measured (82.16±0.94, 77.22±2.15, 75.18±1.95, 11.90±0.45 kg in clump base, respectively) at Jimma, and at Chagni *D. asper, D. membranaceus, G. amplexifolia, B. vulgaris, B. balco* and *D. hamiltonii* had131.2±3.3, 45.07±2.16, 22.27±1.6, 89.73±0.4, 8.27±0.4, and 103.47±0.52 kg, respectively.

Among the four species *D. hamiltonii* showed higher number of total biomass accumulation which was 82.16±0.94 kg/clump to which culm, branch, leaf and rhizome parts contributed about 50.32 %, 16.77 %, 20.25 %, 12.66 %, respectively. *G. amplexifolia* had the lowest total biomass accumulation on each components (11.90±0.45 kg/clump) to which culm, branch, leaf and rhizome parts contributed about 18.82 %, 18.82 %, 17.06 %, 45.30 % respectively. While at Chagni *D.asper* showed higher number of total biomass accumulation which was 131.2±3.3 kg/clump (82 t/ha) to which culm, branch, leaf and rhizome parts contributed about 32.01 %, 8.23 %, 7.835 and 51.92 %, respectively followed by *D. hamiltonii* which had103.47±0.52kg/clump (65 t/ha) whereas, *B.balco* had the lowest total biomass accumulation on each components (8.27±0.4 kg/clump 5.17 t/ha) to which culm, branch, leaf and rhizome parts contributed about 44.15, 13.56, 3, 39.29) %, respectively.

For all species except *Guadua amplexifolia* the biomass accumulation of culm contribution was highest and leaf biomass contribution the second highest at Jimma. For the species *G. amplexifolia*, rhizome biomass covers the higher percentage contribution for the total biomass accumulation (45.30 %). *Dendrocalamus D. membranaceus* showed higher biomass accumulation on leaf biomass component (27.68 %) compared to the other species biomass contributions. While at Chagni rhizome contribution were the highest for the species *D.asper, D. hamiltonii* and *G.amplexifolia* and culm contribution were found to be higher for the species *D. membranaceus, B. balco* and*B. Vulgaris* (Table 4, 5, 6 and 7). At Chagni *D. hamiltonii* and *B. vulgaris* showed higher total dry weight per clump. However, *D. membranaceus* showed better performance in total dry weight per clump base at Jimma (Figure 4).

The grand total dry matter production of the species *D. hamiltonii, B. vulgaris, D. membranaceus*and *G. amplexifolia* measured 82.16±0.94, 77.22±2.15, 75.18±1.95, 11.90±0.45 kg in clump base, respectively at Jimma. At Chagni *D. asper, D. membranaceus, G. amplexifolia, B. vulgaris, B. balco* and *D. hamiltonii measured* 131.2±3.3, 45.07±2.16, 22.27±1.6, 89.73±0.4, 8.27±0.4 and 103.47±0.52 kg in clump base, respectively at the age of 4.

Compared to other studies of biomass production, where the annual yield of air dry bamboo/ha for 3-4 years old plantation was found to be 6-7 t for *.vulgaris* (Chinte *et al.*, 1965), 1 t for *Gigantochloa asper* (Chinte et al., 1965), 1954 to 2354 kg DM for *D. hamiltonii* clump at the age of 13 (Shanmughavel et al., 2003), for six year old *Melocanna baccifera* plantation 1.95 ton to 3.63 ton (Bharat Rai et al., 2013) and *Gigantochloa scortechinii* from Malaysia 71.9 t/ ha in natural stand and 36.67 t/ha in a 3 years old plantations (Othman, 1992) our results were higher, but they were lower than *Bambusa bambos* with 297 ton (Shanmughave et al., 1995).

Total biomass estimates of *D. hamiltonii, B. vulgaris* and *D. membranaceus*measured 51.4 t/ha, 48.5 t/ha, 46.8 t/ha at Jimma and *D.asper, D.hamiltonii,* and *B.vulgaris* measured82 t/ha, 65 t/ha and 56 t/ha*,* respectively at Chagni at their earlier stage, was also comparable to above ground biomass of mature stands of indigenous species *Y. alpina* 51-99 t/ha (LUSO, 1997), 110 t/ha (Kassahun Embaye, 2003), 99 t/ha (Yigardu Mulatu and Masresha Fetene, 2012) and *O.abyssinica 20* t/ha (LUSO, 1997).Adaptability for all species was found to be 100% until now; pest and disease assessment does not show any problem so far.

Conclusion and recommendations

Generally among the species *D. hamiltonii* showed faster growth performance at Jimma and Gamboo and *D. membranaceus* was the second fastest at Jimma and *B.balco* was the second fastest at Gambo. *D. asper* showed higher performance and *D. hamiltinii* the second fastest at Chagni. The results indicated that *D.hamiltonii, D. asper, D. membranaceus* and *B. balco* were good potential bamboo species for cultivation in Ethiopia. Field evaluations made with farmers and development agents (Das) and experts also showed that *B. vulgaris var.* green is a recommendable species for scaling-up. The species could be scaled-up for various end uses such as human food (*D. hamiltonii*) and animals feed, for industrial purposes, for carbon sequestration (because of their high biomass), for soil and water conservation and recreation in Ethiopia. Strengthen research on utilization of these species should be recommended for future work. It should also be very vital to study the relative growth rate of different bamboo species at different seasons and see the performance of this species again over location and over season.

Acknowledgments

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ENVIRONMENTAL POLLUTION CONTROL MANAGEMENT

VERMICOMPOSTING OF TANNERY SLUDGE WASTE FOR SOIL CONDITIONING AND POLLUTION CONTROL

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Abstract

Tannery sludge and the effluents in general are of large-scale environmental concern because they change the color and diminish the quality of soil and water bodies into which they are released. Their disposal into the environment creates adverse effects by altering the normal physiochemical properties of soil and water. This study was conducted to investigate the potential conversion of tannery sludge waste into compost for soil conditioning purposes through vermicomposting using an earthworm *Eisenia fetida*. The experimentwas conducted in circular plastic containers after collection and culturing of earthworms. The containers were filled with different proportion of tannery sludge, cow dung and horse manure at different ratio. The composting period was 45 days during which chemical propertiesof the vermicompost were analyzed in 15 days interval. The study revealed that pH; electrical conductivity, total nitrogen (%), available phosphorus (%) and total potassium (%) were increased towards the end of composting while organic carbon (%) and chromium (ppm) levels were decreased. Up on maturation of the compost, a test plant was used. This study concludes that vermicomposting makes the environment safer and provides with compost that can help improving soil fertility at a lower cost. So, It is recommendable that vermicomposting of tannery sludge is viable and advisable for afield work.

Key word: Addis Ababa Tannery, Vermicomposting, vermicast, tannery sludge, *Eisenia fetida,* soil conditioning.

Introduction

Ethiopia and many other countries are suffering from the entire problems of solid waste due to urbanization, industrialization and population density, deteriorating quality of urban environment is one of its important impacts. Solid waste is complex in character and its volume is greatly increased due to increase of living standards and population density which is a very rapid process and a worldwide phenomenon.Solid waste is the term now used internationally to describe non-liquid waste material arising from domestic, commercial, hospital, industrial, agricultural and mining activities (Gapikrisha, 2002).

Disposal of solid waste should be properly managed. If there are no plans to use the waste it should be vermicomposting or fed to animals well away from the processing site. One of the main problems in using the tannery sludge waste is to ensure that the waste has a reasonable micro biological quality. And yet their casts contain eight times as many microorganisms as their feed. And the casts do not contain any disease and pathogens.In the modern age of development the increasing quantity of solid waste is one of the growing environmental problem in both developed and developing countries (Annapurna et al., 1997).

Vermicomposting

In the modern age of development the increasing quantity of solid waste is one of the growing Environmental problems for both developed and developing countries. Due to rapid growth in industrialization the most of the rural population are migrated toward the urban area in the search of employment (UNDP, 2008). Sludge wastes from tanneries are generated in the effluent treatment process. These sludge wastes from tanneries contain the highest chromium content and currently being dumped in the open areas, thus creating the solid waste disposal problem in tanneries. Vermicomposting is the conversion of biodegradable wastes into a high quality chemical free bio-fertilizer with the aid of Earthworms. Earthworms have a key role in soil biology by serving as versatile natural bioreactors to harness and destroy soil pathogens, thus converting organic wastes into valuable bio-fertilizers, enzymes, growth hormones and proteinaceous worm biomass (Sekaran, 2012). The worms do it by feeding voraciously on all biodegradable refuse such as leaves, paper (non-aromatic), kitchen waste, tannery sludge, vegetable refuse. It then burrows deep into the soil, positioning its castings in to the soil thereby enriching the soil with pre-digested, easy to assimilate bio-fertilizer that is now rich with NPK (Sekaran, 2012).

So when looking for a fertilizer for a farm or garden it would do well if people would consider the revolutionary vermicompost as an option. Certain types of earthworms ingest, digest, and excrete vermicompost with excellent nutrient content. Ingestion ensures the sorting out of only organic matter while the digestion accelerates the maturing process. Excretion ensures the grading of the vermicompost as opposed to any inorganic matter, which may exist in the waste and not concerned with the biological activity in the earthworm gut (Beena et al., 2013). However, applying raw organic materials directly to the soil is not the best way to use organic matter and its nutrients. The C/N ratio is narrowed down substantially and nitrogen retention is more in compost prepared with earthworms than without earthworms. Millions of tons of solid wastes like tannery solid waste and domestic wastes are buried or burned annually. Instead of this, if solid waste is being recycled with the help of earthworms, it would not only solve the pollution problem but generate quality manure for agriculture use (Hemalatha, 2012).

Vermicomposting technology

Vermicomposting is a waste management technology utilizing earthworms to convert organic wastes into high quality castings and vermicomposts of high economic values and the method of employing earthworms in reducing the organic matter present in the waste is called as the vermicomposting. Vermicomposting, also known as worm composting, is simply the way red worms transform decaying organic matter into worm castings. It is also the process involved in the degradation of organic waste into useful components by using earthworms. It is all - together

a natural system in which the earthworms play their major roles in degrading the organic portion of the waste. The use of earthworm in solid waste management is called vermicomposting or vermistablization (Dede et al., 2006; Garg et al., 2008)

Vermiculture (breeding of selected earthworm spices)

Vermiculture is breeding of earthworms to continually increase the number of worms in order to obtain a sustainable harvest. Different quantities of earthworms have been inoculated in culturing material and the earthworm response in terms of growth and reproduction rate has been monitored (Dede et al., 2006). Additionally, parameters such as temperature, feed type, earthworm stock density and feedstock loading rate have been studied to see their influence on earthworm activity the earthworms produced can also be further used in vermin-filtration these earthworms from vermicomposting can also be used in vermi-remediation, which involves the removal of heavy metals in soils (Garg and Yadav, 2001).

Types of earthworm spices

Epigeic Species Suitable for Vermicomposting are*Eisenia foetida, Eudrilus eugeniae*and *Perionyx excavatus* are appropriate for vermicomposting. The desirable attributes of appropriate vermicomposting species are listed below.

Eisenia foetida

Breeding of *Esenia foetida* or more commonly known as the Red wormsthe initial breeding of these worms are done in an open bucket without shade. There is no special change in the bedding material other than a thin layer of horse manure, which was obtained initially along with the worms. It is seen that these worms grow very fast and have much higher reproductive rate as compared with the local worms (Garg and Yadav, 2001).The species has also been in wideusages for various toxicological studies as test worm. Mature individuals can attain up to1500 mg body weight. Each mature worm on an average produces one cocoon every thirdday and from each cocoon on hatching within 23 days emerge from 1 to 3 individuals (Garg and Yadav, 2001; Dede et al., 2006).

Eudrilus eugeniae

This species, popularly known as Night Crawler, can be said to be the second most widely used earthworm for vermicomposting. It grows faster than other species accumulating mass at the rate of 12 mg/day. Mature individuals can attain body weight up to 4.3 g/individual. Maturity is attained over a period of 40 days, and, a week later, individuals commence cocoon laying (on average 1 cocoon/day). Life span in laboratoryis estimated to range from 1 to 3 years. But thisspecies can be used as vermicomposting worm in tropical and sub-tropical regions (Dede et al., 2006).

Perionyx excavatus

*Perionyx excavates*are highly adaptable and can tolerate a wide range of moisture and quality of organic matter. Average growth rate of *Perionyx excavatus* is 3.5 mg/day and body weight (maximum) of 600 mg. Maturity is attained within 21-22 days and reproduction commences by

24thday, with 1 to 3 hatchings per cocoon. Scientists opine that this species is amongst the best suited for vermicomposting in tropical climates (Dede et al., 2006).

Physico-chemical changes in wastes during vermicomposting

Various studies have been conducted in yesteryears to study biochemical changes in the organic matter during vermicomposting process. The most commonly studied parameters in these studies included pH, organic carbon, NPK, enzymes, heavy metals etc. but the most necessary and regulated parameters are listed below (Singh et al., 2013).

- pH
- Nitrogen content
- Organic carbon
- Phosphorus content
- Potassium content
- C: N ratio

Vermicomposting process

It is an aerobic, bio-oxidation, non-thermophilic process of organic waste decomposition that depends upon earthworms to fragment, mix and promote microbial activity. The basic requirements during the process of vermicomposting are (Dede et al., 2006).

- Bedding
- Food Source
- Moisture
- pH
- Temperature

Benefits of vermicomposting ttechnology

There are several advantages of vermicomposting such as a safe treatment option for high nutrient waste and the production of natural fertilizer as an end product. Aerobic conditions in vermicomposting is controlled and managed by earthworms, whereas man power, electrical energy and expensive engineering system are required for aerobic composting the benefits of vermicomposting technology can be seen in different aspects but in generally categorized in economic, health, and environmental perspectives (Satvat and Yadov, 2004; Singh et al., 2013).

Economic

By returning nutrients back into the soil, vermicompost reduces the need for expensive chemical fertilizers.Vermicomposting conserves water as penetration and retention are improved; erosion and runoff are reduced. Expensive landfill sites can be used for longer periods. The amount of waste you send to the landfill will be reduced by about 1/3.The cost of garbage collection services paid by municipal taxes could decrease as disposal and processing costs are reducing (Satvat and Yodav, 2004; Anoop, 2011).

Health aspects

Reducing waste causing disease like smoke borne diseases: headache, eye-irritation, respiratory tract infections etc are decreased because of improved and cleaned environment easier, clean cooking and better hygiene protect from heavy metal accumulation (Rapp, 2004)

Environmental (ecological) benefits

Vermicomposting helps break down heavy clay soils allowing better root penetration and improving drainage.Vermicomposting improves moisture retention in sandy soils so water loss and leaching are reduced or eliminated (Anoop,2011).There is no toxic or harmful residual in vermicomposting.Vermicomposting reduces harmful greenhouse gas emissions.Compost stimulates plant root development (Tamilnadu,2010). Overall root environment is improved due to better structure, porosity, and density of the soil.Vermicomposting adds, stimulates, and diversifies microbial biomass. This helps control or suppresses soil-borne plant pathogens (Anoop, 2011).This study was conducted to investigate the potential conversion of tannery sludge waste into compost for soil conditioning purposes through vermicomposting using an earthworm *Eisenia fetida*.

Material and Methods

Eisenia foetida

Healthy Earthworms are collected from Ethiopia agricultural research Ambo Plant Protection Research center maintained in the laboratory with horse manure as culturing material for more than two months. In the present studies the well known species of earthworm used was *Eisenia foetida*.

Solid tannery sludge (STS)

Fresh STS was obtained from the wastewater treatment plant of a tannery industry located near"kolfe keraniyo sub-city asko adis sefer" Addis Ababa, Ethiopia. The main characteristics of STS were: total solids: pH (1: 10 ratio): 8.23, TOC: 11.14 %, TKN: 2.271 % and C: N ratio: 5.91, the sludge was dried in shade prior to use for vermicomposting.

Table 1: Composition of tannery sludge with cow dung and horse manure

s/n	Initial earthworm density(0.9g/individual)	Tannery sludge(g)	Caw dung(g)	Horse manure(g)
1	80	500	500	0
2	100	600	400	0
3	120	700	300	0
4	80	500	0	500
5	100	600	0	400
6	120	700	0	300

Experimental design

Vermicomposting of tannery sludge was conducted in darkness, at an average temperature of 18 $\pm$ 5°C, and a substrate moisture content of (65-85 %). Three -Litter test circular plastics were

filled with horse manure and caw dunginto each reactor, 80,100,120 individuals were introduced. Three treatmentswith three levels were established: (1) tannery sludge + horse manure (1:1, 3:2, 7:3 dry weight), (2) tannery sludge + caw dung (1:1, 3:2, 7:3 dry weights) earthworm proportion for each sample compositions.

Experimental procedures

Experiments were performed in worm-bins measuring 0.21 m, 0.11 m, 0.13 m (length' width´ depth). This provided 0.003m^3 of exposed top surface. Known weights of earthworms (*Eisenia foetida*), were introduced into each of the similar worm-bins, to provide the desired stocking densities. Earthworm live-biomass loadings were 80, 100, and 120 individuals, respectively.

Table 2: The initial characteristics of tannery sludge, cow dung and horse manure

S/N	Clintes' code	pH (1:10)	EC (dS/m)	OC (%)	TN (%)
1	Cow dung	7.79	2.61	10.21	1.291
2	Horse Manure	7.90	5.43	28.59	1.879
3	Tannery Sludge	8.23	10.29	11.14	2.271

Statistical analysis

Data was analyzed using Microsoft excel and correlation analysis. Considering the treatments as in dependent variables, a significance level of $p < 0.05$ was considered throughout the study (Manuel - Santan, 1982).

Results and Discussion

In this study, tannery sludgewastes were mixed with different proportion cow dung and horse manure. Best results and lowest C: N ration obtained along the end of vermicomposting days (Visvanthan, 2002). If sufficient aeration and well composting conditions provided during preparation by material amendment, aeration or by any means anaerobic condition was not occured in longer preparation duration (Garg and Gupta, 2001). The initial physico-chemical analysis of tannery sludge, horse manure and cow dung was done in Wonjji Sugar Factory Laboratory.

Characterization of compositions

Before vermicomposting the composition had electrical conductivity (EC) from 6.45 dSm^{-1} to 8.832 dSm^{-1}, Total N content of 1.781g kg^{-1}2.1534 g kg^{-1}and total organic carbon from 10.675 % to 16.375 % and pH of the compositionwasfrom 8.01 to 8.131 were characterized. This result shows the maturity of the composition not reached to the standards of fertilizer. It has a low C/N

ratio but finally the expected results should be in a standard form because of vermicomposting process.
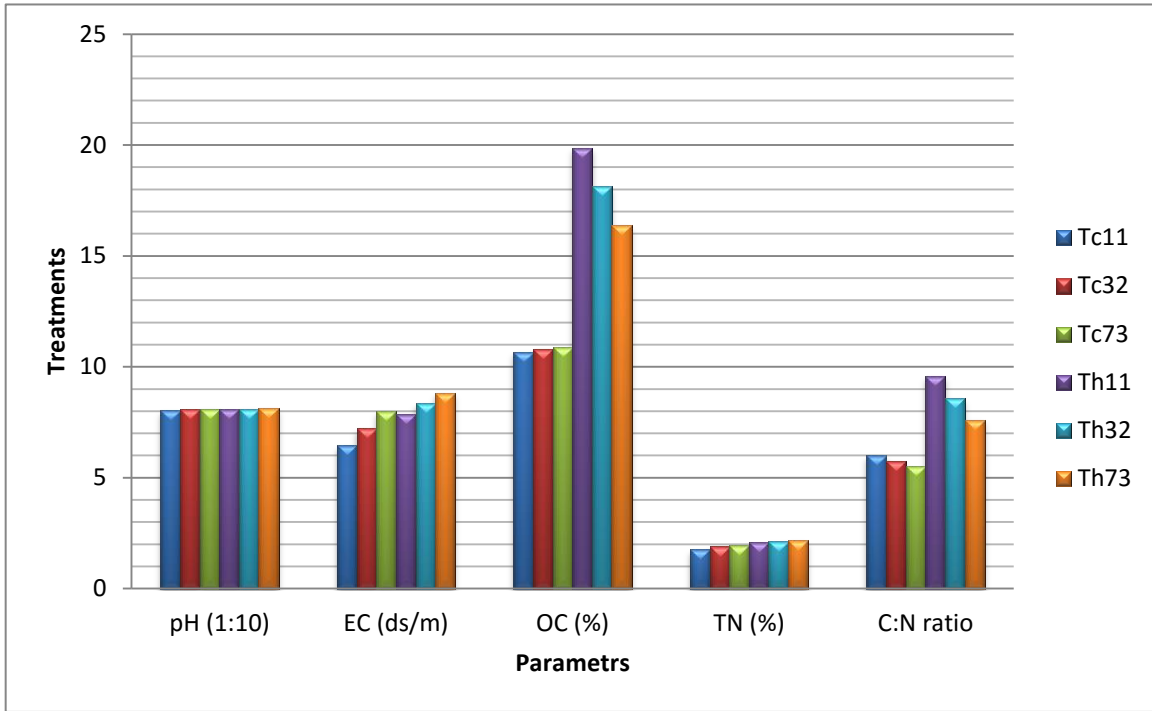

Figure 1: Initial physico-chemical analysis compositions

The initial pre-composted compositions of the sample tannery sludge and the feed mixtures (horse manureand cow dung) with a pH of 8.01, to 8.131 had a C: N ratio, electrical conductivity, less than an optimum range for vermicomposting (Figure 4). After 45 days, the vermicompost had achieved the characteristics of non-chemical fertilizer or vermicompost.

Reproduction rate of earth worm during vermicomposting

The vermicomposting was dark brown in color and earthy odor after 45 days of earthworm's activity. The changes in worm biomass for all the treatments over the experimentation period are illustrated in Table5. At the end of the 40-45 days, the earthworm biomass had increased in all the treatments. In general, the maximum biomass gain was recorded in Th_{73} (120 ± 0.575 worm /day) and Th_{32} (100 ± 0.55 worm /day) treatments. Similarly, the maximum growth rate was achieved in Th_{73} (0.575 worm/day) and Th_{32} (0.55 worm /day) than the other treatments (Hay, 1995). There was no statistical significant difference among Th_{73} and Th_{32} treatments for number of worms $(p < 0.05)$. The growth rate has been considered as a good comparative index to compare the growth of earthworms in different feeds (Edwards, 1998).

 In the present study addition of cow dung and horse manure in the tannery sludge results an increase in number of *Eisenia foetida.* Growth and reproduction of earthworms require OC, N, adequate temperature, moisture, and pH which are obtained from cow dung, horse manure and tannery sludge (Garg and Gupta, 2001). In the present study higher growth rate of earthworms

during vermicomposting may be due to the more palatability of feed by worms and the slow growth rate in other treatments with *Eisenia foetida* was possibly due to the presence of some growth retarding substance in it (Edwards,1998).

Table 3: Reproduction rate of*Eisenia foetida* in different treatments

s/n	Treatment (T) No	Mean initial worm density	Maximum No worm after 40 days	Growth rate/worm/ day
1	Tc_{11}	80	92	+0.30/day
2	Tc_{32}	100	116	+0.40/day
3	Tc_{73}	120	135	+0.375/day
4	Th_{11}	80	96	+0.40/day
5	Th_{32}	100	122	+0.55/day
6	Th_{73}	120	143	+0.575/day

Table **3** describes the reproduction rate of *Eisenia Foetida* during vermicomposting process and also shows the maximum and minimum number of worms in tannery sludge mixing with cow dung and horse manure at the same time in different ratios, relatively the reproduction rate is maximum in the composition of horse manure and tannery sludge thanthat of cow dung and tannery sludge Becausein aeration system horse manure preferable than that of cow dung.

Experimental results of vermicomposting (observations)

The final experimental results of vermicomposting were done in Wonji Sugar Factory soil and water management team soil laboratory all the results like OC (%), pH (1 : 5), Ec ds/m (1 : 5), TN (%),P, K were described in figure 2.
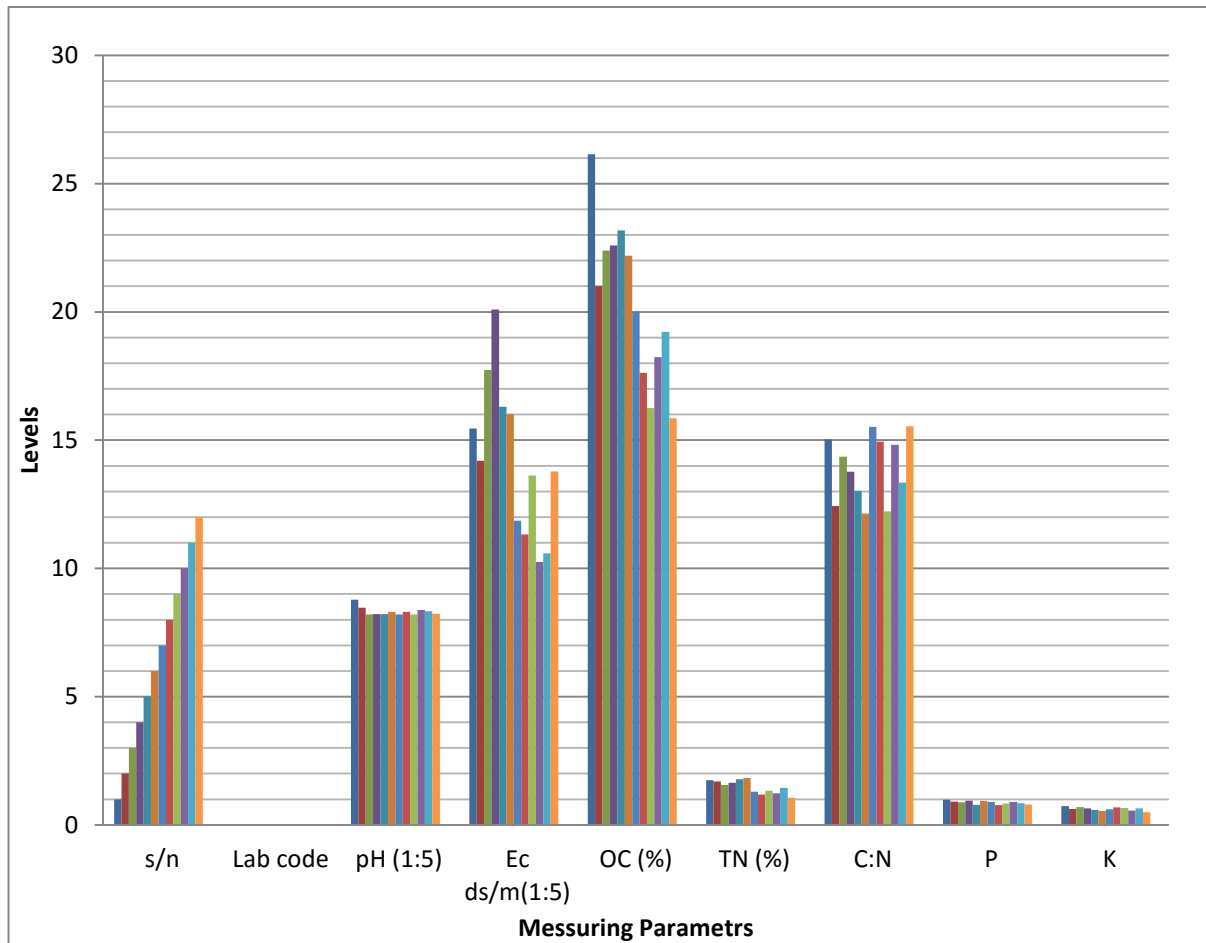
Figure 2: combined representation of all measuring parameters

Figure 2 showsthe main characteristics of chemical or bio fertilizers like nitrogen, phosphorus, potassium, pH, electrical conductivity and carbon to nitrogen ratio and also the micro-nutrients are recommended to present in the fertilizer so, because of these reason the content of vermicompost in this study was cheeked all the nutrients specially the macro- nutrients the results are in the recommended range of bio-fertilizer. Earthworms have the ability to absorb heavy metals by nature so, that heavy metal accumulation of the vermicompost is also not above the standard.
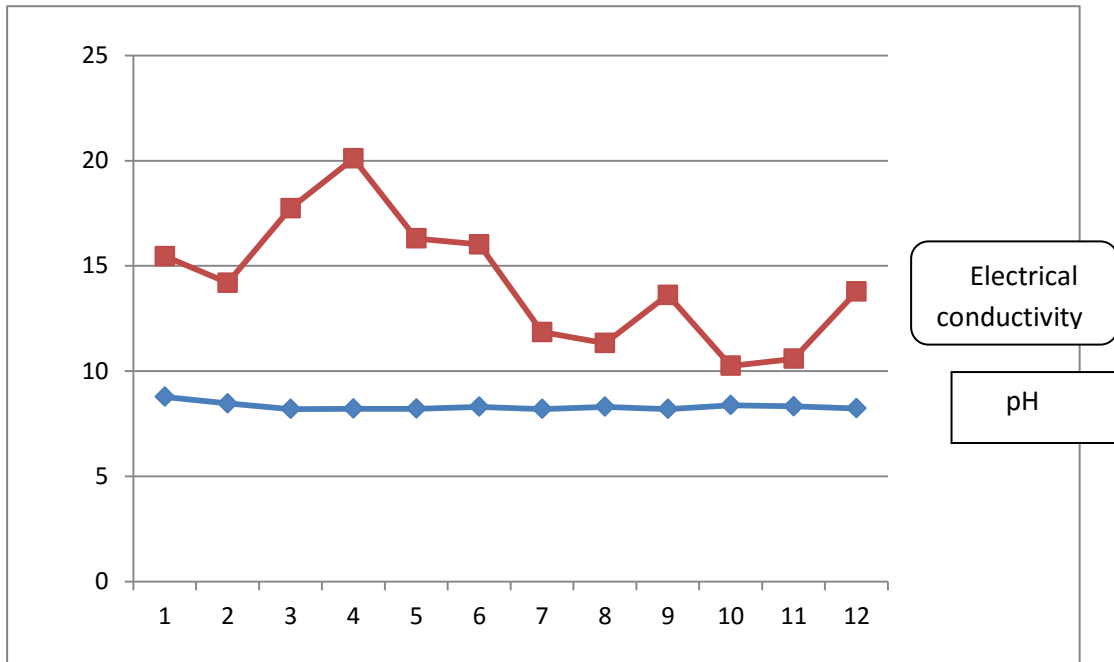
Figure 3: Electrical conductivity and pH chart

Figure 3 shows electrical conductivity and pH of vermicomposting the red color shows electrical conductivity and the blue one shows pH of the vermicompost y-axis indicates the level of the vermicompost and x-axis indicates number of treatments. So, that having recommended electrical conductivity and pH value (5.5 - 9) shows the maturity of vermicompost. The electrical conductivity is done in (1: 5). To measure electrical conductivity in accurate manure it needs sample to solvent ratio (1: 1) but there is a laboratory equipment limitation so, the option is to measure (1: 5) ratio.

Performance measurement of vermicomposting

Performance evaluation of this these is done by cultivating salad within two months in three different plastic containers having 0 % soil + 100 % vermicomposting, 50 % soil + 50 % vermicomposting, 100 % soil + 0 % vermicomposting.

Table 4: Weight of cultivated salad for performance evaluation

Treatments	No of leaves	Leaf weight in gram
T1	04	121.50
T2	04	167.80
T3	04	203.40
T2-T1	No difference	46.30
T3-T2	No difference	35.60
T3-T1	No difference	81.90

Table four mainly describes the effect of vermicompostingof tannery sludge on the biomass of salad and clearly shows the performance vermicomposting by measuring the weight of cultivated

salad after 53 days. As the vermicompost increases from 0 % - 100 % the biomass of the salad also increases proportionally.

Vermicomposting contains plant growth promoters with other nutrients and improves physical, chemical and biological properties of soil on repeated application. Many important factors, such as the presence of beneficial microorganisms or biologically active plant growth influencing substances such as phytohormone are released by beneficial microorganisms present in the vermicompost rich soil (Edwards, 1998). Root initiation, increased root biomass, enhanced plant growth and development and sometimes, alterations in plant morphology are among the most frequently claimed effects of vermicompost treatment (Jakakumar, 2005).
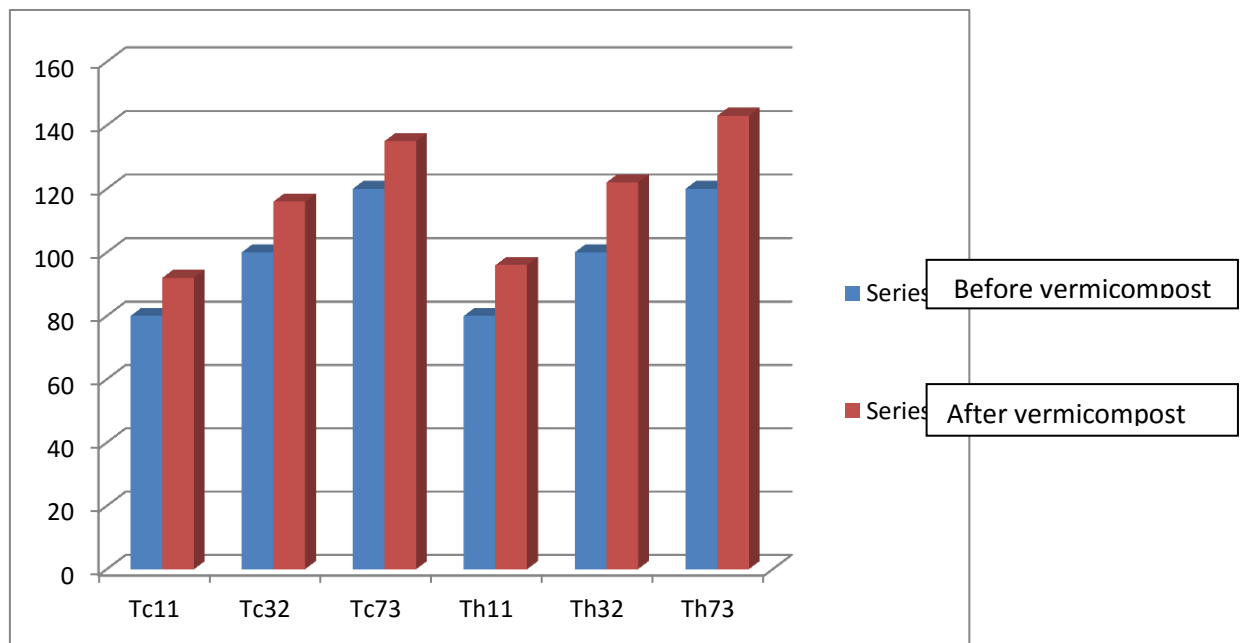

Figure 4: direct effect of vermicomposting on biomass salad

Figure 4 describes the effect of vermicomposting on the cultivated salad, by measuring the weight of the same number of leaves in the same condition and calculating the difference from every treatment. The product or vermicomposting of tannery sludge waste had appositive impact on salad leave. The weight of salad leaves increased as the proportion of vermicomposting increased. Vermicompost had direct effect on the bio-mass of salad.

Conclusion and recommendations

Conclusion

   o   Vermicomposting of tannery sludge has great potential as fertilizer apart from its hazardous and phytotoxic nature. The toxicity is due to very high content of microelements, salts and heavy metals.

- o Application of tannery sludge in agriculture or for soil reclamation is an effective solution for its management.
- o The effect of tannery sludge vermicompost (VC) rates on growth, nodulation and N fixation of saladwas investigated.

Recommendation

There is no tannery sludge treatment option in Ethiopia up-to-date utilization of these wastes used to minimize or avoiding pollution effect on the environment and human health on the other hand, vermicomposting of tannery sludge had a greater potential as organic biofertilzers for the growth and development plants and vegetables for the sustainable agriculture and ecological advantages.

- ▪ Since tannery sludge has a serious environmental problem, it is possible to convert to bio-fertilizer and replacing the chemical fertilizer, but additional research including optimization of parameters should be regulated.
- ▪ Different bulking materials rather than horse manure or cow dung having high carbon content may be best options to improve the standards of vermicomposting in micro and macro nutrients because tannery sludge has high nitrogen content to balance the carbon to nitrogen ratio.
- ▪ This potential was screened using different species of earthworms so, vermicomposting of tannery sludge is advisable to use as a source of essential nutrients to the plants and a good soil conditioner.

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FOREST PROTECTION

FRUIT FLY INFESTATION ON THE FRUITS OF AN INDIGENOUS *PODOCARPUS FALCATUS* IN WESTERN SHOA, ETHIOPIA

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Abstract

Podocarpus falcatus is an indigenous tree species of Ethiopia that is locally threatened by illegal cutting and encroachment, loss of seed viability due to various reasons. This study was conducted to investigate the associated fruit fly and its effects on seed germination of the species. It was found that *Ceratitis* (Pterandrus) *gravinotata* Munro was found associated with fruits of *P. falcatus*. Despite the fact that this polyphagus fruit fly had been recorded in several other species, it is the first time that *C. gravinotata* was recorded in the fruit of *Podocarpus falcatus* in Ethiopia. This study has also pointed out new geographical distribution of the insect and its importance on seed germinal of *P. falcatus*.

Keywords: *Podocarpus falcatus*, fruit fly, *Ceratitis gravinotata*, Ethiopia

Introduction

Podocarpus falcatus (Thunb.) Mirb. (Synonym*Afrocarpus falcatus*) is widely grown in semi-humid lower highland of central and south eastern Afromontane highlands of Ethiopia between 1600-2500m.a.s.l. It is the single representative tree species of Podocarpaceae in Ethiopia. The survival of this tree species is locally threatened by illegal cutting and encroachment, loss of seed viability and seed dormancy during direct sowing. The fruit of *P. falcatus* consists of a fleshy epimatium outer covering with hard woody seed coat of sclerotesta. Podocarpus is extra useful for its shade, firewood, poles, timber and medicine. The fruits of *P. falcatus* serve as source of food for many birds, bats and to rare extent to Colobus monkey (Negash, 2003; Wubet et al., 2003; Yohannes et al., 2011). In Ethiopia *P. falcatus* has become threatened because of selective logging for many decades, whereas the reproductive potential has rapidly declined (Aerts, 2008).

Fruit flies (Diptera: Tephritidae) are one of the most economically important groups of insects in the Afrotropical region. They can infest and damage the fruit, seeds, and/or vegetative tissue of plant commodities (White and Elson-Harris, 1992). The potential for future fruit fly invasions is of great concern to regulatory agencies and domestic growers. The predominantly Afrotropical fruit fly genus *Ceratitis* contains many species of agricultural importance. Thus, true fruit flies are a group of major insects of quarantine importance (Kakouli-Duarte et al., 2001) that threaten horticultural and vegetable industries throughout the world (Sookar et al., 2006).

Despite the fact that several fungal pathogens were known to attack seeds of *P. falcatus*, the damage caused by insect pests is poorly addressed in Ethiopia so far. Therefore, the objectives of this study were to determine the type of fruit fly associated with fruits of *Podocarpus falcatus* and effects of the fruit fly on seed germination of this tree species.

Material and Methods

Study sites and fruit collection

Mature yellow fruits were collected from branches of *P. falcatus* at Addis Alem, 42 km west of Addis Ababa and transported to Forestry Research Center plant protection laboratory for investigation of any infliction by insect pest.

Fruit fly emergence and identification

Field collected fruits were incubated in rectangular plastic dishes covered with fine mesh for weeks at room temperature in a laboratory. During these days, fruits were sprinkled with water to avoid fast desiccation. Emerged adult fruit flies were collected and prepared for morphological characterization. Accordingly, specimens were morphologically characterized for the length and coloration of puparia, male's tibia, cubital band, scutum, scutellum color, and other both in the Center and specimens were sent to Dr. Marc De Meyer at the Invertebrates Unit, Royal Museum for Central Africa, in Belgium.

Seed germination test

The seed germination tests of *P. falcatus* were conducted in unsterilized sand filled in plastic dishes under laboratory condition. Seeds were categorized into four treatments with unequal number of seeds for lack of available infested seeds per respective treatment: non-pierced (100 seeds as control), and infested seeds with one (84 seeds), two (95 seeds) and three (92 seeds) exit holes, in four replications except for seeds having two exit holes. Seeds with a radicle greater than 2 mm were considered germinated.

Data analysis

Descriptive data analysis was done for number of infested seeds. The number of germinated seeds per each replication was divided to the number of seeds available in each Petri dish. This datum undergone a one way analysis of variance (ANOVA) in IBM SPSS version 20 SPSS to determine the possible interaction of different treatments on seed germination of *P. falcatus*. Finally, Tukey's HSD was run after determination of significant difference among treatments at $p < 0.05$.

Results

One species of fruit fly was emerged from fruits of *P. Falcatus* collected from the three study locations. The yellow maggots (larvae) tunnel and feed inside the fleshy portion of the fruit until full development and time of emergence. The puparia which was inside a hard capsule has yellow to black coloration with an average of 4 mm length. The emerged male has long, stout black bristles on the mid tibia. This fruit fly was identified as *Ceratitis* (*Pterandrus*) *gravinotata* (Munro).*C. gravinotata* is characterized by cubital band free (at most with dark impression linking cubital band to discal band) or joining discal band at more posterior point; scutum with ground color brownish black or orange-brown, with silvery microtrichose areas and black spots or stripes; scutellum with white or yellow ground color, with black basal and/or apical spots (scutellar spots merged or separate); marginal band without large hyaline break extending into cell r_1; post pronotal lobe with distinct spot around seta; scutum with gray patches, not distinct vittae; medial band present, usually joined with marginal band, sometimes separated; and black basal scutellar spots present, apical spots merged and touching basal spots; male midtibia not club-shaped, with black feathering on distal 0.75; aculeus tip slender.

Several fruits of *P. falcatus* had harbored both the larva and pupa stage of the insect simultaneously in fruits that remained on the tree for considerable time or in the ground where the fruits fallen down. It has been found that 12.41% of fruits of *P. falcatus* were perforated at single point, less than 1% at two points, and more than 17.38% fruits were found rotten. Infested fruits released resin-like substance from the fleshy pulp that dry on the surface of the fruit. Progressively, damaged fruits were disfigured and became brownish than the healthy yellow coloring. Ultimately pierced fruits shrunk and the fleshy pulp decomposed. However, no cracking was observed in seeds situated inside the sclerotesta or the stony shell that enclosed the embryo.

The mean seed germination of treatments was 0.1900, 0.0975, 0.2400, 0.1600 and 0.1719 for nil, one, two and three holes respectively. The one-way, between-subject analysis of variance failed to reveal a reliable effect of treatments on seed germination, $F(3, 15) = 2.181$, $p=0.143$, $MS_{error}= 0.007$, $\alpha=0.05$. Thus, the Tukey test of ANOVA showed no significant difference among seed treatments.

Discussion

It was found that *Ceratitis* (*Pterandrus*) *gravinotata* Munro has punctured more than 12% of *P. falcatus* fruits collected from Addis Alem, West Shoa.The seed of *P. falcatus* is enclosed with fleshy pulp epimatium and a stony shell sclerotesta having a very little endosperm food reserves for the embryo (Geldenhuys, 1993). Particularly the epimatium has an inhibitor that suppresses germination (Klapwijk, 2002, Geldenhuys, 1993). Thus seedling recruitment under natural condition is low.

Despite the fact that more than 17 per cent of seeds were rotten and less than 15 percent of seeds were predisposed to insect infestation before seeds fall to the ground, the subsequent minimum percent of seed germination might be significantly associated with the presence of stony shell

sclerotesta, which limit rapid imbibitions of water to the embryo. Therefore, the punctures of fruits of *P. falcatus* by *C. gravinotata* might initiated opening of the fleshy pulp epimatium of the seeds for decaying fungi and other macro-and microorganisms that can enhance degradation of stony shell through perforated holes. Thus, infestation of fruit might promote seed germination. Although the main focus of this study was Addis Alem, previously collected seeds of *P. falcatus* from Elena 7 km of Assela town (175 km east of Addis Ababa, the capital city of Ethiopia) and freomthe compound of CEEFRC were also infested by *C. gravinotata.*

In conclusion this study added further geographical distribution of the insect beyond Wendo Genet (reported by De Meyer and Freidberg, 2006) in potential and main seed source of Central Ethiopia such as Addis Alem and Assela. It also explains the importance of the insect in natural scarification of *P. falcatus* and promotes further removal of stony shell when the seeds fall to the ground. Therefore, future studies need to address the identity of bacteria and fungi that involve in the degradation of the fruit stone following punctures of the insect, imbibitions of water and air for seed germination of *P. falcatus*.

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