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Ethiopian Environment and Forest Research Institute

Proceedings of the 2nd Annual Research Outputs Dissemination Workshop

Yigardu Mulatu
Abraham Yirgu
Agena Anjulo
Yalemsew Adela

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REDD+
ETHIOPIA

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The Federal Democratic Republic of Ethiopia
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Welcoming Speech

Agena Anjulo (Dr)

Deputy Director General, Ethiopian Environment and Forest Research Institute

Excellencies, member of the natural resources and environment protection standing committee from the House of People's Representatives;

Your Excellency, Ato Kare Chawecha, State Minister for Environment and Climate Change, Ministry of Environment, Forest and Climate Change;
Excellencies, from respective Regional Environment, Forest and Climate Change Authorities;
Invited participants from Universities; Researchers from international, national and regional research institutions; participants from EEFRI, MEFCC and NGOs;

Dear all,
On behalf of EEFRI, it's my pleasure to warmly welcome you to this research outputs dissemination workshop organized by Ethiopian Environment and Forest Research Institute at this refreshing city of Bishoftu. The workshop is aimed at informing national stakeholders, decision makers, and researchers from various sectors on intermediate research outputs from the year 2009 E.C.

Dear participants,

We are confronted with net deforestation from unsustainable use of forest resources in the country; sever land degradation, biodiversity loss, imbalance of supply and demand for fuelwood and construction materials to the growing industry and booming construction sector. Large tracts of degraded lands need appropriate land management involving suitable tree cover for resilience and productive use. Assessments at national level depicted that deficit in energy supply to the urban and rural population is fulfilled from fuelwood either from legally produced woodlots and plantations or uncontrolled and unmanaged natural forests and woodlands. This may continue for long. The same is true for the row material supply to the construction industry and wood based industries. Much is imported from abroad to feed ever increasing wood demand, the country being net importer of finished wood products and raw timber spending millions in foreign currency.

In the country's path to green growth, much is expected from the forest sector: curving the net deforestation, increasing tree and forest cover through plantation establishment, managing the existing natural forests and combating climate change impacts through sequestering and storing CO_2 in forest biomass and soils. The dry land woodlands are deforested in the west and northwest at alarming rates in bid for unsustainable agriculture which apparently could cause desertification in the sensitive landscapes. This requires our policy influence.

Large tracts of productive rangelands have already been invaded with introduced species like Prosopis or they have been thickened with native encroaching and low laying bushes. This is true for once most productive Borana rangeland now converted to complete bush land with nearly no palatable pasture where large ruminants are left with no choice.

Excellencies and dear participants,

Water hyacinth is recent phenomena in Ethiopia; however currently invading fresh water lakes and rivers to the extent covering the water bodies and threatening hydropower dams. Rivers and water bodies in the country are also carrying excessive amount of silt from exposed to erosion land management systems. Our cities and towns as yet do not have liquid waste sewerage lines and waste water treatment centers. Many of the rivers are carrying pollutants of different kinds from household or industrial source to distant places. This makes researchers and experts in difficult position to design specific measures for solution. We are exposed to do the hardest way. Coordinated efforts of research, sustainable management of all kinds of available forests as well as strengthening policy implementation on environmental pollutions problems may partly help resolve it.

Ethiopian Environment and Forest Research Institute is relatively young organization established in 2014 with proclaimed mandate to adapt appropriate technologies, undertake research on environment management problems, forest development and climate change adaptation and mitigation. Having these huge mandates, however, the institute faces serious shortages of human resource of the experienced category. Currently, recruiting well trained researchers remains a challenge due to scarcity; establishing and equipping new multi-regional environment and forest research centers over the country is also a task we faced in early days of the institutions establishment, forced to work in rented houses.

In spite of such constrained research infrastructure and limited human resource (research staff), it has designed about 88 research projects with about 268 research activities in forestry and agroforestry, environment management and climate change for 2008 and 2009 E.C to start with solving some of the societal problems. Among these research activities, about 42 have been partly completed with intermediate results in 2009 E.C. Hence, this workshop is intended to evaluate how much has been done and how much of it is scalable to end users.

Research outputs produced for your evaluation are:

1. Forest resources utilization,

- Introduced bamboo species for livestock fodder;
- *Moringa stenopetala* ethnobotany at its native place (Konso and Dherashe);
- Nutritional and anti-nutritional effects of Moringa leaves as affected by tree age;
- Trees timber physical and mechanical properties; Lumber seasoning effects;
- Jatropha fruit husk as briquette for energy;
- Latex yield variation among rubber tree clones;

2. Plantation research/ Nursery management
    - Poplar nursery life span;
    - Pot size influences on seedling development
3. Agroforestry
    - AFPs contribution to food security;
    - Comparisons of Biomass and Soil Carbon Stock from AFS and other land uses;
4. Rehabilitation of degraded lands,
    - Community based degraded land rehabilitation programs;
    - Socio-economic determinants affecting investment on degraded lands
5. Ecosystem Management,
    - Management of water hyacinth using biological method
    - Water hyacinth management using eco-friendly chemicals
    - Environmental Factors and Anthropogenic Disturbances on Plant Diversity and Communities in Montane Forests
    - Woody plant diversity of Guji and Borana zones
    - Soil seed bank studies for the regeneration of plant species in Wof - Washa forest
    - Socio-economic importance and threats of lake Ziway
6. Climate change modeling, adaptation and mitigation,
    - Traditional ecological knowledge systems for climate change adaptation and mitigation
    - Teleconnections between Ocean-atmosphere Coupled Phenomenon and Droughts
    - Role of dry forests for climate change adaptation
7. Socio-economic analysis of forestry and environmental problems,
    - bylaws for successful scaling-up of area exclosures
    - Comprehensive forest resource accounting system in Ethiopia
    - Alternative livelihood interventions on household welfare
    - Comparative economic analysis of competing land use systems for informed decision
8. Environmental quality management,
    - Sugarcane pre-harvest burning emission levels
    - Tannery wastewater characterization
    - Perceptions to obsolete pesticide hazard
    - Potentials of water hyacinth as energy source/by briquetting

    9. Forest Protection

- New records of Eucalyptus insect pest (Red Gum Lerp Psyllid: Glycaspis brimblecombei) invasion in Southern Ethiopia
- Observation on parasitic plants in Southwestern and Central Part of Ethiopia
- Diversity of pathogenic fungi on plantation forests
- Fungal tip blight and stem canker diseases on Araucaria heterophylla in Ethiopia

10. Tree Seed Coordination Unit
    - Working manual for standardizing tree seed quality,
    - Testing germination problems,
    - Tree safe climbing training manual for seed collection,
11. Environmental laboratory
    - Waste water analysis procedure manual
12. Three policy briefs on important national environmental and forest/agroforestry issues were also produced for your assessment and professional feedback.

Dear Participants,

EEFRI's research directors, responsible for their specific research projects will highlight you their thematic areas, on type of projects under implementation and on their completed results. Poster presentations on research outputs have been made ready for sessions and your feed backs.

I would like to extend my gratitude to all EEFRI researchers who managed to undertake their research responsibilities within resource and facilities limitation. The Ministry of Environment, Forest and Climate Change deserves special mention for the financial support through their environment and REDD+ Projects. Both sectors have been helpful all the time we stretched our hands for such a support. I also thank all the participants travelled from far and near, for taking your time, respecting our invitation to be with us in this special event.

Thank you very much

Agena Anjulo (Dr)
Deputy Director General,
Ethiopian Environment and Forest Research Institute

Opening Speech

Kare Chawecha
State Minister for Environment, Forest and Climate Change,
The Ministry of Environment, Forest and Climate Change

Distinguished Standing Committee Members of the Parliament on Natural Resources and Environment Protection,

Honorable Guests, Presenters of the Studies, Ladies and Gentlemen,
On behalf of the Ministry of Environment, Forest and Climate Change, I would like to express my sincere gratitude for all of you coming to attend this workshop. Secondly, I would also like to express my deep acknowledgements the Environment and Forest Research Institute for having this great opportunity to present the opening remark.

Honorable guests, ladies and gentlemen, as it is obvious, our country Ethiopia is striving to join the medium income status by 2025 through setting the goals for all sectors of development. With regard to this, the Ethiopian government formulated various policies and strategies which enhance the rapid growth and development withstanding a number of difficulties which have internal and external emanations. In order to implement the policies and strategies, we have accomplished the first phase of Growth and Transformation Plan (GTP) and begun the second phase. With the intention of accomplishing the plans in a timely, quality oriented and cost effective manner, we are applying the key tools of changes which are effectively tested in the developed countries. Apart from this, to ensure the rapid growth of the country, all the governmental institutions, including the higher officials of the Ministry, are assigned based on their professional and leadership competencies.

With this regard, the Ministry of Environment, Forest and Climate Change is one of the recently established new sectors which are considered to ensure the growth and development goals set by the government. This sector in turn founded the Ethiopian Environment and Forest Research Institute (EEFRI) with the purpose of solving the problems which face the country in the areas of environment, forest and climate change through the use of technologies and research based scientific data. Though the Institute is recently established, we closely know that it has been running solution oriented researches on environment, forest and climate change study areas so as to realize its visions and missions by making its plans consistent with that of Growth and Transformation Plan (GTP) of the country. For instance, as Ethiopia follows agriculture led industrialization, the

Research Directorate on Environmental Pollution Management within the Institute is currently undertaking studies with various stakeholders so as to prevent and control the emerging pollution due to the increase of industries before the pollution brings damage on humans and the environment as well. In addition to implying the solution for immediate harms, the outcome of this research is also believed to bring a fundamental contribution on formulation of a better policy on environment protection. Besides, the experiment laboratory on environmental studies of the Institute has been established and serving the Ministry of Environment, Forest and Climate Change so as to bring the law of environment protection into implementation.

On the other side, it is through the implementation of the research outputs of the sector that we could sustain the benefit that our country could gain from this sector via minimizing deforestation and maximizing the coverage of forest by afforesting the exposed lands. Putting this in mind, currently this Research Institute is placing its own involvement on development of this country by running several projects within forestry study areas, by encompassing the constructive ideas that the stakeholders raise during the annual forums of discussions on forestry studies and by making the projects practical by bringing information and technologies in a better way. In addition to this, the Institute is undertaking various studies on climate change hence it is a global issue. The first and the basic importance of the studies, apart from benefiting the country from forest resources, is to project the potential situations of disaster that emanate from the climate change so as to enable the concerned governmental bodies to minimize the possible disaster and to strengthen preparedness. Therefore, this Institute is an organization striving to contribute scientific information and technologies which are crucial for the country regarding environment, forest and climate change.

So that this research institute publishes the finalized research works to all stakeholders every year. As we know, today's workshop is also scheduled to confirm the research project works which are finalized in 2009 E.C to the stakeholders. This is the main reason for us to meet here. Thus, on behalf of the Ministry of Environment, Forest and Climate Change, I kindly request the honorable guests of this annual workshop to visit the Institute's research findings which describe the information and technologies in poster and manually; and to actively involve by pointing out the constructive ideas for future improvement.

Finally, I declare that the workshop is officially opened. Thank you.

Kare Chawecha
State Minister for Environment, Forest and Climate Change,
The Ministry of Environment, Forest and Climate Change

Table of content

Chapter One: Plantation and Agroforestry Research

Comparative Assessment of Biomass and Soil Carbon Stocks in Multi-strata Agroforestry Systems and Khat (Catha Edulis) Farming, Northern Ethiopia

Desalegn Getnet[1,2], Mesele Negash[2], Abeje Eshete[1]

[1]Ethiopian Environment and Forest Research Institute, [2]Wondogenet College of Forestry and Natural Resources

Abstract

Nowadays, the demand for short-term economic benefit has derived multi-strata agroforestry system towards monoculture production such as khat (Catha edulis) and eucalyptus species. Thus, this study was aimed to investigate biomass and soil carbon stocks of two multi-strata agroforestry systems (coffee based agroforestry system (CAF) and fruit tree based agroforestry system (FAF)) and Khat monoculture (KF) in Raya valley, Northern Ethiopia. From each system 20 smallholder farmers were randomly selected. A vegetation survey was made from randomly laid out plots of 20 m X 20 m. Within in a bigger plot three nested plots of 1 m X 1 m were laid to collect litter and soil samples (depths 0-30 cm, 30-60 cm) that were used to determine soil organic carbon. Above and belowground biomass of fruit bearing trees and coffee plants were estimated using already developed allometric equations, while for khat plant a new allometric equation was developed for estimation of above ground biomass. The mean total biomass carbon stock of CAF (60.46 Mg ha^{-1}) and FAF (57.7Mg ha^{-1}) were significantly ($p < 0.001$) higher than KF (23.3 Mg ha^{-1}). The mean total C stocks (biomass plus soil) at ecosystem level of the CAF (198 Mg ha^{-1}) and FAF (194.7 Mg ha^{-1}) were significantly ($p < 0.001$) higher than the total carbon stock at KF (132.5Mg ha^{-1}). SOC stocks accounted for 69.5, 70.3 and 82.4 % of the total ecosystem C stocks for CAF, FAF and KF systems, respectively. Conversion of CAF and FAF to KF would result in loss of 33 % and 32 % carbon stocks, respectively. The study revealed that conversion of multi-strata agroforestry systems to cash crop would contribute to removal of carbon stock through the biomass, and reduce the climate change mitigation roles of the existing land uses. Thus, land use conversion should be carefully dealt to enhance their potential role to climate change mitigation.

Key words: *Aboveground biomass, Coffee, Fruit, Khat, Organic carbon*

Introduction

Anthropogenic factors such as use of fossil fuels, deforestation and land use change have resulted in emission of GHGs (IPCC, 2014). The relative contribution of tropical deforestation and forest degradation account 12 % of the total CO_2 emission (van der

Werf, et al., 2009). Forest resources are subjected to extensive deforestation and forest degradation for expansion of agriculture, fuel-wood collection, and illegal logging among others. This necessitates looking for complementary land use such as agroforestry systems (AFS) for enhancing climate change mitigation roles.

Agroforestry systems at global scale have a potential to sequester carbon over the next 50 years (Gupta, et al., 2009). The system has also indirect role to enhance carbon sequestration to the natural forests as they reduce pressure on natural forests. Recognizing such advantage of AFS to store carbon in the living biomass, products and soil, it was considered as part of climate change mitigation strategies under afforestation and reforestation programs in the Kyoto protocol (UNFCCC, 1997).

According to Montagnini and Nair (2004), the tree components of AFS are potential sinks of atmospheric C due to their fast growth and productivity, high and long-term biomass stock, and extensive root system. According to Nair et al. (2010), the aboveground carbon sequestration of tropical agroforestry ranged from 0.29-15.21 Mg ha^{-1} $year^{-1}$ and 30- 300 Mg C ha^{-1}up to 1m depth in the soil.

Although the area of AFS is not well documented in Ethiopia, according to some estimates based on satellite imagery for the base year 2006, it was around 2.32 million ha in East and West Africa (Brown, et al., 2012). For instance, a study showed that the indigenous agroforestry systems on the southeastern Rift Valley escarpment in Ethiopia are important sinks for carbon stocks in biomass and soil. Coffee, fruit and Enset based agroforestry systems were substantially higher than those of tropical forests and other agroforestry systems in their productive and protective functions (Negash and Starr, 2015).

The home garden AFS are the most popular and very common agro forestry system in most parts of Ethiopia (Tesfaye, 2005; Mengistu and Hager, 2009; Agize et al., 2013). Cash crops like coffee and khat are involved in some AFS and Coffee and khat cash crops are among the top three export products in the country.

More recently, AFS have been challenged by population pressure, shrinking farm size, poverty and a new market situation. The short-term economic benefit has derived the multi-strata AFS towards monoculture production such as khat (*Catha edulis*) and eucalyptus species. The khat is cultivated in almost one-third area of coffee cultivated land (Telake, 2007). Reports showed that the area coverage of AFS with Khat increased by 62394.56 ha from 2007 to 2011 by replacing coffee based AFS in different parts of the country (Dube, et al., 2014; Woldu, et al., 2015). Farmers have gradually integrated the culture of growing khat into the once coffee-based production system. There has been a huge shift in land use with over 63 % of the total coffee land being uprooted and converted into khat (Woldu, et al., 2015). As part of informing the public about the impact of converting land uses this study was, therefore, aimed at evaluating the potential of biomass and soil organic carbon stocks of multi-strata agroforestry systems and Khat (*Catha edulis*) monoculture farming in Raya Azebo, Northern Ethiopia.

Material and Methods

Geographical Location and Characterization

The study was conducted in Raya Azebo, Northern Ethiopia (Figure 1). Geographically the area is located between 12^0 18′ 43′′ and 12^0 53′ 24′′ N latitude and 39^0 33′ 3′′ and 40^0 2′ 27′′ E longitude. The site covers 175, 804.55 ha, comprising 60% of the Raya Valley, which is part of the Ethiopian Great Rift Valley system (RVADP, 1998). The population density of the woreda was 63.7 per sq.km which is less than the national level average of 67 persons/sq.km with average land holding size of 1.84 ha per household (CSA, 2007). The elevation ranges from 930 and 2300 m.a.s.l. Traditional classification of agro-climatic zones of the Raya valley consists low land (7%), midland (90%) and the remaining highland (3%) (TARI, 2009). The mean monthly temperature ranged from 16 °C to 30 °C and mean annual rainfall ranges from 426 to 826 mm. The rainfall distribution is a bimodal type with light rainfall from February to April and heavy rainfall between July and September (Meles, et al., 2009). Vertisol is the dominant soil types and covers over 70 % of the study site (RVADP, 1998; Tesfay, et al., 2014).

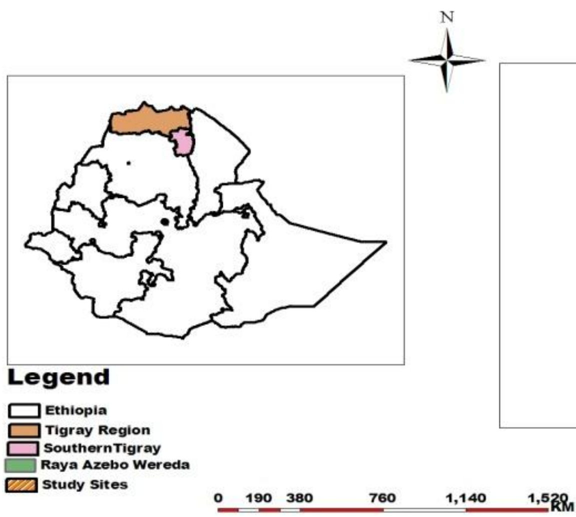

Figure 1: Map of study site

The most common farming system in the study area includes parkland agroforestry, coffee based agroforestry system (CAF), and fruit-tree based agroforestry system (FAF) and khat monoculture (KF). CAF and FAF integrate different plant species occupying three vertical strata. While KF involves only Khat monoculture plant with hedge practiced by different shrubs.

Household Selection

A total of 60 farms (10 farmers x 3 systems x 2 sites) were randomly selected, i.e. 20 farms from each system. Nested plot size of 20 x 20 m was randomly laid down on the selected farms for inventory of woody species across the agroforestry systems (Pearson, et al., 2005). Three sub-plots that measured 1 m x 1 m were randomly laid down (nested) within a bigger plot to collect litter samples (Figure 2).

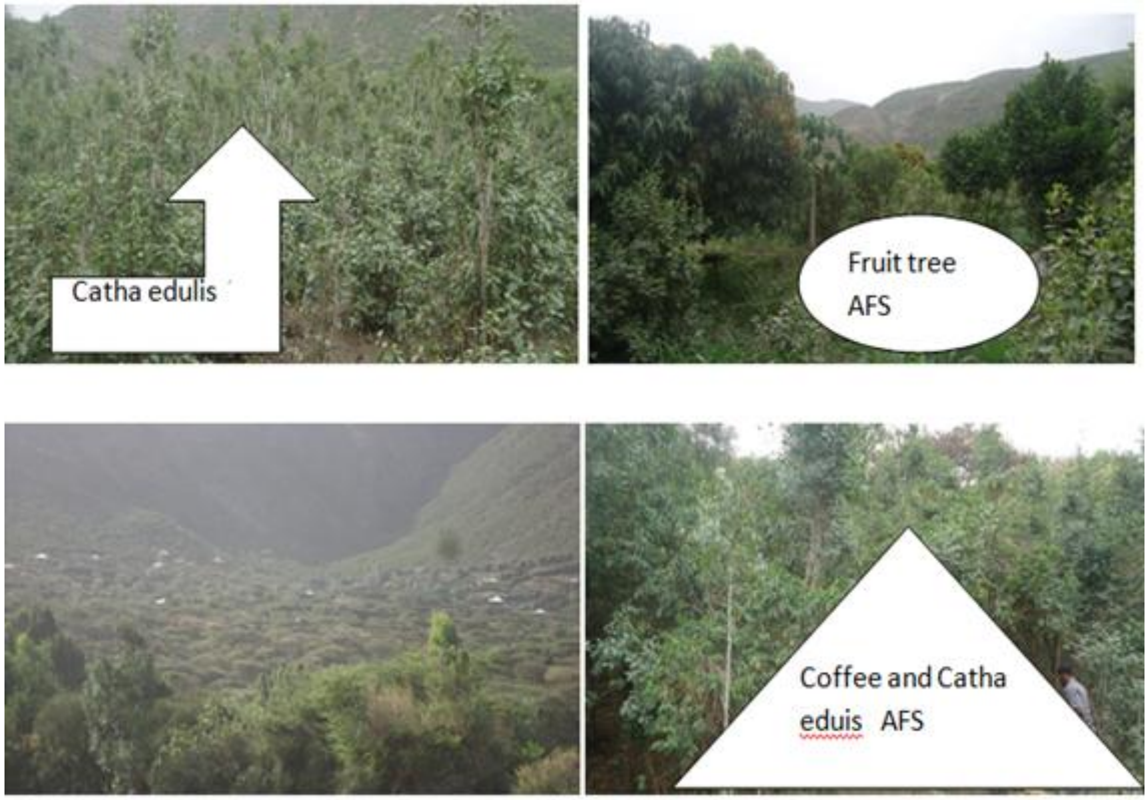

Figure 2: Photographs of a representative samples in each of the two studied agroforestry systems: Coffee; Fruit and Khat monoculture.

Inventory of Woody Plants

All woody species ≥ 2.5 cm in diameter at breast height (d) and total height (h) ≥ 1.5 m were measured for their diameter at breast height and total height across the three studied systems. Additionally, for coffee and khat plants, stump diameter at 40 cm above the ground (d_{40}) and basal diameter at height of 10 cm above the ground (d_{10}) were recorded, respectively. All stem diameters (d, d_{40} and d_{10}) were measured in two perpendicular directions and averaged. The diameter equivalent equation was used for multi-stemmed individual woody plants, plants having more than one stem. Diameter equivalent is the square root of the sum of diameters of all stems per plant (Snowdon, et al., 2002).

$de = \sqrt{\sum_{i=1}^{n} di^2}$ ....(Eq. 1)

Where de is diameter equivalent (at breast or stump height), cm; d_i is diameter of i^{th} stem at stump or breast height, cm.

Litter Biomass and Soil Sampling

The litter was randomly collected from three 1 m x 1 m sub-plots established in each 20 m x 20 m bigger plot. The litter samples included dead leaves, branches, twigs, flowers, and dead wood; no fractionating. The samples from each of the three plots were combined for each small holding on site and fresh weight of both litter were measured right on the field. Then, sub-subsample of 100 gm litter was taken to laboratory. The sub-sub sample was sun dried for one day and, oven-dried at 70 °C for 24 hours and weighted. The soil samples were taken from 0-30 and 30-60 cm depths in each of the 5 sub-plots (four at the corner and one is center) within 20 m x 20 m and composited by layer. A total of 120 composited samples were collected across the three farming systems using a soil auger (8 cm diameter and 15 cm length) for determination of SOC, TN, pH and texture analysis. For bulk density 120 soil samples were collected separately using soil core sampler (5 cm diameter and 10 cm length) from the center of inventory plot. The samples for bulk density determination were oven-dried at 105 °C for 48 hours. The weight of >2 mm and <2 mm fractions were recorded. The soil samples for SOC, TN, pH and texture determination were air-dried, to pass through a two mm diameter sieve.

Data Analysis

Determination of Biomass C Stocks

Biomass C stocks for woody species (Mg ha^{-1}) were calculated from dry matter biomass and C content. For estimation of above ground biomass of trees, allometric equation developed by Kuyah et al. (2012a) was used:

$$AGB_{trees} = 0.225 \times d^{2.341} \times \rho^{0.73};\ R^2 = 0.98;\ n = 72 \quad \ldots\ldots\ldots\ldots (Eq.2)$$

Where: AGB is the aboveground biomass of trees (kg dry matter/plant), d is diameter at breast height (cm); and ρ is species wood density (g cm^{-3})

For estimating the aboveground biomass of coffee plants (kg dry matter/plant) allometric equations developed by Negash et al. (2013b) were used:

$$AGB_{coffee} = 0.147 \times d^2_{40};\quad R^2 = 0.80.\ n = 31 \ldots\ldots\ldots\ldots (Eq.3)$$

Where: AGB coffee is the aboveground biomass of coffee plants, d40 = stem diameter (cm) of the coffee plant at 40 cm height

We developed new allometric equation to determine the above ground biomass and carbon content of Khat plant (*Catha edulis*). The developed equation was:

$$AGB_{khat} = 0.4796 \times D_{10}^{1.5818} \times DH^{0.1089};\quad R^2 = 0.96.\ n = 31 \ldots\ldots\ldots\ldots (Eq.4)$$

Where: AGB $_{Khat}$ is the aboveground biomass of Khat plants, D_{10} is basal diameter (cm) at 10 cm height and DH is dominant height (m) of khat plant.

Belowground biomass of tree, coffee and khat was estimated using the generic equation developed by Kuyah et al (2012b):

$$BGB = 0.490 \times AGB^{0.923};\ R^2 = 0.95;\ n = 72 \ldots\ldots\ldots\ldots (Eq.5)$$

Where BGB is the belowground biomass (kg dry matter/ plant) and AGB is aboveground biomass (kg dry matter/plant).

Extrapolating carbon stocks from plot basis to per hectare was done as follow (Pearson *et al.*, 2007):

$$\text{Carbon stock of sample plot } \left(\frac{\text{Mg}}{\text{ha}}\right) = \frac{\text{carbon stock of sample plot}}{1000} \ldots\ldots\ldots\ldots (\text{Eq. } 6)$$

Where plot size was 20 m x 20 m = 400 m^2

The expansion factor was calculated as a hectare (ha) in square meters divided by the area of the sample in square meters. Hence, the biomass density was calculated by multiplying the dry mass by an expansion factor calculated from sample plot size (Pearson, et al., 2007). For estimation of litter biomass C stock, the sub-samples taken in the field was used to determine oven-dry to fresh weight ratio (Pearson, et al., 2005):

$$\mathrm{BLC} = \frac{\mathrm{Wfresh}}{\mathrm{A}} * \frac{\mathrm{Wsub-plot, dry}}{\mathrm{Wsubsamplefresh}} * \frac{1}{100} * \%\ \mathrm{C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq.7)$$

Where: BLC – Biomass of litter (Mg C ha-1), W– Weight of the fresh field sample of leaf litter measured on the site (g), A – Size of the sample area in which leaf litter is collected (ha), W sub-sample, fresh – Weight of the fresh sub-sample of leaf litter taken to the laboratory to determine moisture content (g), W sub-sample, dry - Weight of the oven-dry sub-sample of leaf litter taken to the laboratory (g).

Total aboveground biomass C stocks is defined as the sum of tree, coffee, khat and litter biomass C stock, and total belowground biomass C stocks is the sum of the C stocks associated with tree, coffee and khat plant stumps and coarse roots. Total biomass C stocks are defined as the sum of the total aboveground and belowground biomass C stocks.

The SOC stocks (C) (Mg ha^{-1}) were determined using the Pearson et al. (2007):

C (Mg ha-1) = ((soil bulk density, (g/ cm3) x soil depth (cm) x C %)) *100.................... (Eq.8)

Volume correction by the default value gives an estimate of rock volume, which can be used to calculate density of rock fragment (g/cm^3) given as 2.65 g/cm^3. The SOC stock values for the two layers (0–30 cm and 30–60 cm) were summed to give the SOC stock for the entire 0–60 cm layer. Agroforestry C stocks are defined as the sum of the total biomass C and 0–60 cm SOC stocks.

Determination of C Contents

The C content (%) of the khat and litter biomass samples were calculated from organic matter contents through loss-on-ignition (LOI at 550 °C for 2 hr), assumed 50 % of the organic matter lost through burning is C content (Berhe, et al., 2013). The litter biomass organic matter contents in CAF, FAF and KF were 71, 73 and 67 %, respectively. Multiplying these values by 50 % resulted in 46 % C for khat leaf plus twig, and litter C valued 35 % for CAF, 36 % for FAF and 33 % for KF

Results

Stand Characteristics

The highest stem density was recorded for the KF, followed by CAF and FAF systems (Table 1). The stem density of native woody species accounted for 16 % and 22 % of the total in the FAF and CAF, respectively. The basal area was not significantly different between the two Multilateral agroforestry system but both multilateral AFS recorded basal area significantly ($p < 0.01$) different form KAF system. The basal area of native woody species shared 35 % and 49 % of the total in FAF and CAF, respectively. This is because basal area is highly influenced by tree diameter than stem density.

Table 1: Summary (mean ± SD) of the stand characteristics of the three studied systems

Stand characteristic	FAF (n=20)		CAF (n=20)		KF (n=20)
	Fruit [a]	NFT	Trees	Coffee	Khat
d_{10}, cm	-	-	-	-	10.68±2.85
d_{40}, cm	-	-	-	8.7±2.5	-
d, cm	12.3±3.5^{b}	21.5±5.2^{c}	23.2±10.2^{c}	4.7±2.2^{a}	6.04±3.1^{a}
h, m	6.3±1.8^{ab}	10.8±3.1^{b}	12.78±3.7^{d}	4.3±1.87^{a}	4.9±2.3^{a}
B. area, m^2 ha^{-1}	13.1±4.9^{b}	7.5±4.3^{a}	8.76±6.5^{a}	8.5±5.3^{a}	9.9±6.4^{a}
Stem density (ha^{-1})	778±102^{b}	177±58^{a}	275±54^{a}	1073±208^{c}	2249±424^{d}

NFT = non-fruit tree, d_{10} =diameter at 10 cm height, d_{40} = diameter at 40 cm height, d = diameter at breast height, h = height, [a] Fruit trees are mainly Citrus sinensis, Mangifera indica Persea americana and Psidium guajava are frequently recorded. Different superscript letters denote significant differences between system components at $p < 0.05$.

Biomass Carbon Stocks

There were significant ($p < 0.001$) differences in total biomass carbon stock among the CAF and FAF systems and KAF systems. The total biomass C stocks were the highest in

CAF (60.46 Mg C ha^{-1}), followed by FAF (57.7 Mg C ha^{-1}) and KAF (23.3 Mg C ha^{-1}) (Figure 3). The proportion of total aboveground C to the total C stock was on average 76 % (ranged from 74 to 78) for all the three studied systems. Wood tree species including fruits accounted for 73 % and 90 % of the total C stocks in the CAF and FAF systems, respectively. The contribution of the cash crops to total carbon stocks varied among the three studied systems. For instance, fruit trees accounted for 69 %, coffee 22 %, Khat 95 % of total C biomass stocks in FAF, CAF and KAF, respectively. While litter shared 4.7 %, 5 % and 5 % of the total biomass C stocks in FAF, CAF and KF, respectively. The khat litter carbon stock was significantly (p < 0.001) lower than by 87 % compared to the rest two AFS.

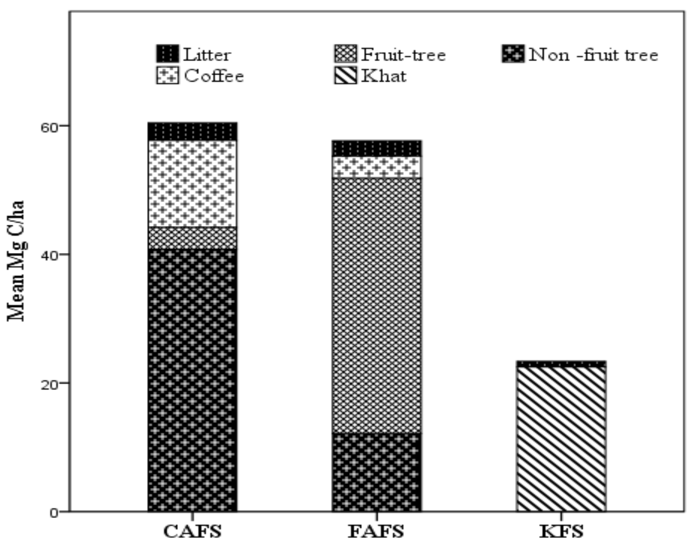

Figure 3: Total carbon stock based on biomass components among three stuided systems

Soil Organic Carbon Stock

The soil C stocks significantly (p < 0.001) varied between two multi-strata AFS and KAF studied systems as indicated at table 3. The highest total SOC stock was recorded in CAF and the least in KF. The SOC was influenced by input material like liter fall, root and stem density. The surface layer (0–30 cm) contributed 57 % of the total soil C stocks (0 –

60 cm) under CAF, 53 % for the FAF and 57 % for the KF. The shift of khat system to either coffee or fruit system would improve the SOC stock on average by 26 %. While conversion of the two-agroforestry systems to Khat farming would decline soil SOC stocks by 20 to 21 % at 60 cm depth.

Table 2: The mean (± SD) of SOC (Mg C ha^{-1}) along soil depths for the three studied systems

Soil depth(cm)	CAF (n=20)	FAF (n=20)	KF (n=20)	F	P
0-30	78.15±11.57^{a}	72.62±11.57^{a}	62.44±6.60^{b}	12.26	0.0001
30-60	59.66±5.17^{a}	64.34±6.73^{a}	46.73±6.04^{b}	21.66	0.0001
0-60	137.81±10.87^{a}	136.96±9.15^{a}	109.17±6.22^{b}	22.46	0.0001

Similar letters show not significance deference and different letters refer significant different at 5 % level of significance.

Ecosystem Carbon Stocks for the Studied Systems

The total ecosystems C stocks significantly (p < 0.01) differed between the two agroforestry systems and Khat farming systems. The highest total C stock was recorded in CAF (198.3±46.11 Mg C ha^{-1}), followed by FAF (194.7±32.03Mg C ha^{-1}) and KF (132.5±20.95Mg C ha^{-1}). The greater total ecosystem C stock densities were found in AFS probably due to the presence of trees and greater litter production than KAF and also recovery of SOC stocks after an initial decline following clearance of the AFS and replacement by the KAFS. The decomposition of litter from broadleaved species tends to be faster than that of khat plant. The highest range of total C stocks were found in the CAF (175 –252 Mg C ha^{-1}), followed by FAF (156–226 Mg C ha^{-1}), and the least for the KF (96–163 Mg C ha^{-1}) among smallholdings. The SOC accounted for 69, 71 and 82 % of the total ecosystem C stocks in CAF, FAF and KF, respectively. The shift of CAF and FAF to KF would contribute to decline in C stock by 33 % and 32 %, respectively (Figure 4).

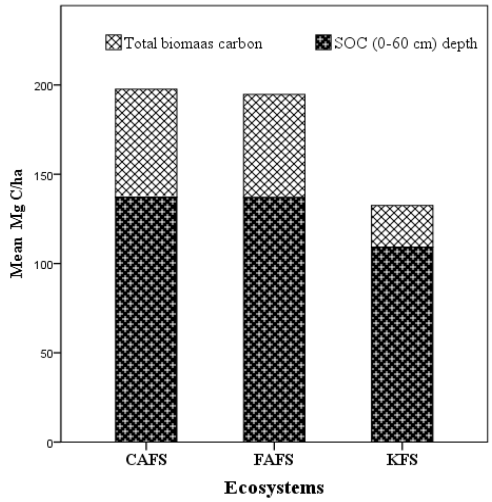

Figure 4: Summary (mean ± SD Mg ha-1) of biomass, soil organic carbon (0-60 cm) and total agroforestry carbon stock of the three agroforestry systems (n = 20 in each system; α = 0.01).

Discussions

Biomass Carbon Stocks in *Multistrata afs* and *Khat afs*

The total biomass C stocks of the multistara agroforestry systems (17.7 -116.45 Mg C ha^{-1}) were comparable with the findings of Negash and Starr (2015) (22 and 122 Mg C ha^{-1}) in indigenous agroforestry of southern Rift Valley escarpments of Ethiopia. However, this finding was slightly higher than those total biomass carbon stocks reported in Lanzones (*Lansium domesticum*)-fruit tree and Falcata (*Paraserianthes falcataria*)-forest tree based Agroforestry Systems in Philippines (Malayao and Mendoza, 2013). Total biomass C stock in KAF was comparable with coffee shrubs total biomass C in Guatemala (Schmitt-Harsh, et al., 2012), in Peru (Ehrenbergerova, et al., 2016) and with coffee grown in the open (22.9 Mg ha^{-1}) in Southwestern Togo (Dossa, et al., 2008). Labata et al. (2012) also reported similar results for Taungya AFS aboveground (20.24 Mg C ha^{-1}) stock in Philippines. Khat above ground C stock has slightly lower than teak monoculture (34.53 Mg C/ha) age of 20 year in Malaysia (James, et al., 2016).

The higher total biomass contribution in the AFS (73-90%) was due to the larger diameter class that stored a large stock of AGC whereas a small amount of AGC has been stored by small diameter class. This result is supported by those reported on native trees in Wenago district (78-82 %) (Seta and Demissew, 2014); in Semi forest coffee system in the Jimma zone Highlands (85 %) (Denu, et al., 2016) and in indigenous AFS on the south-eastern Rift Valley escarpment (77 %) (Negash and Starra, 2015) Ethiopia. On average 44.65 Mg ha^{-1} biomass C contribution was higher than the global tree component contribution in agricultural land (Zomer, et al., 2016).

The variation of biomass C stocks in the present study could be related to stand density (trees ha^{-1}). Moreover, the Khat biomass production was affected due to the loss of leaves and twinges in the three harvesting season. This may have affected the khat plant growth and biomass production. According to Raman (1983), khat grows 15-25 m height when cultivated outside, but it is usually growing 7m height under monoculture crop production. Woldu et al. (2015) also reported khat naturally, a tree crop that can grow up to 15 m or more if left monoculture, but it is often kept to 1.5-4 m, when cultivated as a cash crop in Harrarghe, Ethiopia.

Soil Organic Carbon Stock in Multi Strata AFS and KAF

The present study indicated the SOC stocks in the two studied multistrata AFS were significantly higher than the monoculture KAF. The lower SOC in KAF could be related to frequent and intense leaf biomass removal in the latter, hence, affecting the litter fall, addition of organic materials. Frequently hoeing also facilitates the decomposition rate and easy up take by plant while frequently hoeing also results in higher soil carbon emission. Similarly other studies like Sherrod et al. (2005) and Benbi et al. (2012) also indicated that intensive cropping; site preparation and live biomass removal resulted in lower soil carbon stocks. Moreover, soil organic carbon stock is closely linked to the vegetation, soil types and climate (Rojas, et al., 2012).

The SOC stocks (0-30 cm layer) in the studied agroforestry practices were similar with the findings of Soto-Pinto and Aguirre-Dávila (2015) in Chiapas, Mexico for non-organic poly culture coffee (75.8 Mg C ha^{-1}). However, it was slightly lower than those SOC stocks reported in the shade coffee AFS and falcate shade coffee plantation (Labata, et al., 2012); for organic *Inga* shade and organic poly culture coffee in Chiapas, Mexico (Soto-Pinto and Aguirre-Dávila, 2015) and mixed story agroforestry and taugya at same depth (Labata, et al., 2012).

The total AFS SOC stocks (0-60 cm) in this study was almost similar with the reported under sub-humid *Podocarpus-Croton* mixed AF and it was found to be higher compared with dry transitional woodland (97.5 Mg ha^{-1}), semi-arid acacia woodland (40.3 Mg ha^{-1}) and on farmland average SOC storage to a depth of 50 cm in Southwest Ethiopia (Lemma, et al., 2006*).* While the KAF system SOC stock was comparable value with of coconut (98 .7 Mg C ha^{-1}) and higher than in mango AFS (76 .3 Mg C ha^{-1}) in southern India (Hombegowda, et al., 2016) SOC stocks within the studied agroforestry practices in this study was lower than that of the indigenous agroforestry practices (Negash and Starra, 2015).

The variation of SOC stock in the current study area may be attributed to differences in management, microclimate, plant residues, vegetation and plant species composition, litter inputs and litter quality (Belsky, et al., 1989; Tangjang, et al., 2009). This results from intensive management like slashing, hoeing and collecting of firewood, which reduce input of organic matters. This is a site found under Semi-arid zone of rift valley, with annual rainfall between 400 and 700 m; that may affect the plant species growth and residual decomposition rate. On the other hand, the litter input and quality was higher in coffee agroforestry system as the plant species composition was high. However, in khat agroforestry system liter input and quality is lower than coffee agroforestry system. This may be because khat leaf takes longer time to decompose. Additionally, tree basal area and clay fraction exhibited positive linear correlations with SOC stock which mean increases in SOC stocks resulting from agroforestry establishment are ultimately attributed to higher organic matter inputs from above- and belowground sources (leaves, wood, roots, fungi, animals, etc (Montagnini and Nair, 2004). The seasonal variation in the collection of the soil samples for C analysis would also lead to variation in SOC stocks. For instance, Leite et al. (2014) reported that higher SOC stocks in rainy season than dry season in different agroforestry systems. This means that the humic substance essential to the soil quality is higher at this period and is considered the most stable pool of soil organic matter representing the main reservoir of soil organic matter.

Ecosystem Carbon Stocks and Effects of Land Use Options

The total ecosystem (biomass plus soil) C stock in this study was found to be on average 157 Mg C ha^{-1} that ranges within 96.22 to 251.5 Mg C ha^{-1} across all the three AFS. A comparable report was presented by Schmitt-Harsh (2012) which was conducted in western highlands of Guatemala on mixed dry tropical CAFs (74.0 to 259.0 Mg C ha^{-1}).

If CAF and FAFs converted to KF, the total C stocks would decline by 3-50 % and 8-50 % in the smallholdings, respectively. This is mainly due to high contribution of shade trees with high wood density for the biomass C stock in agroforestry practices. Besides, harvesting of the khat leaf biomass (2-3 times per year) would reduce the biomass C stocks. However, KF system total C stock were higher than total C stock of *Inga* spp. Shade tree coffee agroforestry system and Sun coffee plantation ecosystem carbon stock in Villa Rica, Peru (Ehrenbergerová, et al., 2016). This study also indicated that conversion of KF to CAF and FAFs would increase the soil carbon stocks (0-60 cm) on average by 28 % (28.3 Mg C ha^{-1}) and 24 % (26.7 Mg C ha^{-1}). Brown et al. (2012) study in east and West Africa including Ethiopia found that conversion of rain fed cropland to agroforestry system would increase carbon sequestration by 6-22 t CO_2e ha^{-1} yr^{-1}. The current study showed that shifting AFS to KF is similar to (20 to 30) % SOC loss after conversion from native vegetation to cultivated land (Murty, et al., 2002; Houghton and Goodale, 2004).

Conclusion

Coffee, fruit and khat plants in the study area, besides, income contribution they also contribute to climate change mitigation. The khat ecosystem biomass and SOC stocks were significantly ($p < 0.001$) lower than two AFS (CAF and FAF) systems. Conversion of CAF and FAF to KAF would reduce biomass carbon stocks on average by 60 % and 33 % of total ecosystem carbon stocks, respectively. The tree (fruit plus non- fruit) biomass carbon substantially had a share of total biomass C stocks in the study area. The SOC (0-60cm) stocks were significantly higher than total biomass C stocks in each AFS. This study revealed that maintaining coffee based and fruit coffee based agroforestry practices would better serve to enhance carbon accumulation potential of the agricultural landscape in the study area than khat farming system. Promoting the CAFS and FAFS and shade trees in smallholding farmers, will support large sinks of C and help to mitigate climate change.

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The Contribution of Agroforestry Practices for Food Security in Selected Districts of Amhara National Regional State, North Western Ethiopia

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Abstract

Agro-forestry Practices (AFPs) are believed to provide basic day-to-day needs of farmers; relieve pressure on natural forest and contribute to food security by providing goods and services on sustainable basis. The present study was conducted to know the contribution of AFPs for food security in selected districts of north western Ethiopia. The study involved 201 randomly selected respondents from Ebnat, Farta, Guagusa, Gozamen, Jabitehnan and Burie districts of Amhara National Regional State (ANRS). Data were collected using questionnaire, key informant interview and direct observation. Data were analyzed using SPSS version 22 and both descriptive and inferential statistics were used to interpret the data. The study revealed that 96% of the respondents are engaged in AFPs. About 80% of them got cash income from their AFP mainly from sale of wood and fruits. However, only 56.2% of respondents who got cash income were able to quantify and give information on the amount of money they got from the practice. With regard to the effect of AFP, 64%, 56% and 95% of the respondents stated that AFP affected positively crop, pasture production and improved the local condition/environment respectively. Seventy one percent and 50% of the respondents respectively stated that AFP contributed a lot to food security of the household and reduced complete crop failure. In addition, more than half of the respondents stated that AFP has significant contribution in soil and water conservation. However, about 8% of the respondents replied AFP takes long time to provide these services and products. Therefore, it is important to diversify the species composition especially early maturing fruit trees/shrubs and vegetables in AFP so as to diversify products and shorten the time required for AFP to provide these goods and services after establishment. Research intervention is also required to optimize the benefits of these AFPs. Selection of multipurpose trees to various AFP particularly integrating trees with fodder value, research on tree use, market promotion and product diversification activities are also important to achieve food self sufficiency and maximize products and services that are accrued from AFPs.

Key words: *Community, Farmforestry, Homegarden, Livelihood, Trees on farmland*

Introduction

Ethiopia's economy is mainly dependent on agriculture accounting about 36.2% of the GDP. Since low input and intensive agriculture has a long history in the country, there is substantial depletion of natural resources including forest resources, which resulted in reduction of agricultural productivity mainly due to loss of soil fertility and ecological imbalance. With increasing realization of the environmental crisis and worsening food situation in developing countries, outlooks that are more integrated have begun to emerge. One of these is agroforestry. Agroforestry is a collective name for land-use systems and technologies where woody perennials trees, shrubs, palms, bamboos, etc. are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (Nair, 1993). The association among agroforestry components can be in time and space. These components can also exhibit ecological and economic interactions (Nair, 2005). The capacity of trees to maintain or improve soils is shown by the high fertility status and closed nutrient cycling under natural forest, the restoration of fertility under forest fallow in shifting cultivation, and the experience of reclamation forestry and agroforestry (Young, 2005).

In Ethiopia different traditional agroforestry practices exist in different agro-ecologies of the country. Traditional tree management techniques, woody species mix, and economic and ecological benefits perceived by farmers vary among agro-ecological zones and land use systems of the country. Individual farmers also pursue their own way of species selection and arrangements, which lead to tremendous variation in number, size, and placement of specific component arrangement. Moreover, the structural and functional attributes of components vary between and within agro-ecologies in traditional agroforestry systems and practices in the country. This indicates the need to tap existing knowledge to efficiently utilize scarce resources for better economic and ecological benefits. In this context, Ethiopian farmers have a long history in incorporating/maintaining various tree species in their farming systems although they are not well evaluated or documented. No systematic in-depth study has been undertaken to characterize and fully understand the existing structural and functional attributes of component admixtures and their synergistic interactions as well as their contribution in food security and mitigation of climate change. The present study was conducted to document the contributions of selected AFPs for food security in selected districts of northwestern Ethiopia and to indicate future research direction to optimize the potential merits of these activities.

Materials and Methods

Description of the Study Area

This study was conducted in Amhara National Regional State (ANRS) in the three different agro-ecologies (Kola, Dega and Weynadega) in 4 administrative zones namely: South Gondar, Awi, East and West Gojjam. These areas were selected purposively based on existence of AFP and their representation of different AgEcs. ANRS is located in the central highlands of Ethiopia with a total area of about 17,075, 200 ha and the majority of the region is located in altitudinal ranges of 2000-3000 masl (AFAP, 1999).

In the region, agriculture and settlement has a long history of more than three thousand years (Fentahun, 2008) contributing to loss of large forest resources and resulted in forest cover change from perhaps 40 % or more to less than 1 % within 50 years. Currently, the majority of the forest resources of the region are degraded and only remnant intact forests remain as small patches around churches, monasteries and inaccessible areas (Alemayehu, et al., 2005). Natural forest resources of the region are fragmented and isolated dry Afromontane forests that need special conservation (Alemayehu, et al., 2010). GIS based forest resource assessment of the region showed that only 8.5 % natural forest cover as per EFAP (1994) definition of forest (BoA, 2012). Most of the forest cover of the region is found along the lowland belt of West Gojjam, Awi and South Gondar zones bordering Sudan, Tigray and Benishangul Gumuz Region. The percent coverage of woodlands, natural dense forest, riverine forest, bush lands and plantation of the region, respectively, are 4.71; 2.95; 0.13; 5.66 and 0.40 respectively.

High human population and large number of livestock and free grazing system are the main causes for the destruction forest resource in the region. The human population of the region has been growing by more than 3% yearly since 1984 which resulted in higher demand for agricultural land and wood products. The remaining forest resources of the region have been encroached so as to satisfy the wood and food demand of the farming community (BoA, 2012). Conversion of forest lands and plantation forests to cropland in the region also caused serious soil and nutrient losses (Yihenew and Yihenew, 2013).

To alleviate the destruction of the forest resources and accompanied environmental and socio-economic problems, forest protection and forest development has been practiced for long. And also both traditional and modern AFPs have been conducted for long period of time. Different reports indicate that people are getting different uses and services from these practices, though, not scientifically described. The contribution of these practices to food security and climate change adaptation and mitigation is also not known. Therefore, the present study was conducted to fill these knowledge gaps and provide information for decision makers.

Data Collection and Analysis

First, reconnaissance survey was conducted to assess the potential traditional agro-forestry practices in the three agro-ecology zones of ANRS. Secondary information was collected from reports, maps, censuses, thesis and other publications to have an overall picture of AFP and the study district across the different agro-ecology of the region. Multistage sampling technique was employed to select sample study areas. Specific sites for the study were identified in collaboration with a multidisciplinary research team, local people and administrative bodies. Accordingly, four zones (South Gondar, Awi, East Gojjam and west Gojjam) were purposively selected based on the existence of traditional agro-forestry practices and representing the three major traditional agroecologies of the regions. Sample districts were selected from each selected zones and from each agroecology of the region. Accordingly, *Ebnat, Farta, Guagusa, Gozamen, Jabitehnan* and *Burie* districts were selected (Table 1).

Table 1: Study districts selected for the study

S. N	Zone	District	Latitude	Longitude	Elevation (m asl)	Agro-ecology
1	South Gondar	Ebnat	12°18'32.1"N	038°16'28.3"E	1912	Kola
		Farta	11°47'02.9"N	038°59'00"E	2870	Dega
2	Awi	Guagusa	10°46'20.1"N	037°03'22.2"E	2456	Dega
3	East Gojjam	Gozamen	10°15'35.7"N	037°32'57"E	2213/2523	Dega/Woyna Dega
4	West Gojjma	Jabitehnan	10°41'10.2"N	037°10'51.2"E	1979	Woyna Dega
		Burie	10°38'53.52"N	037°05'08.64"E	2002	Woyna Dega

From these districts, 8 Kebeles (*Balarb, Awuzet, Gassay, Shinkurta, Giraram, Chertekel, Mankusa and Adelagata*") which have traditional AFP were selected so as to represent the three traditional agro-ecologies of selected districts (Table 2). Within each *kebele* (smallest administrative unit), sample "*gots*" (sub units of kebele) were selected for data collection.

Table 2: Sample districts and kebeles selected for the study

S/N	Zone	District	Kebele	Agro-ecology
1	South Gondar	Ebnat	Balarb	Kola
		Farta	Awuzet	Dega
			Gasay	Dega
2	Awi	Guagusa	Shinkurta	Dega
3	East Gojjam	Gozamen	Giraram	Dega
			Chertekel	Woyna Dega
4	West Gojjam	Jabitehnan	Mankusa	Woyna Dega
		Burie	Adelagata	Woyna Dega

Total number of households in each "*kebele*" was obtained from respective districts and the actual number of households in each "*got*" were collected from "*kebele*" offices so as to determine the number of respondents in each study area. The total sample size was determined using the following formula.

$$n = N / (1 + N (e)^2)$$

Where; n= Total sample size of the study, N=Total number of house hold in all sample kebeles, e= Level of precision, 1= the probability of event occurring

Proportional sample size formula (Singh, 2014) with 5-10% level of precision was used to determine the number of respondents in each Kebele and got.

$$ni = \frac{\mathbf{n(si)}}{\mathbf{N}}$$

Where; ni= sample size of each kebele; N=total number of house hold in all sample Kebele; n= total sample size of the study; si= total house hold of each Kebele.

Households in each *Got* were selected randomly to administer the questionnaire. Accordingly, a total of 201 respondents were selected to administer the questionnaire.

Secondary data were collected from district and zonal agricultural offices. Informal survey was also conducted to have an insight on traditional AFP and other related activities of the study areas. Formal survey was conducted to collect data from the selected *Kebeles* mainly through questionnaire and focused group discussion (FGD). Key informant interview was also conducted to get more concrete information about the practice. The questionnaire was pre-tested for its consistency, logical flow and length and corrected as per the feedback obtained from the test. The type of data collected among others include species planted, form of plantation, purpose of plantation, niches for planting AF species, major AF components, share of AGF in the household income, types of management on AFP, major problem and solutions undertaken, effect of trees on the performance of other AGF components, type of fruit trees species and the parts that are edible, area and percentage of land occupied by AFP, contribution of AGP for food security, perception and knowledge of the farmers on the contribution of AFP for economic, social and ecological purposes.

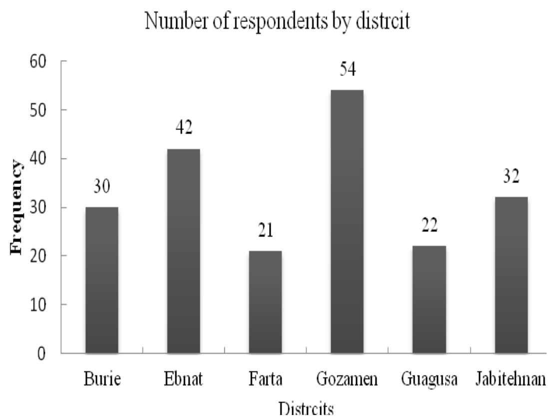
Data Analysis

The filled questionnaires were coded and entered in to SPSS (version 22) and both descriptive and inferential statistics were used to analyze the data. Responses from open ended questions were summarized and used to enrich and supplement information collected through discussion and closed ended questions.

Results and Discussion

Respondent Information

Number of respondents by different categories such as age, sex, marital status, agro-ecology, educational status, family size, landholding size and other parameters were assessed in order to see their relationship with AFPs being implemented by the local farmers in the region. Since the number of respondents in each district was selected with proportional sample allocation method, the majority of the respondents (27%) were from Gozamen district (Figure 1). The respondents aged between 20-65 years. Thirteen percent of the respondents were 20-30 years old. Those respondents who are more than 60 years old were only 7% (Figure 2). In terms of agro-ecology, higher number of respondents was selected from Dega and Woyina Dega agroclimatic zones of Ethiopia (Figure 3). With regard to marital status, almost all of the respondents were married while 8 and 3 respondents were widowed and divorced respectively (Figure 4).



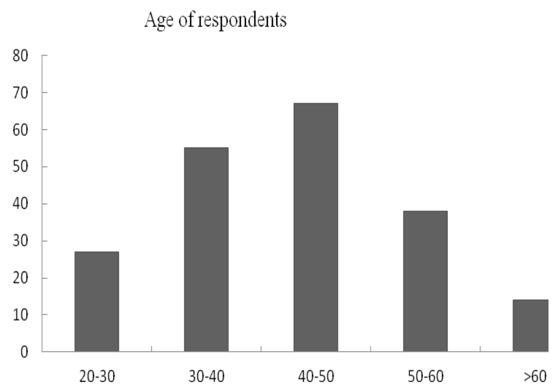
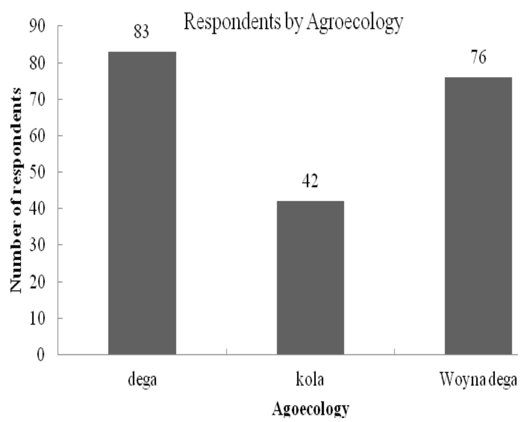


Figure 1: Respondents by District

Figure 2: Age category of respondents



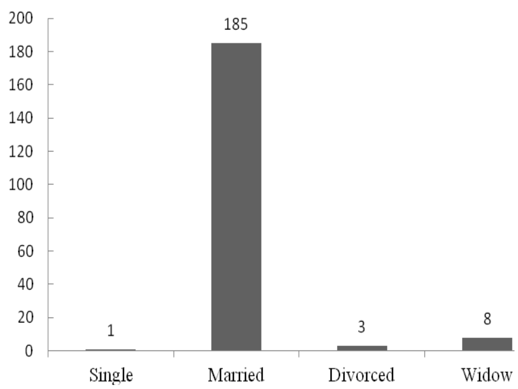


Figure 3: Number of respondents from each AgEc

Figure 4: Marital status of respondents

Average landholding size of the respondents was 1.18ha; however, the farmers allocate significant size of their lands to AFPs in order to get different products and services that can be accrued from the practice. Percentage of farmland allocated for AGF.

The Contribution of AFP as a Means of Livelihood to the Local Community

Form the total 199 valid responses, only 60 respondents replied that they have been supporting their livelihood by selling AF products. Only one respondent mentioned that forestry is the first priority in providing means of survival for his family while 19, 22, and 16 respondents replied that selling of forest products is 2nd, 3rd, and 4th priority respectively in being means of survival for their family through the provision of goods and services. The relative contribution of plantation forest to livelihood improvement was also compared with other economic activities of the respondents such as crop production, livestock and possible combinations in the form of AFPs, and it was found out that 10, 62, 49, and 19 respondents mentioned block plantations as the 1st, 2nd, 3rd and 4th priority, respectively, in its contribution for livelihood improvement. From the overall response, it is possible to generalize that AF and forestry practices have significant contribution in providing good and services for livelihood improvement of the local community. Sole crop production was found as the first priority as a means of survival for the majority (90.5%, n=201) of the respondents. Only 8.5% and 1% of the respondents mentioned crop production as the 2nd and 3rd priority, respectively, in being means of livelihood.

Type of AFP in the Study Areas

From 201 respondents, 193 respondents (96%) are engaged in agro-forestry practice (Table 3). The dominant AFPs (*ca.* 79%) practiced by these farmers is homegarden, followed by planting trees on farmland. However, there is problem on the diversity of the species. It was only 103 tree/shrub species encountered as agroforestry components across all study districts, the dominant species being *Rhamnus prinoides* followed by *Cordia africana*. The number of persons who are involved in planting fruit trees is limited. Even, the diversity of and number of fruits trees per household is very limited. The study revealed that 53% of the respondents were not involved in planting any fruit tree and shrub (either wild or domesticated) species for the purpose of consumption or income generation. Therefore, it is of a paramount importance to increase the motivation of the framers in AFPs by introducing more number of fruit trees since increasing motivation is the first step to designing appropriate farm forestry options (Reid and Stephen, 2001).

Table 3: Number of respondents involved in AFP

Response	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	193	96.0	96.0	96.0
No	5	2.5	2.5	98.5
Not response	3	1.5	1.5	100.0
Total	201	100	100	

With regard to the number of trees planted by the farmers in each district, significance difference ($p < 0.00$, $\alpha = 0.05$) among the districts was observed on the mean number of trees planted per household. The highest number of trees per household (8) was recorded in Jabitehnan district followed by Bure and the lowest was recorded in Ebinat district (Table 4).

Table 4: Mean number of trees planted per household in the study districts

S/N	District	Number of respondents	Mena of No. of trees planted per household $\pm$ SD
1	Burie	30	7.53$\pm$2.81
2	Ebinat	42	4.976$\pm$2.042
3	Farta	21	5.667 $\pm$3.246
4	Gozamen	54	5.296$\pm$ 2.826
5	Guagusa	21	5.048$\pm$ 2.418
6	Jabitehnan	29	8.000 $\pm$ 2.94
	Grand mean	197*	5.98$\pm$2.7

**Note: Four respondents who did not give appropriate responses*

Highly statistical significance difference ($p < 0.00$, $\alpha = 0.05$) was also recorded among the different agro-ecologies. The highest mean number of trees per HH (*ca*. 7) was recorded in mid altitude (Woyina dega) areas while the lowest was recorded in low altitude (kola) and high altitude (dega) altitude areas (Table 5).

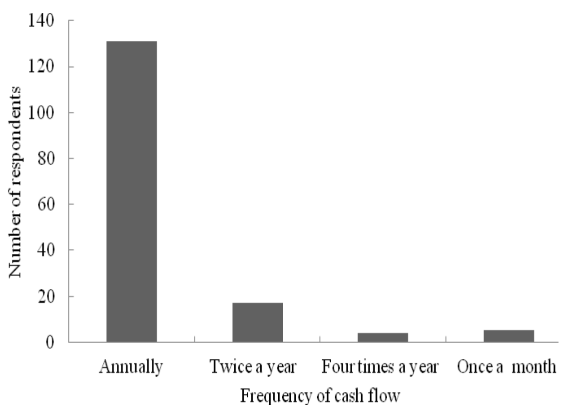
Table 5: Mean number of trees planted per household by Agro-ecology

S/N	Agro-Ecology	Number of respondents	Mena of No. of trees planted per household $\pm$ SD
1	Dega (High altitude)	72	4.958 $\pm$2.575
2	kola (low altitude)	42	4.976$\pm$2.042
3	W. Dega (mid altitude)	83	7.373$\pm$ 3.027
	Grand mean	197*	5.98$\pm$2.7

**Note: Four respondents who did not give appropriate responses are excluded from the analysis*

With regard to cash income generated from AFP, about 80% (n=201) of the respondents stated that they get cash income from AFP on their farmland. But only 113 (56.2%) respondents were able to quantify the monetary value of products they get from their AFP. The amount of income from AFP ranges from 100 to 50,000 ETB per year. The lowest and highest cash income was recorded from Burie district. The highest value (50,000) was also recorded from Burie and Gozamen mainly from the sale of Eucalyptus poles and coffee. These products are obtained on different frequencies. The majority (65.2%, n=201) of the respondents got cash income from AFP on annual basis. Only 5 respondents got cash income from the sale of agro-forestry products on monthly basis (Figure 5). This may be attributed to lack of fruit and other short rotation crops which can provide food and other products within short period of time.

Fruits and short rotation crops are important to supplement food during food shortage periods. Since significant number of respondents (30%, n=201) face critical food shortage (Figure 6).



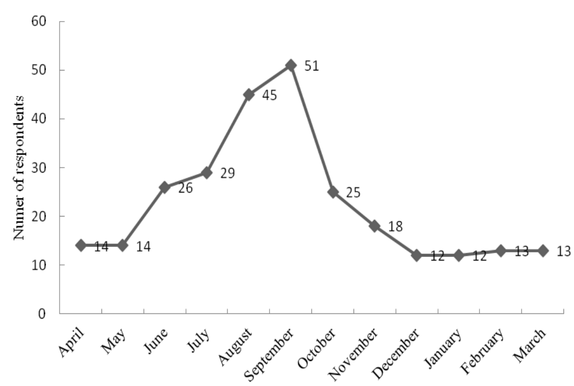


Figure 5: Timing of cash flow from AFPs   Figure 6: Food shortage periods

Therefore, it is of a paramount importance to diversify the species composition and look for fruit bearing tree species so as to augment food shortage periods. The study also revealed that the majority of respondents get mix of products from AFP (Figure 10). However, there is a need to diversify species and increase the proportion of multipurpose tree species. The type of fruit and commercial fruit trees and other NTFPs trees/shrubs planted by the local farmers also vary with locality. However, the overall assessment of the response revealed that the three most dominant fruits trees being planted by the local community are apple, mango avocado and orange followed by coffee and banana (Figure 7).

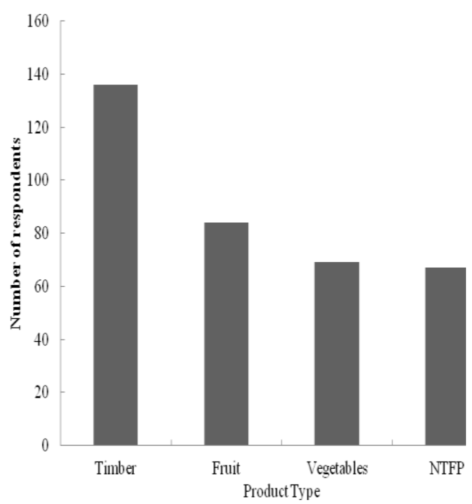


Figure 7: products from AFP

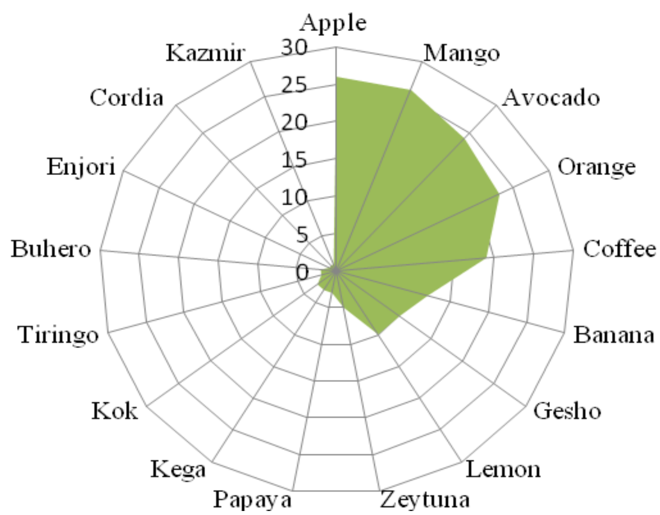


Figure 8: Fruit trees planted

With regard to planting niches of fruits trees and shrubs, about 93% of the fruit trees or shrubs are planted around homes in the form of homegardens. The remaining (7%) of the fruit tree/shrubs are planted on farmlands mostly at irrigated areas. This may be due to the fact that there are free grazing problem and water shortage in farmlands far from homes. With regard to the type of AFP contributing most to livelihood, more than half of the respondents stated that agrosilvopastoral system is contributing most to livelihood improvement followed by agrisilvicultural systems. The type of agro-forestry practice contributing least to food security is silvipastoral system, a system consisting of tree and pasture production. There were only 5 respondents who selected tree silvipastural system as the first priority in contributing to livelihood improvement.

Management Practices being implemented by the Local Community on AFP's

About **93.5%** of the respondents replied that they give care to agro-forestry practices. The type and intensity of management the farmers are implementing varied with the type of AFPs. Cultivating, watering, pollarding, and fertilizing with manure and weeding in order of importance were the major types of management on homegardens (Table 6) while pollarding, fencing and lopping are practiced on farmlands (Table 7). However, there is limitation on the frequency of management they are practicing. About 71.3 % of respondents who are practicing AF do care to their practices only sometimes. It was only 27% of the respondents who are practicing agro-forestry responded that they give due care to their AFPs on daily basis.

Table 6: Type and frequency of Management on homegarden

S/N	Type of Management	Frequency	Rank
1	Manuring	98	4
2	Hoeing	214	1
3	Watering	135	2
4	Coppice handling	17	6
5	Weeding	65	5
6	Pollarding	115	3

Table 7: Type and management frequency of tree on farmlands

S/N	Type of Management	Frequency	Rank
1	Fencing	55	3
2	Pollarding	163	1
3	Pruning	76	2
4	Weeding	11	5
5	Lopping	16	4

One of the reasons for the low productivity of AFPs in various parts of the region may be due to lack of proper management. Tree management practices can help the development and improvement AFPs. Once established, the timely use of various tools such as fertilizer application, pruning, fire and thinning can help direct future growth in any number of ways (Reid and Stephen, 2001).

Effect of AFPs on Crops and Pasture

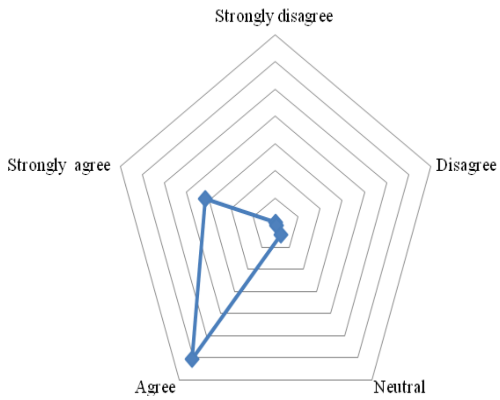
When the farmers were asked about the effect of AFPs on crops, about 64% of the respondents replied that AFP affects crops positively. However, significant number of respondents (22%, n=201) mentioned that AFP does not have any effect on crops. With regard to the effect of AFPs on pasture, about 56% of the respondents mentioned that AFP affects pasture positively. However, significant number of respondents (38%) mentioned that AFP does not have any effect on accompanying pasture (Table 8).

Table 8: Response of respondents on the effect of AFPs on pasture

S/N	Response	Frequency	%
1	No effect	77	38
2	Positive	112	56
3	Negative	8	4
4	No response	5	2.5

Effect of AFPs on Soil and Water Conservation, Maintaining Soil Fertility, Surrounding Condition Environment

More than half of the respondents agreed that AFP has significant contribution in soil and water conservation and nearly 30% of the respondents strongly agreed that AFP can help in conserving soil and water. With regard to the effect of agroforestry on soil fertility, about 60.7% of the respondents agreed that AFP increases soil fertility, while only 1.5% of them stated that the practice does not increase soil fertility (Figure 9). This also indicates that there is a problem on tree/shrub species selection for the purpose. Therefore, it is of a paramount importance to screen tree species, which will have positive effect on soil. It is also important to create awareness on the role of agroforestry to soil fertility since some of the farmers (4%) were neutral in responding to the role of AFP on their farmland.



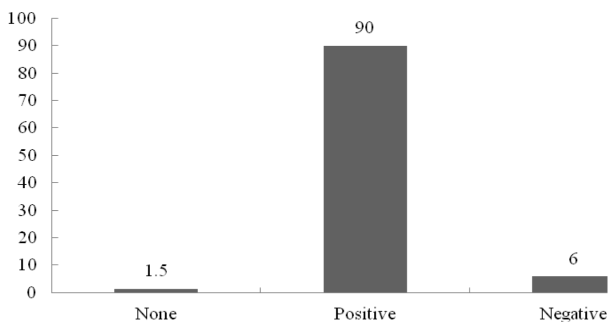


Figure 9: Response on "AFP Increases Soil fertility"   Figure 10: Response on "Effect of AFP on environment"

When the farmers were asked about the effect of AFP on environment, about 90% of the respondents responded that AFP has positive effect on the environment and improved the surrounding condition (Figure 11). This indicates that farmers are better aware of the role of AFP on the environment.

With regard to the role of AFP in maintaining /improving the environment, 95% of the respondents agreed that AFP maintains/improves the surrounding condition (Table 10). However, there were few people who responded that AFP does not maintain or improve the environment. In general, among the various knowledge areas that were assessed, the knowledge of farmers on the role of AFP in improving the surrounding condition in many dimensions was better than the other. This implies that it is of a paramount importance to create awareness about the role of AFPs in providing good and services. Nevertheless, this will be possible if people are using appropriate species, manage properly and become aware of the various services and products that can be accrued from various AFP.

Table 10: Role of AFPs in maintaining /improving the surrounding condition

Response	Percent	Frequency	Valid Percent	Cumulative Percent
Strongly disagree	1.0	2	1.0	1.0
Disagree	.5	1	.5	1.5
Neutral	1.0	2	1.0	2.5
Agree	63.2	127	63.2	65.7
Strongly agree	31.8	64	31.8	97.5
Don't know	2.5	5	2.5	100.0
Total	100.0	201	100.0	

Role of AFPs to Household Nutrition and Family Income and Contribution to Food Security

When the farmers were asked about the role of Agro forestry practice to food security, 71% of the respondents replied that AFP is contributing a lot to food security of the household. It was only 21% of the respondents who replied that AFP has little contribution to household food nutrition (Table 11). In general, it was found out that there is a need to diversify the species composition of AFP and increase the proportion of food/fruit trees in agro-forestry components.

Table 11: Response on the role of AFPs to household nutrition

Response category	% of Respondents	Number of Respondents
None	2	4
A lot	71	143
Little importance	21	43
No response	6	11
Total	100	201

Role of AFP on Farm Income

About 72% of the respondents agreed that AFP increased farm income despite the fact that their agreement was not strong. Only three respondents strongly disagree with the idea that AFP increased farm income (Figure 11).

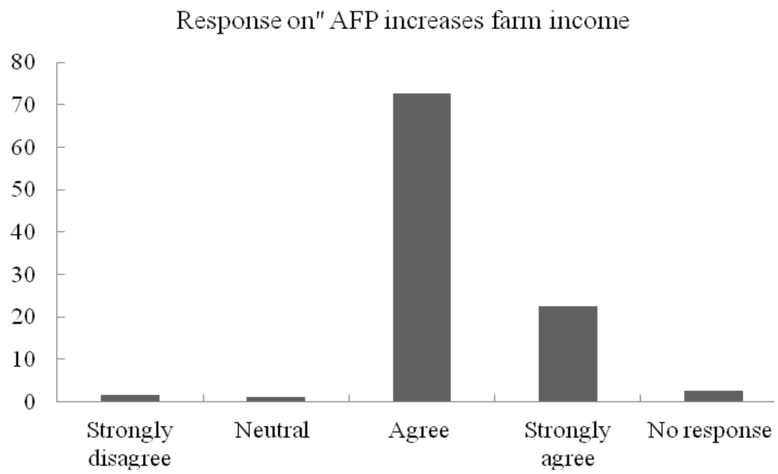


Figure 11: Response on "AFP increases farm income"

It was also found out that from the total number of respondents 114 respondents replied that they are generating significant amount of income from their AFP. The amount of income in ETB generated from AFPs ranged from 100 to 50000 ETB, where as the average income generated per year was found to be 6000 ETB. Though, the farmers are generating income from their farmland, the diversity and amount of income is not much as compared to other agroforestry practices carried out in other parts of the country such as the southern part of Ethiopia. Therefore, it is of a paramount importance to diversify the species composition and increase the contribution of AFP to food security and to reap other benefits that can be accrued from the agroforestry practices. Different authors described the importance of different AFPs for food security. Tree planting through agroforestry and social forestry are an integral part of rural development programs and should provide the community with food, fuel wood, income and environmental benefits (Badeg Bishaw, 2001).

Role of AGF in Reducing Complete Crop Failure

With regard to the contribution of AFP in reducing complete chance of crop failure, half of the respondents replied that the practice reduces complete crop failure. However, significant numbers of respondents (20%) were neutral in responding this question (Table 12). This indicates that either the local people did not have information about the role of AFP or the species they are using are not appropriate to get the required purpose. Therefore, it is of a paramount importance to screen tree/shrub species suitable for a particular use. First, most of the plantation activities in Ethiopia are not planted with specific objectives. The seedling survival and plantation success assessment carried out during 2016 in ANRAS in particular and the country at large revealed that the majority of plantations especially individual plantation do not have clear objectives and management plan. The species planted in different AFP may have the same situation. Even, there were some farmers (about 10%) who stated like "AFP does not help in reducing complete chance of crop failure". This means that the practices are not providing the necessary uses and services and bring synergetic effect and reduce crop failure.

Table 12: Response of farmers on the role of AFPs in reducing complete crop failure

Response category	Frequency	Percent	Valid Percent	Cumulative Percent
strongly disagree	4	2.0	2.0	2.0
disagree	17	8.5	8.5	10.4
Neutral	40	19.9	19.9	30.3
Agree	101	50.2	50.2	80.6
strongly agree	33	16.4	16.4	97.0
No response	6	3.0	3.0	100.0
Total	201	100.0	100.0	

Role of Afps in Saving Time Needed for Collecting Fodder and Fuel Wood from the Forest

With regard to the role of AFP in saving time to collect fodder and fuel wood, 85% of the respondents replied that AFP reduced the more time required for collecting fodder and fuel wood (Table 13). Since women and youth are more responsible in providing fuel wood, AFP will have great contribution in reducing women and youth workload, thereby contributing fair distribution of education and producing healthy society and community. However, it is of a paramount importance to diversify the species composition of AFPs.

Table 13: Response on AFPs saves time needed for collecting fodder and fuel wood

Response category	Frequency	Percent	Valid Percent	Cumulative Percent
strongly disagree	4	2.0	2.0	2.0
disagree	2	1.0	1.0	3.0
Neutral	15	7.5	7.5	10.4
Agree	118	58.7	58.7	69.2
strongly agree	56	27.9	27.9	97.0
No response	6	3.0	3.0	100.0
Total	201	100.0	100.0	

In this study about 58% agreed that AFP takes long time to give services and products (Figure 12). It is known that AFP usually does not provide products and services within short period of time. Therefore, it is of a paramount importance to select the best performing and early maturing tree species so that farmers will be more interested in planting tree species.

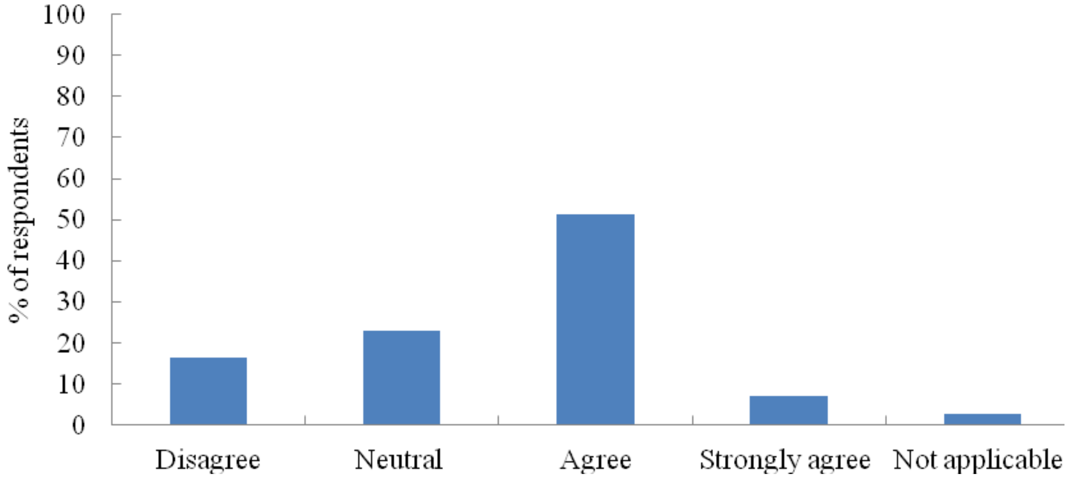


Figure 12: Response on "AGP takes long time to provide income"

Seedling Production of Multipurpose Tree Species by the Local Community

In this study, it was also revealed that about ***39%*** of the respondents raise seedlings of multipurpose tree and shrubs on their private nursery for their use and for sale. However, about 59% of the respondents are not involved in raising tree seedlings for various reasons. Therefore, those farmers are dependent on other source of seedlings. The result is similar with the seedling survival and plantation success assessment that was carried out by MEFCC in Collaboration with Ethiopian Environment and Forest Research center in 2016 in selected districts of ANRS. During the assessment it was found out some local people are producing seedling by them.

It is becoming one of the business areas for some people in some districts of the region. The major reasons for not raising seedling are water shortage, land shortage, lack of technical knowledge, and lack of seeds for fruits tree/shrub species on the production of seedlings especially fruit tree/shrub species.

The respondents mentioned lack of technical support as one of the major reasons for not involved in trees seedling production. It was also revealed that about 74% of the respondents who raise tree seedlings (29% of the total respondents n=201) got technical support from experts on how to raise and manage tree seedlings in the nursery. More than 50% of the respondents involved in raising tree seedlings produce seedlings both for private use and for sale.

Another major challenge for the production of tree seedlings is lack of water supply. This problem was mentioned by nearly 50% of the respondents. This problem has to be solved through constructing water harvesting structures, pond construction, river diversion or any other water source. Technical and financial support should be provided to the local community in their efforts to solve these problems. Different bodies such as government, NGOs and others can be involved in providing support. To solve lack of fruit tree seedling supply, it is necessary to promote and support private seedling producers. Most of the seedlings raised by the local farmers in the study districts are *Eucalyptus* and the proportion of indigenous tree seedlings is very limited. It is know that, exotic tree species and indigenous species have their own pros and cons. In order to get the maximum benefit out of plantation efforts, it is necessary to diversify the species composition through the promotion of indigenous tree seedling production and plantation. Moreover, it is also important to create awareness on the value of indigenous tree species. The diversity of the tree species planted by the local communities varies considerably with agroeclogy and study districts.

3.10. Major Problems Encountered In Practicing AF in the Study Areas

There were different problems mentioned by the farmers they encountered while practicing AFPs in their respective areas. The major problems faced by the farmers in practicing AF in study areas vary from place to place. From the overall assessment, it was found out that the major problem mentioned by the farmers is water shortage during the dry spells of the year which resulted in drying of the tree seedlings after they are planted out in the field. The second, third and fourth major problems reported by the respondents were lack of planting materials especially fruit tree seedlings, (labor, land shortage and wildlife damage) and technical knowledge gap on establishment and management of AFPs (Figure 13).

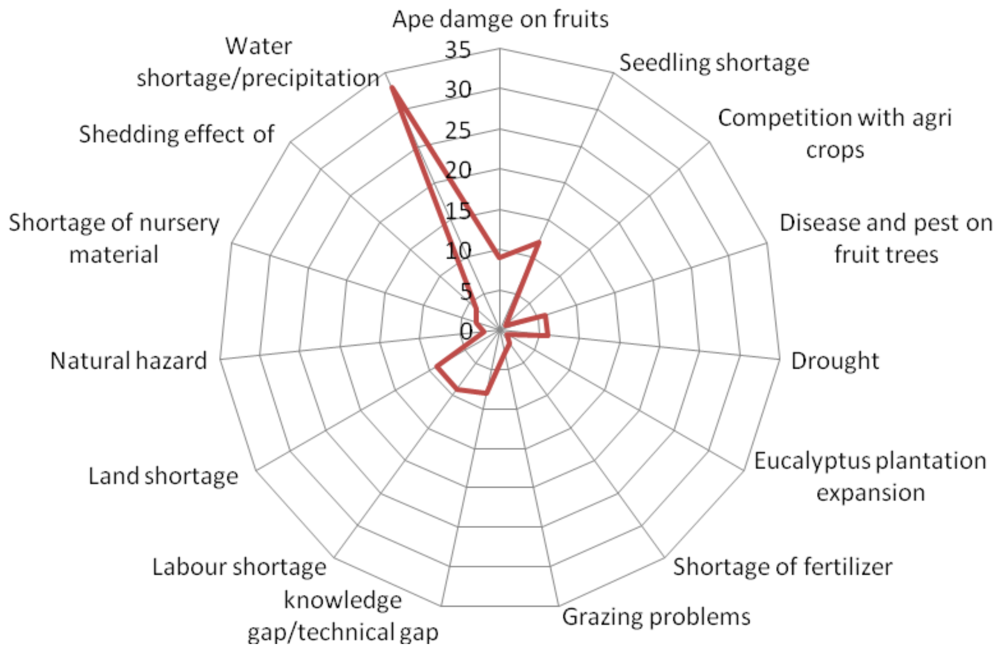


Figure 13: Magnitude of problems encountered in AFPs in study areas: Preferred tree species for varies uses and services

Most planted trees species across all agroecologies and study districts is *Codia african*a followed by *E. globulus* and *Sesbania sesban*. The species most planted for different uses and services are the following: for beauty purpose, *Sessbania sesba* and *Chamacytus palmensis* are the most planted species, while *Rhamnus prinoides*, coffee, Eucalyptus species and *Cordia africana* were the species planted with highest frequency planted for income generation. *E. globulus* and *E.camaldulensis* are the species planted with highest frequency for construction purpose. In addition to construction purpose, *E. globulus* is also the top priority species used for fuelwood. With regard to soil fertility management, *Sesbania sesban* was mentioned with the highest frequency followed by

Croton macrostachyus and *Chamacytus palmensis.* In addition to providing other uses and services, *Sesbania sesban* and *Chamacytus palmensis* were the top species used by the local as source of fodder for their livestock and as biological soil and water conservation. Through, the type of disease and way of application was not mentioned, *Vernonia amygdalina* and *Cordial africana* were mentioned as medicinal plants used by the local people.

Conclusion and Recommendation

The study revealed that almost all of the respondents (96%) are engaged in agro-forestry practice and AFP is contributing more to food security of the community in the study districts. The dominant AFPs (about 79%) practiced by these farmers is homegarden, followed by planting trees on farmland. There are different uses and services being provided by these AFP and famers allocate significant amount of land for AFPs. More than half of the respondents (60) respondents stated that they have been supporting their livelihood by selling agro-forestry products. The study revealed that from the total 199 valid responses, only 60 respondents have been supporting their livelihood by selling AF products.

In general, it was found out that AF and forestry practices have significant contribution in providing goods and services for livelihood improvement of the local community. Surprisingly, more than half of the respondents are not involved in planting of any fruit trees on their farmland. The amount and proportion of fruit trees planted in AFPs was highest in highland and lowlands. AFP for food security would have been better if more cash generating and fruit trees are included and their proportion is increased especially in the highland and lowland areas. Mid altitude areas such as Burie and Jabitehnan have better fruit tree and other income generating species than the other study districts. July to October is the period where there is critical food shortage for the majority of the respondents. However, the availability of income and other products from the AFPs is very low. Apple, mango, avocado orange, coffee and banana in order of importance are major fruits and cash crops being produced by the local community.

Despite, the fact that more number of respondents (93.5%) are managing their AFPs, the type and quality of management were found not to be diverse and satisfactory. Though, farmers are managing their AFPs, type of management being practiced by the local community is not diverse and quality is not satisfactory. With regard to the effect of management on the effect of trees, more than half of the respondents do agree that AFP have positive effect on crops, soil, and environment, significant number of respondents also state AFPs have negatives effects. This problems need to be resolved though research. There are also respondents (22%, n=201) who responded that AFP does not have any effect on crops.

A number of problems such as lack of water, lack of seedling supply, wildlife damage and labor shortage were mentioned by the respondents as major factors that hinder AFP development is in the majority of the study districts. Farmers are aware of the multiple uses and services of agro forestry practices; however, they are constrained by species choice and management technologies.

Recommendation

- It is necessary to screen tree species for particular uses in different agro forestry practices. Further study is required to screen multipurpose tree species for different AFP. In dry land areas of Ethiopia in Ebinat, the species are not known and studied properly, that is the reason why most of the tree species are called by their vernacular names.
- More awareness creation is required in order to expand and improve different AFP.
- It is also necessary to look for early maturing fruit and shrub species so as to shorten the time taken to generate income from AFP.
- It is necessary to arrange credit access for the development of fruit based AFP.

- Timely and frequent management of AFP such as weeding and pollarding is necessary to maximize the services and products and minimize the negative impacts of the common AFPs in the study areas.
- There has to be reliable seedling supply, low price and equitable distribution of seedlings for sustainable development of AFP
- Model AFPs have to be established so that the local people will learn from.
- Technical support has to be provided in better way for better development of AFPs in the study areas in particular and the region in the general.
- As there is land shortage for the development of AFPs and seedling production, allocating communal land/mountain areas will relive and cut down the problem. Land availability and secure tenure is important to foster farmland tree planting and promote farmers to involve in resource conservation activities (Badeg and Abdu, 2003).
- Watering the seedling especially commercial and fruit tree seedlings during the dry periods of the year may increase the survival of seedlings, even to the extent of construct. Water harvesting structures may be one of the solutions to increase the survival of seedlings and increase fruit production. River diversion may be also one of the solutions. Using drought tolerant species may be also one of the solutions for poor or lack of water supply.
- Standard way of establishing AGPs is necessary since most of the AGF are traditional.
- It is necessary to stop or reduce free grazing through integrated livestock production, management and forage production.
- Wildlife damage (ape) especially in Jabitehnan district has to be resolved. Farmers were very much desperate since they loss almost all of their fruit production.
- Technical support on how to cut trees and fruits is necessary since disease and pests are occurring because of bad harvesting and management techniques

- In order to solve the soil fertility problem reported on AFPs by the local community, for it is of a paramount importance to produce compost and add manure locally.

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Assessment of Biomass and Soil Carbon Stocks of Agroforestry Systems and Adjacent Cultivated Land, in Cheha District, Gurage Zone, Ethiopia

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Abstract

The present study examined biomass and soil carbon stock potentials of different AFS (homegarden and woodlot) and cultivated land in Cheha Wereda, Gurage zone, Ethiopia. The sites were selected based on dominance and accessibility through reconnaissance survey prior to sampling. A total of 60 sample plots (20 plots from each land use type) of 20 m x 20 m were randomly selected. Above ground biomass and below ground biomass were calculated by adopting available site and species allometric equations. A total of 120 Soil samples (0–20 and 20-40 cm) were also collected from selected cultivated lands using to determine soil organiccarbon (SOC), pH, texture and bulk density. Additional 120 soil samples were collected to determine soil bulk density. The results showed that the total ecosystem carbon stocks in homegarden and woodlot AFSwere estimated at 100.4 and 72.9 Mg C ha^{-1} respectively. The SOC stock was significantly different among the studied land uses.The highest SOC stock was recorded in homegarden agroforestry system (94.2 Mg C ha^{-1}) followed by cultivated land (73 Mg C ha^{-1}) and woodlot agroforestry (68 Mg C ha^{-1}). The total ecosystem carbon stock ranged between 55 -140 MgC ha^{-1}. Homegarden holds the highest contribution for both biomass and SOC for total ecosystem carbon accounting 84.3% for total SOC and the remaining for total biomass. Homegarden AFS has the highest SOC stock. Conversion of homegarden Agroforests to cultivated land would decrease SOC stock by 23% and wood lots to cultivated land would increase SOC by 7%. The study also revealed that AFS enhance carbon stocks accumulation both in the biomass and soil besides the socioeconomic benefits over cultivated land. Hence, AFS can be taken as potential climate change mitigation strategy in central highlands of Ethiopia.

***Keywords**: Carbon stocks, Agroforestry, Cultivated land*

Introduction

Forests ecosystem and some other ecologically and environmentally sustainable land uses act as a sink for carbon dioxide (CO_2) through photosynthesis and storing carbon as biomass (Benites, et al., 1999) .Biomass and soils also act as a sink through reducing the amount of CO_2 in the atmosphere, thus both vegetation and soils provide benefit to the global carbon balance (Kort and Turnock, 1999). Therefore, land use management is an important option in reducing CO_2 concentration. Agroforestry systems have been recognized to sequester carbon and have therefore gained attention from both industrialized and developing countries (Makundi and Sathaye, 2004; Takimoto, et al., 2008).

Agroforestry system comprises one or more agricultural and forestry systems with beneficial effects by creating biological, socioeconomic and ecological interaction among trees or shrubs (woody perennials) with crops and/or animals. The major components of agro forestry systems are trees, shrubs (woody perennials, including bamboos) and animals. These are intentionally retained or planted on the farmland to provide multiple products as a source of income generation and house hold consumption and other ecosystem services including carbon sequestration, biodiversity conservation, improving soil fertility and reduce erosion hazards (ICRAF, 2006). Besides the economic contribution, carbon stock studies in agroforestry systems (AFS) ensures the significance of the system for global carbon balance and enhance the potential of farmers in AFS expansion considering the fact that many of AFS are changing to mono cropping land use system.

Forest ecosystem in particular agroforestry systems play a significant role in global climate change mitigation strategy, as the source of income and ecological benefits. Though several efforts have been made to reduce carbon dioxide emission through forestry sector like afforestation and enhancing agroforestry systems most of them are unaccounted locally to show the contribution of the systems. Gurage zone, Cheha Woreda was selected since it incorporates diversified Agroforestry systems and cultivated lands.

This study largelyaimed in assessment of biomass and soil carbon stocks accumulation potentials of AFS and adjacent cultivated land in Cheha District, Gurage Zone and Central Highland of Ethiopia. The study Explicitly intended to estimate and compare above and belowground biomass carbon stocks of home garden and woodlot AFS it also aimed to determine and compare soil organic carbon stocks of the two AFS and cultivated land at large to determine and compare total ecosystem carbon stocks (biomass plus soil) of home garden and woodlot AFS.

Materials and Methods

The study was conducted in Cheha Wereda, located in Gurage Zone of Southern Nations, Nationalities and Peoples Regional State (SNNPRS), Ethiopia. The geographical location of the study area is between 8° 00' 18" and 8° 15' 28" N and 37° 35' 46" and 38° 03' 59" E (Figure 1); and the average elevation ranges from 1950-1970 meters above sea level. Based on information obtained from the Cheha Woreda Agriculture and Rural Development Office, the area is characterized by bimodal rainfall pattern '*Kiremt*', is the main rainy season, extends from June to September with the peak rainfall occurring during July and August. The short rainy season called '*Belg*' stretches from March to May. However, the short rains are highly erratic in nature that farmers do not rely on them for grain production. The mean annual rainfall obtained from the monthly data on the bases of ten years of records at the neighboring meteorological station (Imdibir, Gubre and Wolkite) is 1268 mm. The mean monthly maximum and minimum temperatures are 25 °C and 11 °C, respectively.

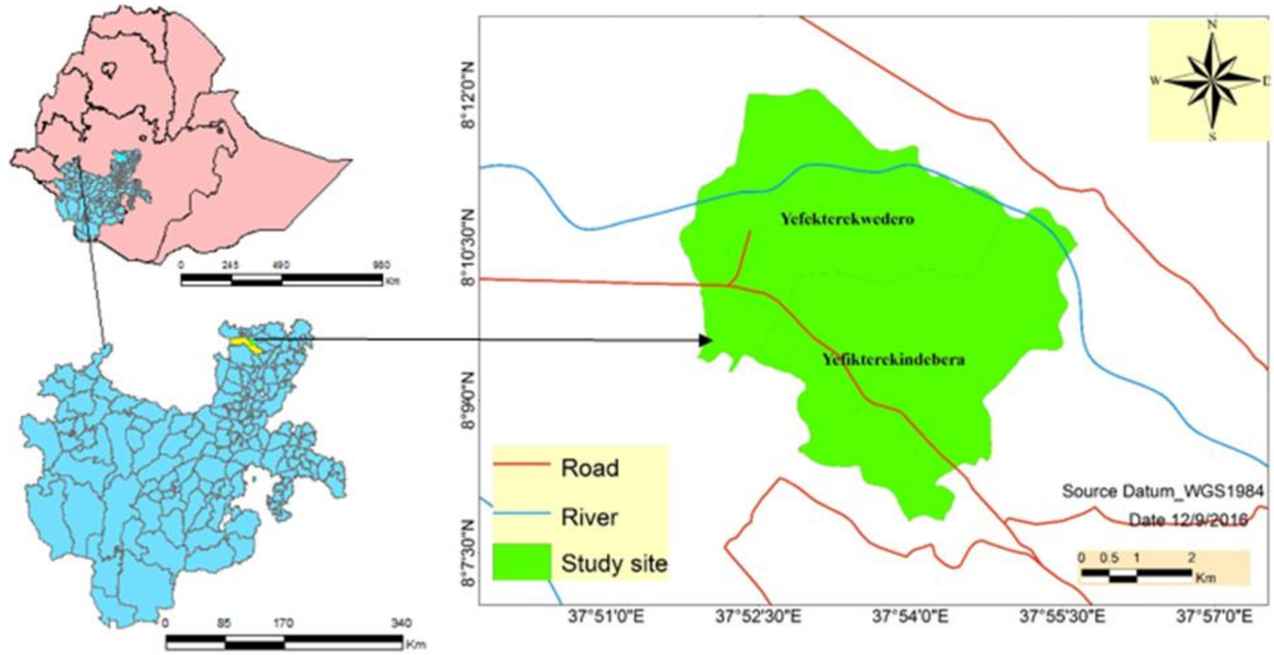

Figure 1: Map of the study site showing selected kebeles

The dominant soil type of the study site is Vertisol which covers 82.4 %.Of the study area. Soil properties among the studied land uses are shown in Table 1.

Table 1: Soil properties (Mean±SD) of different agroforestry systems along soil depths

Soil properties	Cultivated land (n=20)	Homegarden (n=20)	Woodlot (n=20)
	Soil depth 0-20 cm		
*p*H (water)	5.8±0.3	6.5±0.5	5.7±0.4
Sand %	24.6±7.1	30.3±7	27.4±8.5
Silt %	26.3±8	26.2±6.1	20.4±4.3
Clay%	49.1±4	43.5±9.2	52.2±7.7
BD, g cm^{-3}	1.3±0.0	1.0±0.0	1.2±0.0
	Soil Depth 20-40cm		
*p*H (water)	5.9±0.3	6.4±0.5	5.6±0.4
Sand%	24.6±7.1	28.2±5.2	21.5±8.5
Silt %	26.3±7.9	26.4±5.2	21.5±7
Clay%	49.3±4	45.4±8.5	57.3±7.8
BD, g cm^{-3}	1.4±0.2	1.2±0.2	1.3±0.1

The description of vegetation characteristic of agroforestry system practiced in the study area is given in Table 2. Both agroforestry systems contain components such as staple food crops *Ensete ventricosum*, fruit trees, coffee and woody species specifically *Eucalyptus viminalis.*

Table 2: Stand characteristics (Mean±SD) of two studied agroforestry systems in the study area

Stand characteristics	Homegarden (n=20)			Woodlot (n=20)
	Enset	Fruit tree	Coffee	
DBH	_	5.6±4.3	_	4.8±2.8
D_{10}, cm	22.7±3.1	_	_	_
D_{40}, cm	_	_	3.6±0.7	_
H, m	4.6±1	4.2±1.7	3.6±0.5	5.8±1.5
BA, m^2ha^{-1}	5.7	0.5	0.1	3.7
SD, Stem ha^{-1}	2035±256	105±25	107±22	2550±427

D, refers to diameter at breast height; D_{10} is to diameter at 10 cm height; D_{40} is to diameter at 40 cm height; H is total height; BA basal area, SD is the Stem density.

Selection of Study Sites and Sampling Size

A preliminary reconnaissance survey was conducted to identify the study area. Key informants i.e. development agents, elders and district's natural resource experts were consulted to identify dominant agroforestry systems. Accordingly, *Yefekterkendebera* and *Yefekterkwedro* kebeles were selected based on agroforestry dominance and accessibility.Kebeles with homegarden, woodlot agroforestry system and cultivated land were identified. Then, among the list of identified kebeles two kebeleswere randomly selected as site replications. The criteria used to select 20 households include site conditions like accessibility and location. The selection was limited to 20 smallholdings based on the resource and time as these criteria's are most important factor in limiting the sample sizes in most experimental researches. A total of 60 farms consisting of 20 farms for each land use were randomly selected. This sampling size determination has considered the availability of resources and accessibility.

Data Collection Methods

Woody Species Inventory

A plot size of 20m x 20 m was randomly laid down in each sampled farm to inventory woody species in both the studied land use systems (Pearson, et al., 2005). All woody species including fruit trees and non- fruit trees with DBH ≥2.5 cm diameter and height ≥1.5 m were measured and recorded (Negash, et al., 2013).

For coffee plants, stem diameter at stump height (40 cm, d40) was measured. Stem diameter measurements (d_{40}) were taken in two perpendicular directions and the average value taken. In the case of multi-stemmed coffee plants, fruit trees and non-fruit tress (2 to 11 stems per plant), all steam in single plant was measured and the equivalent diameter of the plant calculated as the square root of the sum of diameters of all stems per plant:

$$de = \sqrt{\sum_{i=1}^{n} di^2} \quad \text{(Eq 1)}$$

Soil samples were collected from the same plots (20m x 20m) used for woody species inventory. In this study the soil sample were collected in two depths (0-20cm and 20-40cm) from three sub plots (two at the corner and one at the centre) using soil auger and made a composite sample for determination of sub plots lottery method were used. A total of 120 composite samples were taken. The composite samples from the three subplots were taken to laboratory to determine SOC, pH, soil texture, and bulk density using the standard method. Soil samples for bulk density analysis were collected separately from sample plot (20m x 20m) and1m x 1m subplot using core sampler size of 5cm diameter consecutively from 0-40cm. A 5cm diameter core sampler was used to take samples for bulk density and four cores were taken for each depth.

Laboratory Analysis

The soil texture was analysed using the standard hydrometer method and for pH determination analysis was done by measuring in water suspension at the ratio of 1:2.5 (soil/water). The soil samples for SOC were air dried and sieved with 2 mm sieve for making them ready for further analysis. The samples were oven dried at 105 °C for 48 hoursand weighed then Walkley and Black method was used for further analysis of the required parameters (Walkley and Black, 1934).

Data Analysis

Above and Belowground Biomass Estimation

Biomass C stock for each plot (Mg ha^{-1}) was estimated as the product of dry matter biomass and carbon content. All the allometric models are adapted based on site and species compatibility with previous developed models.

In the case of the trees, coffee and enset plants the biomasses were estimated using the plot inventory data (d, d_{40}, h) and allometric biomass equations. For woody species (Trees) including fruit trees incorporated within homegarden agroforestry, AGB was estimated using allometric equation developed by Kuyah et al. (2012) 48% were used for carbon stock conversion.

$$AGB = 0.091 \times d^{2.472}; \quad R^2 = 0.98, n = 72 \text{ .... (Eq 2)}$$

Where ABG; is the aboveground biomass (kg dry matter/ plant), d = Breast height diameter (cm)

AGB_{coffee} 49% was used for carbon stock conversion by Negash et al. (2013).

$$AGB_{coffee} = 0.147d240; \quad R2 = 0.80. \ n = 31 \text{ .... (Eq 3)}$$

BGB = 0.490AGB0.923; R2 =0.96, n = 72 ....(Eq 4)

Kuyah, et al. (2012)

Where: AGB_{coffee} is aboveground biomass for coffee, d40 = Stem diameter (cm) of the coffee plant at 40 cm height

AGB and BGB of ensetwas computed with allometric equation developed by Negash et al., (2013). 47% was used for carbon stock conversion.

$\ln(AGB_{enset})$ = - 6.57 + 2.316ln(d10) + 0.124ln(h); R2 = 0.91, n=40……………………….(Eq 5)

BGB_{enset} = 7×10-6 × d104.083; R2 = 0.68, n = 40..(Eq 6)

Where AGB_{enset} is aboveground biomass for enset, d_{10} is the basal diameter (cm) of the enset at 10 cm height and h is total height (m), BGB enset is belowground biomass for enset.

For above ground biomass estimation of *Eucalyptus viminalis* Zerfu (2002) was adopted. Since *Eucalyptus viminalis* has similar vegetation characteristics with *Eucalyptus camaldulness.*

Y=0.0155 (DBH^2 (2.5823)) ……………………………………………………............... (Eq 7)

Belowground biomass estimated using global average value of 26% of aboveground biomass (Cairns, et al., 1997). 50% (default values) was used for carbon stock conversion (MacDicken, 1997).

T_{AGBC}=Biomass carbon stock of tress+coffeeplants+enset+fruit tress……................... (Eq 8)

T_{BGBC} =Biomass carbon stock of tress + coffee + enset ……………………................... (Eq9)

TBC=T_{AGBC}+T_{BGBC}……………………………………………………….................. (Eq 10)

Where: T_{AGBC}= Total Above ground biomass carbon, MgC $ha^{-1,}$ T_{BGBC}= Total below ground biomass carbon, MgC $ha^{-1}$and $T_{BC= Total}$ biomass carbon

Basal area is a cross sectional area of the steams found in the plot (Kent and Coker, 1992).

BA (m2) = (DBH/200)2*π…………………………………………………….............(Eq 11)

Where, BA = Basal area, m2 ; DBH=Diameter at Brest height, cm; π= 3.14

SBA (m^2/ha)=Sum of the basal area of tress in all plots (m^2)/Area of the plot (ha). ……………………………………………………………………………………...(Eq12)

BD and Soil Organic Carbon

SOC was calculated as below (Pearson, et al., 2005)

SOC=BDx%C x depth x 10……………………………………………………………(Eq 13)

Where, SOC = Soil Organic Carbon (Mg ha^{-1}), BD = Bulk Density (g cm^{-3}), Depth of the soil sample (cm), % C = Carbon Concentration

The Total Carbon Stock Density Estimation

The total carbon stock density from different carbon pools was calculated using the following formula (Pearson, et al., 2005).

CTotal = CAGTB+ CBGTB+SOC…………………………………………….............(Eq 14)

Where, CTotal = Carbon Stocks (Mg ha-1)
CAGTB = Carbon Stock in Above Ground Tree Biomass (Mg ha-1)
CBGTB = Carbon Stock in Below Ground Tree Biomass (Mg ha-1)
SOC = Soil Organic Carbon (Mg ha-1)

Statistical Analysis

Microsoft excel version 2010 was used to record, calculate and organize data. IBM SPSS version 20 software was used for statistical analysis. One way Analysis of Variance (ANOVA) was performed to examine the variations in biomass and soil carbon stock among the agroforestry system and cultivated land. Post hoc test was used to evaluate the mean differences across the studied systems, followed byTukey test to compare statistical mean differences among the systems. One way ANOVA shows presence of significant differences among mean values of agroforestry systems and cultivated land in both biomass carbon and soil organic carbon stocks.

Results

Biomass Carbon Stocks in Homegarden and Woodlot

The mean total biomass carbon stocks of homegarden and woodlot agroforestry system ranged between 3-13 Mg ha^{-1} and 1-11.5 Mg ha^{-1} , respectively. Woodlot agroforestry system was lower by 22% compared to homegarden agroforestry system in TBC. Mean above and belowground biomass carbon stocks showed similar leaning. The contribution of above ground biomass carbon stock for total biomass carbon stock in homegarden and woodlot agroforestry systems is averaged at 69%. Total biomass carbon was highest in homegarden as compared to woodlot and it showed difference between the two studied agroforestry systems but the difference was not significant ($P<0.05$). Mean biomass carbon stock of homegarden and woodlot agroforestry system was estimated to be 6.092±2.3 Mg ha^{-M} and 4.74±6.3 Mg ha^{-M}, respectively (Table 3).

In home gardenagroforestry system enset and coffee plus tress accounts 83% and 17% respectively for the total biomass in the system. This study assumes the difference in carbon between the two studied agroforestry systems was not significant at 5% level of significant. BGBC of the two studied agroforestry systems ranged from 1-4 Mg ha^{-1}. BGBC homegarden agroforestry was higher between the two agroforestry systems (2 Mg ha^{-1}). The contribution of BGBC for the total biomass carbon stock was 33% and 40% for homegarden and woodlot agroforestry systems, respectively (Figure 2).

Table 3: Mean (±SD) carbon stocks (Mg ha^{-1}) by biomass component for each of the two studied agroforestry systems.

Biomass component	Homegarden (n=20)	Woodlot (n=20)
AGBC	4.06±5.2[a]	3.76±5[a]
BGBC	2.03±3.3[a]	1.9±1.3[b]
TOTAL	6.092±2.3.[a]	4.74±6.3[a]

Note: Similar letter shows not significant difference and different letters indicates significant difference between groups at 5% level significant.

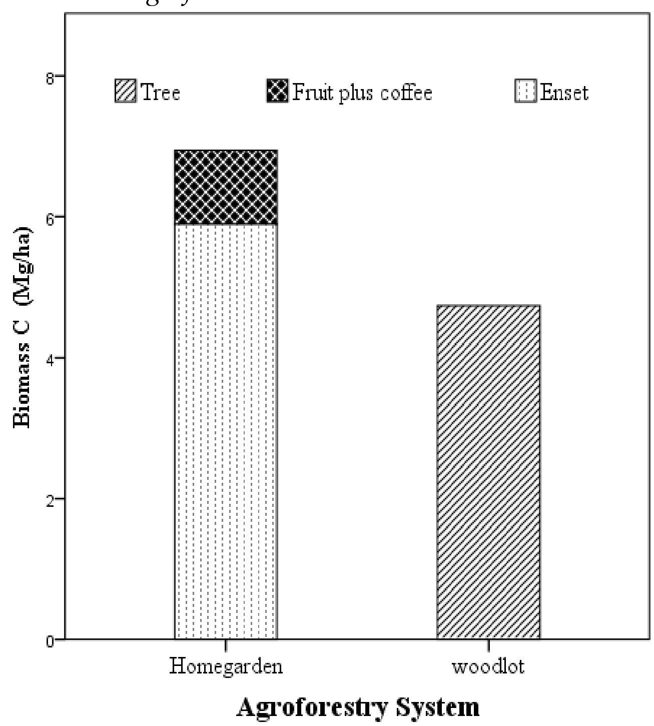

Figure 2: Total biomass carbon stocks by biomass component for each of the two agroforestry systems.

Soil Stocks among Studied Land Uses

The SOC (0-20 cm) in homegarden agroforestry system was higher by 28% and 23% than woodlot and cultivated land, respectively (Table 4). The contribution of the upper soil layer (0-20cm) to total SOC stocks was highest for homegarden agroforestry (62%), followed by cultivated land (61%) and woodlot agroforestry (58%). The remaining contributes for the sub soil layer (20-40cm). Conversion of homegarden agroforestry and woodlot to cultivated land would decrease SOC stock by 23% and increases by 7%, respectively.

The SOC stocks significantly ($p<0.05$) differed between homegarden and the other two studied systems. The SOC stock was the highest in homegarden and the least in woodlot.

Table 4 : Mean SOC (±SD, Mg ha^{-1}) among three land uses systems, n= 20 for each agroforestry system

Soil depth (cm)	Homegarden(n=20)	Cultivated land (n=20)	Woodlot (n=20)
0-20	58.5±11 ^{a}	44.6±11^{b}	39.4±11.4^{c}
20-40	35.7±9 ^{a}	28.6±9^{b}	28.6±11.4^{b}
0-40	94.2±15 ^{a}	73±20 ^{b}	68±15 ^{b}

Note: Similar letter shows not significant difference and different letters indicates significance difference between groups at 5% level significant.

Ecosystem Carbon Stocks among the Three Studied Land Uses

Amongst the studied land uses, the highest mean ecosystem carbon stock was recorded for homegarden agroforestry system (100.38 Mg ha^{-1}) and the least was for woodlot agroforestry (72.9Mg ha^{-1}) (Table 5).

Table 5: Ecosystem carbon stocks (biomass plus soil) of the studied land use systems (Mg ha^{-1}) n= 20 for each.

Carbon stock	Cultivated land	Homegarden	Woodlot
Biomass carbon	-	6.09±2.3^{a}	4.74±6.3^{b}
SOC (0-40 cm)	73±20^{a}	94.2±15^{a}	68±11.4^{a}
Total	73±20^{a}	100.4±15^{b}	72.9±14^{a}

Discussion

Biomass Carbon Stock in Studied Agroforestry System

The mean total biomass carbon stock of homegarden agroforestry system accounted in this study was comparable with the findings in the same agroforestry system in

GununoWatersheWolayitta Zone, Ethiopia, (Bajigo, et al., 2015) and in African tropical dry forest (10-34 Mg ha^{-1}). Homegarden agroforestry system total biomass carbon in this study was substantially higher than the parkland agroforestry system in Gununo Watershed, Wolaytta Zone, Ethiopia, (Bajigo, et al., 2015) and lower than the studies in enset and enset coffee agroforestry system in Southern escarpment of Ethiopia (Negash and Starr, 2015) and in tropical dry deciduous forests (14.7 -43.2 Mg ha^{-1}) (Chaiyo, et al., 2011) and in Western Kenya (36.9 - 115.9).

The study by Weifeng et al. (2012) described that the stand structural parameters such as size and height have significant positive relationship with aboveground carbon stocks. The study also ascribed species diversity has a significant positive relationship with aboveground carbon. Therefore, the higher biomass carbon stock in home garden agroforestry system could be due to diversified components in the system while low biomass carbon is can attributed to single species based woodlot agroforestry system.

The present study revealed that total biomass carbon stocks were highest in homegarden as compared to woodlot. This could be due to lower diameter trees documented in the earlier system than the later one (Terakunpisut, et al. 2007). Besides, homegarden agroforestry system includes diversified species such as fruit trees, coffee and enset, which could contribute a lot in carbon storage. Similar studies have also shown that the differences in biomass carbon stocks depend on several factors such as stand age, stand structure, diversity and composition and management system (Chave, et al., 2004; Bajigo et al., 2015).

SOC in Studied Land Use Type

Soil organic carbon is a significant carbon pool because it has the longest dwelling time of carbon among organic carbon pools. The mean soil organic carbon stocks for the 0 – 40 cm soil depth within the ranges of African savannahs and woodland 30–140 Mg C

ha^{-1}. SOC in our study was remarkably high as compared to results estimated to be 43 Mg ha^{-1} for semi-arid *Acacia etabica* woodland in southern Ethiopia (Lemenih and Fisseha, 2004), 27 Mg ha^{-1} for agroforestry systems in Central India .

In this study, higher SOC was recorded than the studymade inhomegarden and woodlot agroforestry in Gununo Watershed, Wolaytta Zone, Ethiopia, which accounted 61.6 Mg ha^{-1} and 48.6 Mg ha^{-1} respectively for homegarden and woodlot agroforestry. The SOC in this study was lower than the finding in the southeastern rift valley escarpment of Ethiopia (Negash, et al., 2013). Soil physical structure, species composition and litter quality could be the factors for the variation of SOC among the systems.

Management systems determine SOC of different land use system. Organic matter input and aeration alters SOC potential since they are the main driver of SOC stock. The results in this study support this claim, homegarden agroforestry with high litter input as mulching management system could be the main driver for high SOC than single species woodlot agroforestry with no additional organic carbon. Low tillage considered as a measure to sequester carbon. In the present study low SOC stock recorded in cultivated land comparing with homegarden agroforestry, this could be related to high tillage management system in cultivated land.

Ecosystem Carbon Stock in Studied Land Use Types

The present study revealed that more carbon is accumulated in soil than biomass. Accumulation of fine roots and litter decomposition could be the factors for SOC and biomass carbon stock density variation. Land use history and management systems could also be additional factors (Girmay, et al., 2008).

In this study, comparatively high ecosystem carbon stocks were recorded in agroforestry system than that of cultivated land. This implies the system has a significant carbon sequestration potential which could help as climate change mitigation option in the study area.

Conclusions and Reccomendation

The study indicates AFS have high carbon stock potential compared to cultivated land use systems. Higher carbon stock in both biomass and SOC was observed in homegarden agroforestry system.This study attributes higher biomass carbon stock in homegarden agroforestry than woodlot but the difference was not significant. The contributions of SOC stocks for total ecosystem carbon were higher in both studied agroforestry systems than biomass carbon stock. In a conclusion this study showed that land use conversion has a significant effect in biomass and SOC stock potential. Overall this study will add up information about carbon stock potential of AFP in central highlands of Ethiopia. This study implies, practicing mixed agroforestry system could support soil fertility and enhance production than monocropping system. It also proves AFS has great potential SOC storage, emission reduction and carbon financing scheme as climate change mitigation strategies. Therefore, the current recognition for agroforestry as climate change mitigation strategies is strengthened by this study.

Therefore,Climate change mitigation (carbon emission reduction) strategies such as REDD^{++} should give a great recognition for agroforestry since it has remarkable potential on contribution for climate change mitigation in addition governmental bodies should consider carbon incentive in agroforestry which could offers an opportunity for sequestering a large amount of carbon, at the same time meeting demand for other household food requirements and other socio-economic activities in smallholder farms.

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Socioeconomic Determinants that Affect Investment on Degraded Lands

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Abstract

Although there have been several efforts made to reduce land degradation and improve land productivity in Ethiopia, and particularly in Wulbareg district, farmers' investments on degraded land remain limited because of limited farmers' capacity to invest on degraded land, farmers' incentives for investment on sustainable management of degraded land and external factors beyond the control of farmers such as institutional support and policies. This study aims to identify the socio-economic factors that significantly affect investment on degraded land across Silte Zone of Southern Ethiopia; and to interpret the causalities underlying the effects. The total sample size was 100. The average land holding size of the respondents is 1.04 hectare per household. Most of the sampled households (88%) in the study area were engaged in agriculture and derive their livelihood from mixed farming (crop production and animal rearing). About 77% of the interviewed respondents indicated that the vegetation cover was increased. The rest 22% (most of them are elders) indicated as the vegetation cover were decreased. According to the respondents the most important reason for vegetation cover increment was the integration of different physical and biological soil and water conservation structures which was strongly supported by local community participation. Respondents mainly recommended the allocation of enough budgets on rehabilitation and enclosing of the degraded land, access to electric power to minimize pressure on forest resources, access to clean water and nursery site establishment and management by experts to overcome the problems such as species to site matching, inappropriate site preparation and many technical issues that could result in death of planted seedlings on degraded area.

Key words: *Land degradation, Sustainable land management, Watershed management*

Introduction

Land degradation is any reduction or loss in the biological or economic productive capacity of the land resource base. It is generally caused by human activities, exacerbated by natural processes, and often magnified by and closely intertwined with climate change and biodiversity loss (UNCCD, 2014). The problems of land degradation are most serious in tropical regions, where communities' livelihoods depend on land productivity (e.g., food production and products from forests) and the land and soil resources are exposed to natural constraints (e.g., high annual rainfall and steep terrain conditions). Land degradation is a major factor affecting against agricultural productivity in Africa (UNEP, 2015). Tropical regions are also home to the poorest communities in the world, where there is a downward spiral between poverty and land degradation: poverty and economic marginalization lead to land degradation, and land degradation leads to further poverty (IFPRI, 2000). In similar way, Ethiopia has experienced rampant land degradation problems over many centuries, which mainly include decrease in land productivity, the formation of immense wide and deep gullies, soil erosion, vegetation cover alteration, the disturbance of herbaceous species and water resource degradation (Hurni, 1993; Angassa, 2014; Lemenih, et al., 2014; Teshome, et al., 2014).

Based on Bekele and Mekonnen (2010), in Ethiopia, land and other related factors affect farmers' decision at household plot-level to adopt conservation technologies. The land factors include farm size and tenure arrangement among others while the other factors are asset holdings (e.g. livestock) and income level. They have also added that institutional factors such as access to extension and, membership of association affect farmers' decision to adopt land conservation measures.

Serious land degradation problems were found both in the lowlands and highlands of Ethiopia (Lakew, et al., 2000; Rahmato, 2001). These problems lead to the deterioration of soil fertility and productivity. Consequently, the agriculture sector of the country has been hindered by this massive problem, which has further contributed to negative impact on the country's economic development at large.

Although there has been several efforts made to reduce land degradation and improve land productivity in Ethiopia, farmers' investments on degraded land remain limited because of limited farmers' capacity to invest on degraded land (Temesgen, et al., 2014; Mohammed and Teshome, 2015). This study aims to identify the socio-economic factors that affect farmers' decision to invest on degraded land across Wulbareg district of Siltie zone in SNNPRS, Ethiopia and to interpret the causalities underlying the effects.

Material and Methods

Wulbareg district is geographically located at (07°44′ to 08°01′) N and (38°02′ to 38°22′) E in Siltie zone, SNNPRS of the Federal Democratic Republic of Ethiopia. It is 187 Kms far away of Addis Ababa, capital of Ethiopia to the Southwest direction (Figure 1). The district covers an altitudinal range between 1891 and 2461 m above sea level. The soil property of the district was characterized by poor soil fertility having with black soil/Vertisol (60 %), red soil/Nitosol (25 %), gray soil/Luvisol (15 %) because of severe land degradation and high water erosion (resulting in gully formation) exacerbated by recurrent drought and flooding.

The agro-ecological condition of the Wulbareg district is characterized under the dry *Woynadega* agro-ecological category. The rainfall of the study site fallows bimodal rainfall pattern having mean annual rainfall varied between 900 and 1125 mm year^{-1}, with an average of 1012 mm year^{-1}. The mean annual minimum temperature ranged from 19 to 27 ^{o}C, with an average of 23 ^{o}C.

The district is formed by 13 rural Peasant Associations (PAs) and a small town. Based on the 2007 Census conducted by the CSA, this district has a total population of 79,981, of whom 38,284 are men and 41,697 women; 2,198 or 2.75% of its population are urban dwellers with annual population growth rate of 2.7% and population density of approximately 280 persons per km^2. The average family size was 5 per household. The majority of the inhabitants were Muslim, with 98.65 % of the population reporting that belief, while 1.04 % practiced Ethiopian Orthodox Christianity.

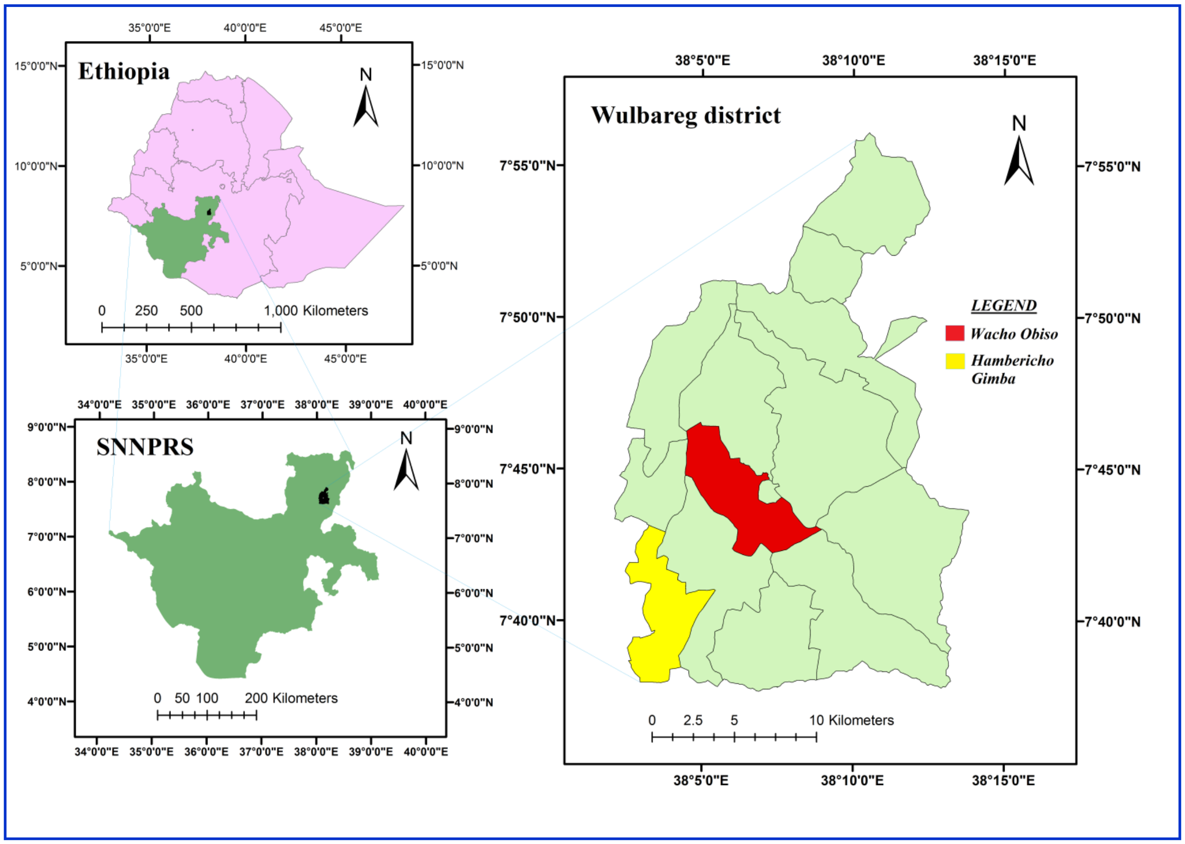

Figure 1Geographic location of study area under map of Ethiopia

As far as economic activity is concerned, the people of the Silte communities live in sedentary life based agriculture, involving a complex system of crop rotation and transplanting. They also breed cattle and cultivate crops like *Teff*, maize, sorghum, wheat, and false banana. Enset (*Ensete ventricosum*) is also used as stable food crop that considerably support farmers' livelihood.

The study areas have little of their original vegetation cover as a result of the high rate of population growth and also the consequent need of more land for cultivation, more wood for construction and the absence of systematic and continuous efforts of conservation over generations. There are remnants, although few, of the various species of original natural vegetation, showing that they used to be areas of diverse vegetation. Remnants of natural vegetation consists of *Juniperus procera*, *Podocarpus gracillor*, varieties of *Acacia* species, *Olea africana*, *Fiscus sur*, Warka, *Croton macrostachyus*, and *Cordia africana* that also include exotic trees such as *Eucalyptus* species.

Data collection

Secondary data was assessed to screen out and narrow potential study site. In relation to the assessment consultation meeting was held with SNNPRS Forest Development and Environment Protection Authority officials and expertise to specifically pin the study site. Based on their recommendation, Siltie zone and Wulbareg district were selected purposively due to their serious problem on land degradation. This study was conducted in two peasant associations (PAs) of Wulbareg district (*Hambaricho Gimba* and *Wacho Obiso*).

Purposive sampling technique was used to select sample households. A total of 100 households were systematically selected from the list of local community members received from the village administration considering their gender and participation on rehabilitation of degraded land programs. Side by side, formal discussion with the key informants was conducted to classify and categorize wealth status and perception of the local community towards investment on rehabilitation of degraded lands. Semi-structured questionnaire was administrated to these 100 households to collect data on demographic characteristics of the respondent/household (HH) and also to identify determining factors that affect investment on degraded lands. Sample respondents were calculated using a statistical formula as follows:

$$n = \frac{z^2 * p * q * N}{Nd^2 + Z^2 pq} \qquad \text{(Eq 1)}$$

Where, n= sample size; N= total population of households in both sites ; Z^2= confidence interval (1.96, constant) ; d^2= margin of error ; p= proportion of population (0.5, constant); q= 1- p ; Assumption: let d= 0.05 and q= 0.5

$$= \frac{1.96^2 * 0.5 * 0.5 * 135}{135\,(0.05)^2 + (1.96)^2(0.5)(0.5)} = 100$$

Statistical Package for Social Scientists (SPSS) version 20.0 software was employed to analyze data drawn from the household survey. Descriptive statistics like mean, percentage and frequency distribution were used to analyze quantitative data. Then, analyzed data was summarized and organized in tables and figures.

Results and Discussion

Demographic Characteristics of Household

Majority of the respondents (96%) were youngsters and adults with age class between 18 and 30 (50%), 31 to 45 (29%) and 46 to 64 (17) respectively, which can be considered as active, productive and working age population (OECD, 2017). Considering the marital status of the sampled households (HH), almost all (96%) of the respondents were married having 86% husband HH head, 12% wife HH head and 2% son HH head. The average family size is in the study area was seven. In the study area, 65% of the sampled household heads were illiterate that are unable to read and write. The respondents who can read and write but do not have formal education accounted 17% and similarly the same figure was obtained for respondents who joined primary education. Only a single respondent attended secondary education.

Livelihood of the Respondents

Based on the criterion set by the key informants (land holding, housing materials, number of livestock owned, farming system), wealth status of the respondents in the study area resulted very poor (22%), poor (36%), medium (34%) and rich (8%). The average land holding size of the study area was 1.04 ha signifying acute shortage of land which deters farmers' ability to produce enough crops to feed the fast growing population. Results from the survey indicated that more than half of the respondents

(57%) get a hold of their land in kind of inheritance and some (12%) others in the form of gift.

Most of the respondents (88%) were engaged in agriculture and subsist from mixed farming (mostly crop production and rarely animal rearing) (Figure 2). One third of the respondents practiced intensive farming system whereas 60% and 9% exercised semi-intensive and extensive farming system respectively. Regarding the purpose, about 59% of the respondents produce agricultural crops for consumption, 15% for sale and 26% for both. The most dominant and favorite food crop in the study area is maize (99% of the respondents' produced Maize). In general speaking farmers produced maize, teff, wheat and sorghum in different rate for consumption and/or sale.

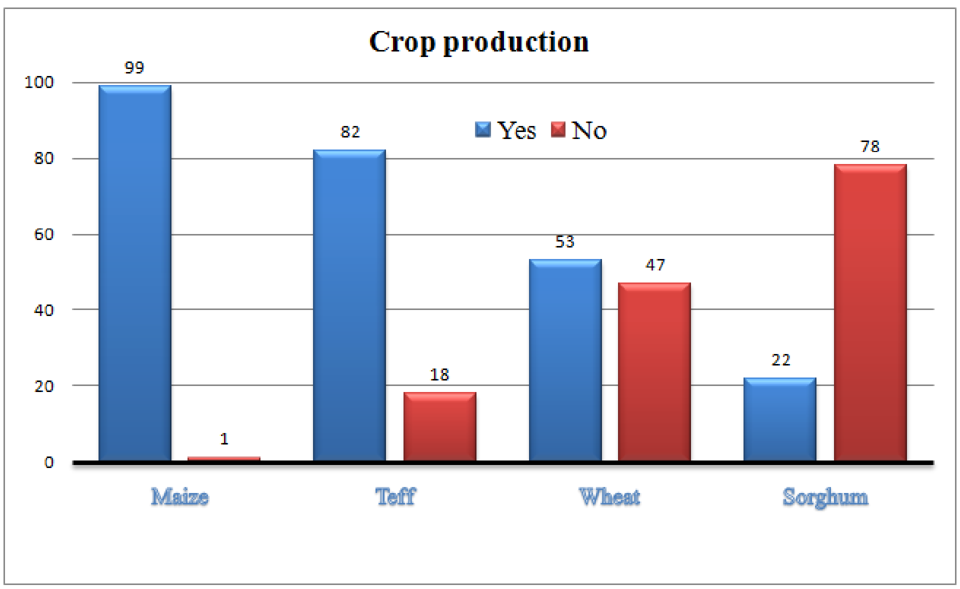

Figure 2: Crop production in the study area

About 56% of the respondents produce agricultural crops (maize, teff, sorghum, and wheat) and had livestock of different kinds (cows, oxen, heifers, calves, sheep, goats, donkeys and *Poultry*) whereas 40% of them had no livestock and they are dependent on their agricultural production. The number of respondents practicing Agroforestry was almost none (3) and also 1 respondent was engaged on cattle fattening. Other than above mentioned crops participation in fruits, tubers and vegetables is minimum resulting 48%, 24% and 16% production involvement respectively. Respondents with livestock asset reported that the purpose of keeping their livestock was for insurance, store of wealth, means of income, replacing the stock, milk production, prestige, animal draft and manure production purposes.

Regarding access to basic social services, all of the respondents had access to market, all weather roads, health center and (Table 1).

Table 1: Access to basic social services

Access to basic social Services	Yes	No
Market	100	0
All weather road	100	0
Telephone	97	3
Water supply	48	52
School	100	0
Training center	65	35
Credit service	100	0
Health center	100	0
Veterinary service	100	0
Agri. Input provider	100	0

Determining Factors

Based on the results obtained from respondents, 30 years ago, farmers used to buy metal part of agricultural materials from market and they obtain wooden part from forests. Despite this fact, now, some of them buy forest products from market which might be accessed from farm land and /or wood lots. The fact most respondents indicated was they buy metal parts from market and handles of agricultural materials like: Axe, Spade, Hoe and others for their cultivation and rehabilitation duties. Nowadays they are shifting to planting trees on their wood lots (mostly *Eucalyptus* species) and manage naturally regenerated *Acacia* species.

The perception regarding vegetation cover was different. Most of the respondents (77%) think increase in vegetation cover. According to them, the reasons behind were: different physical and biological soil and water conservation structures built by government organizations (GO) and/or non government organizations (NGOs) with active participation of local community, tangible benefit from rehabilitated area, area closure and attention given to the issue by GO, NGOs and the local community (Table 2). In contrast 23% (most of them were elders) responded decrease in vegetation cover. These respondents noted the following causes as governing factors for vegetation loss: Primarily the distribution and uniformity of physical and biological soil and water conservation structures was irregular and awareness created on rehabilitation of degraded lands was not enough. In addition, conflict between neighbor districts, climate change, frequent forest fire and erosion were mentioned. In general, the integration of rehabilitation works among districts and between kebeles was promising with limitations.

Table 2: Reasons on vegetation increment and decrement

Reasons for vegetation cover increment	Frequency/100
Different physical and biological soil and water conservation structures built by GO and/or NGOs with active participation of local community	35
Government have given focus on water shed management	10
Area is closed so that no encroachment	10
Tangible benefit from rehabilitated area	8
Reasons for vegetation cover reduction	
Awareness created on rehabilitation of degraded lands was not enough	10
The distribution and uniformity of physical and biological soil and water conservation structures was irregular	4
Climate change	3
Population increase	2
Conflict between neighbor districts	2
Frequent fire and erosion	2

Advantages of the Rehabilitation Program in the Study Area

Respondents noted numbers of advantages from rehabilitated areas. They get benefit from Grasses which can be used as a feed for livestock and as construction material (roofing). In addition, advantages such as: enhancement of natural regeneration, erosion control, agricultural yield improvement (soil productivity improvement), ground water enhancement, micro climate amelioration, recreation, means of income (direct or indirect incentives from GO and NGO), access to construction material and wildlife support were mentioned by the respondents (Table 3).

Table 3: Advantages of rehabilitated lands

Response	Frequency
Erosion control	72
Grasses used as fodder and roofing material	69
Enhancement of natural regeneration of trees, herbs and shrubs increased	29
Amelioration of micro climate	12
Means of income	7
Recreation	6
Soil moisture and nutrient will be improved	5
Construction	4
Ground water improved	4
I don't know	3
wildlife do not affect our farm land they stay in rehabilitated area	1

The Constraint/Challenges to Invest on the Rehabilitation Program of the Study Area

The constraints to invest on rehabilitation program of the study area were identified through interview. Problems such as: Conflict, Lack of uniformity physical and biological soil and water conservation structures, Lack of awareness, Lack of access to food and tap water, Site difficulty (hard to dig), Absence of incentive, Lack of awareness and Lack of materials were mentioned. Their corresponding frequencies are shown in Table 4.

Table 4: Challenges to invest on rehabilitation of degraded lands

What are the challenges to invest on rehabilitation program?	Frequency/100
Lack of awareness	31
Reluctance to invest	28
Conflict between neighboring farmers	22
Lack of uniformity on physical and biological SWC structures	20
Lack of materials	15
Lack of access to food and tap water	12
Site difficulty	8
Absence of incentive	5

The Constraints for the Success of the Rehabilitation Program

In most cases, the success of rehabilitation programs become tangible evidences for local communities to further convince them on advantages and benefits gained from the program. In contrast, the failure of these programs further result loss in motivation and unwillingness to invest on degraded lands. This study assessed possible reasons behind success of rehabilitation of degraded lands in the area and the respondents raised a numbers of barriers, which can be noted as potential treats, on the success of rehabilitation of degraded lands in the area. These are: species to site matching, lack of awareness, inappropriate site preparation, inappropriate planting techniques, agricultural land expansion, lack of physical conserving structures, encroachment, erratic rainfall, poverty, and illegal settlement.

The Role of Government on the Rehabilitation Program

Most of the time, programs related to rehabilitation of degraded lands are chiefly monitored and financed by government bodies. Side by side, other developmental actors such as NGOs, investors, and local communities also monitor and participate in the program. The respondents testified that government was supporting the program by: creating awareness regarding the rehabilitation of degraded lands, coordinating the local community, giving training on the benefits of the program and enforcing the laws.

In addition, respondents also suggested further measures that should be taken by government to realize the success of the program. Primarily, they had indicated that government should raise and distribute site specific seedlings and provide materials and moral support to the local community (Table 5).

Table 5: Government role in rehabilitation of degraded lands

What measures should be taken by the government	Frequency/100
Support (Material, Financial, Infrastructure development and Moral)	47
Seedlings should be prepared on nursery site and distributed to community by experts, give material and moral support	31
Recognition and reward	10
Attention and follow-up	8
Sustainability	7

Land degradation not only affects families and communities but it is a threat to wider nation peace and stability. It is one of the world's greatest environmental challenges. Desertification affects around 45% of Africa's land area, with 55% of this area at high or very high risk of further degradation. It is often considered that land degradation in Africa has been vastly detrimental to agricultural ecosystems and crop production and thus an impediment in achieving food security and improving livelihoods (UNEP, 2015). Similarly, this study indicated rehabilitation of degraded lands program implemented on district level was not uniform. Ethiopia is particularly vulnerable to land degradation and desertification and is the most severely affected. There is a huge gap between implementing and non implementing peasant associations resulting conflict of interest which hinders the willingness to invest on degraded lands.

Conclusion and Recommendation

This study revealed that lack of awareness, uniformity of GO and NGOs programs on rehabilitation of degraded lands, conflict and absence of technical support as determinants that affect investment on rehabilitation of degraded lands. According to the respondents, the involvement of government in rehabilitation programs is promising but not enough. Further assistance on seedlings management, distribution and materials support is critical and a must to do task to realize the success rate and motivate individuals to invest on rehabilitated lands. In addition, capacity building programs must be performed regarding community by law development and creation of sense of belongingness of the program.

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Determining nursery life span of *Populus tremuloides* in Ethiopia

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Abstract

An experiment on the preparation of planting material (seedlings) of Populus tremuloides from cutting was conducted in the nursery site of Central Ethiopia Environment and Forest Research Center. According to the result of the experiment, it is possible to produce seedling either from the cuttings at the bottom, middle or tip of a one year old P. tremuloides branch. Even if there was no significant variation in root collar diameter in all the three durations after planting (30, 45 and 60 days), the root collar diameter from the middle cutting was found to be greater than that of the base and tip. Height growth is greater from cuttings of the base than the middle and the tip at 45 and 60 days after planting. The leaf number of the shoots of all cuttings was highest at 45 days after planting. This may be due to the shedding of the leaves as it gets matured (60 days after planting). Therefore, this study implies that vegetative propagation of P. tremuloides either from a bottom, middle or tip of a one year old branch can reach plantable size from one to two months which requires little resource in plantation forestry and is important in maintaining the genetic characteristics of the plus mother tree.

Key words: *life span, popular, cuttings, propagation, production forestry*

Introduction

The effort to mitigate current changing climate and meet escalating demand for fuel and construction wood could be achieved with an introduction, evaluation and management of economical tree species in Ethiopia. This helps in further promotion of these species with the participation of relevant stakeholders. Likewise, production of planting material to establish fast growing tree species such as Populus tremuloides is one means of fulfilling the demand for construction and industrial wood products. *Populus tremuloides* is one of the target species that needs to be promoted at farm level and in different large plantation enterprises as a raw material for big industries (pulp and paper). It is a fast growing tree species that mainly reproduced by replicating its self from off shoots. Rooting of stem cuttings varies depending upon the time of year and the clone from which cuttings are taken (Barry and Sachs, 1968). Production of planting material and testing methods of establishment of *P. tremuloides* is a means of laying out baseline information for its large-scale promotion to achieve the demand for construction and industrial wood products.

Although Aspens (*Populus tremuloides*) can reproduce both from seed and by suckering, suckers have a competitive advantage over seedlings as they can draw on the parent root system for moisture and nutrients (Day, 1944). Tree seedling nursery lifespan is one of the most important parameters in forest development. Different tree species have different nursery lifespan. Tree species nursery life span also varies with location. Tree species nursery lives span in temperate is different from tropics due to various reasons. Thus, determining nursery lifespan of tree species is important for afforestation and reforestation plans and for producing sufficient amount of seedling stock for industrial plantation. It helps in budgeting resources for seedling production in a specified period. Thus, this experiment was conducted to determine the impact of cutting thickness on shoot growth performance of *Populus tremuloides* Cuttings in central Ethiopia.

Materials and methods

This study was carried out in 2012 at the Central Ethiopia Forestry Research Center (CEEFRC), Addis Ababa. Planting material was collected from Tigray and Addis Ababa and propagated at CEEFRC nursery. The rate of propagation was assessed at nursery level by sub-sampling the cuttings into base, middle and tip and data on seedling height and root collar diameter was collected for one year. In addition, rootability was assessed at green house in three-soil substrate (nursery soil composite, gravel rock, and mixture) and data was collected for successive two months.

Cutting collection and preparation

Thirty healthy mother trees of Populus tremuloides were identified and marked in Addis Ababa parks and home gardens. A one-year-old healthy Populus tremuloides branches were collected. After immature and damaged parts were removed the branches were cut into different parts (base, middle and tip). Cuttings that have at least two or more active buds were prepared for propagation. Fresh cuttings were soaked in tape water for three days and planted in 30 cm wide polythene tube filled with composited nursery soil of forest soil, compost and sand with 3:1:2 proportions in 2012 (Figure 1).

Figure 1 Sprouting cuttings (left) and propagation activities (right) of *Populus tremuloides*

Experimental design

Completely randomized design (CRD) was employed for the experiment. Forty-eight cuttings of each Populus tremuloides branch parts (base, middle and tip) were planted in the polytene bags filled with the soil mix and placed in green house for sprouting. The pots were regularly watered using tap water in the green house. A month later, the seedlings were moved to open place in nursery making sure that all the cuttings grow well.

Data collection and analysisData on root collar diameter, number of leaves and height of shoots was collected every week for 60 successive days. Data analysis was made using SPSS 20 software. The mean difference in RCD, height and number of leaves of the seedlings was estimated using one-way ANOVA. Pearson correlation was carried out to determine relationships between RCD, height and number of shoots.

Results and discussion

Seedling height and root collar diameter are widely used to assess quality nursery seedling. In many cases, these variables correlate with seedling survival and/or growth after out planting (Bayley and Kietzka, 1997; Jacobs, et al., 2005). The result of the study revealed that though there was no significant variation in root collar diameter of branch parts (RCD), in all the three durations (30, 45 and 60 days), and the RCD of the middle part of cutting out weighed that of base and tip (Figure 1). On the contrary, except 30 days after planting, height (cm) growth of shoots of base part of the cuttings is greater than the middle and the tip (Figure 2). The study also revealed that the leaf number of the shoots of the cuttings was the highest at 45 days after planting (Figure 3). This may be due to the shedding of the leaves as it gets matured (60 days after planting).

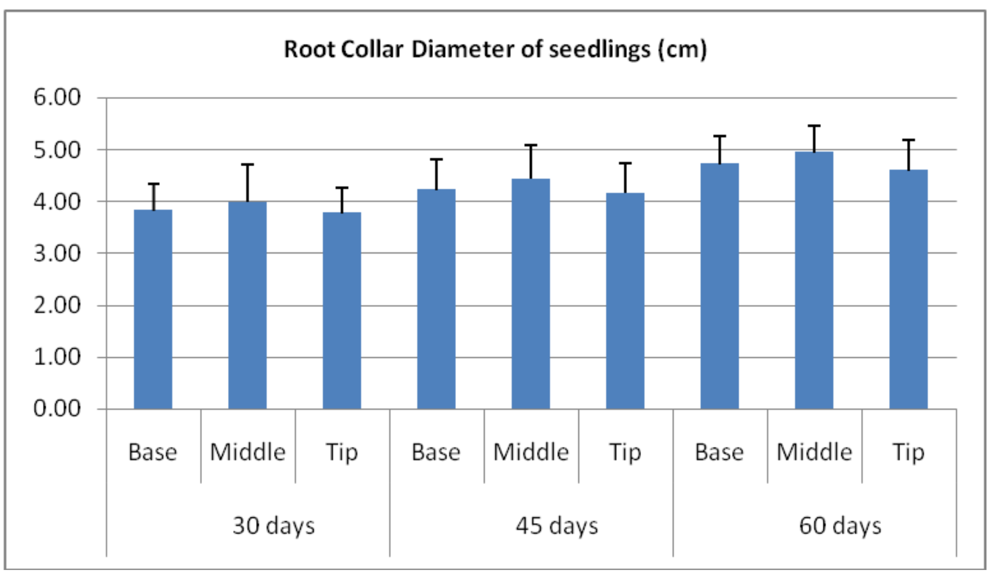

Figure 1: Root collar diameter (cm) of *Populus tremuloides*. Shoots per cutting

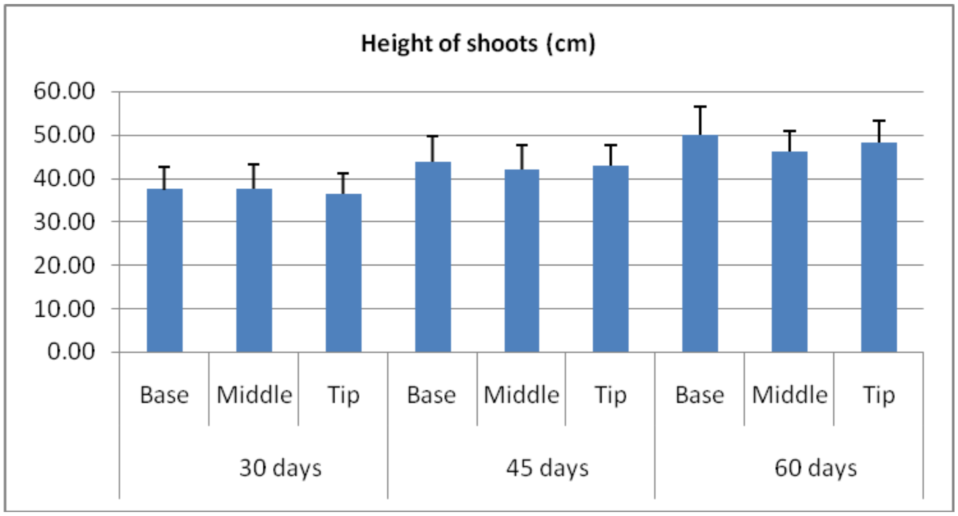

Figure 2: Height of *Populus tremuloides* shoots 30, 45 and 60 days after planting

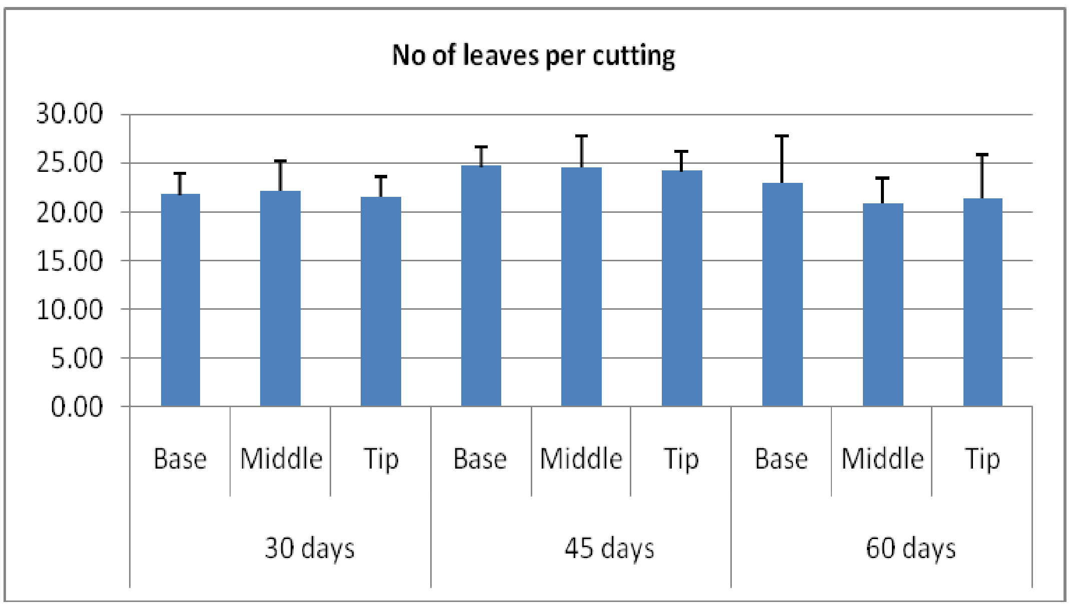

Figure 3: Number of leaves of *Populus tremuloides* shoots per cuttings 30, 45 and 60 days after planting

Significant positive correlation was obtained between root collar diameter and height of the shoots (r =0.786, $p<0.0001$) indicating the higher association between the parameters. Similarly, the study indicated that there was significant positive correlation between numbers of leaves and RCD and height of the shoots (r = 0.41 and r = 0.4, $p<0.001$) indicating associations among the parameters (Table 1).

Table 1: Pearson's correlation between variables: RCD, H and number of leaves

	RCD of shoots (cm)	Height of the shoots (cm)
Height of the shoots (cm)	0.786**	-
Number of leaves by cuttings	0.405**	0.404**

** *Correlation is significant at the p < 0.001 level (2-tail)*

The study also revealed that it was possible to produce Populus tremuloides seedling either from a bottom, middle or tip of a one-year-old branch. The result also showed that there was no significant difference among periods and parts of branch cuttings (base, middle and tip).

Conclusion and recommendation

This preliminary study implies that Populus tremuloides can reach plantable size within short period of time (one or two months) that requires little resource in plantation forestry. This may encourage an investor and/or stakeholder including small-scale farmers to engage in production of seedling either for sale or to establish Populus tremuloide Plantation that could be a raw material for pulp, paper and match industries.

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Socio-economic and Environmental Impacts of Community-based Rehabilitation Programmes on Degraded Lands: The Case of Silte Zone, Southern Ethiopia

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Abstract

Eventhough the trend of rehabilitation made in different watersheds has improved ecosystem health and land productivity in Ethiopia, due to the extreme dependence of the rural community on natural resources, particularly land, as a means of livelihood, the country is vulnerable for land resources degradation. However, the current rate and status of environmental degradation still calls for more extended and coordinated intervention actions to rehabilitate degraded lands. The study was conducted in Ambaricho Achamo kebele model watershed, Hulbareg district, Silte Zone of southern Ethiopia, to assess and evaluate the socio-economic and environmental impacts of community-based rehabilitation programmes on the degraded lands to support beneficiary's livelihood and well-being. Total of hundred (100) respondents were randomly selected to assess the impact of community rehabilitation of degraded lands on the farmers' livelihood improvement. This study used descriptive analytical method that was based on the field observations, interviews with key informants, household survey questionnaire, and focus group discussion that was supplemented by data from district office of agriculture. The results revealed that 90.8% of respondents' household income enhanced due to remuneration gained through area enclosure. Meanwhile, 43.3% of respondents agreed that the rehabilitated land created better prospect of employment for the nearby community members. About 95% of the respondents indicated that the vegetation cover in the enclosed area substantially enhanced in terms of biodiversity and species density. On other hand, nearly 79% of interviewed farmers confirmed fodder availability increased considerably that enabled them to feed their livestock they stern. Hence, the conversion of degraded land through the deployment of enclosures is relatively low-cost. It reverses land degradation processes, with many associated advantages: it reduces runoff and soil erosion; produces livestock fodder, woodfuel and grass for house construction; and enhances biodiversity. They also have the potential to be scaled up quickly in areas where tree and shrub species have the ability to re-sprout after harvest and where rights to resource use are appropriate.

Keywords: *Enclosure, Land Degradation, Rehabilitation, Socioeconomic Impacts*

Background and Justification

Land degradation is an indicator of under development resulted from amalgamation of social and economic factors such as poverty and inequitable distribution of land resources, inappropriate land use systems and farming practices in developing countries. In developing countries, it causes a severe crisis to the livelihoods of the rural community and the environment. In Ethiopia, due to the extreme dependence of the rural community on natural resources, particularly land, as a means of livelihood, the country is vulnerable for land resources degradation (UNEP, 1986).

In response to the alarmingly degraded ecosystems, the practice of rehabilitation of degraded ecosystems is becoming an option to reclaim degraded sites globally. In Ethiopia, the trend of rehabilitation made in different watersheds has improved ecosystem health and land productivity (Sonneveld, 2003). However, the current rate and status of environmental degradation still calls for more extended and coordinated intervention actions to rehabilitate degraded lands. Enclosures (Area closures) are among various land management and rehabilitation strategies practiced to improve species diversity, soil quality and ecosystem productivity (Lal and Stewart, 1992). They are degraded lands that have been excluded from human and livestock interference and left to regenerate naturally. The strategy has been instrumental to reclaim degraded lands in terms of cost, time of revival and the benefit it offers to the rural communities (Kindeya, 1997; Kidane, 2002).

On other words, the land degradation is one of the major environmental threats in Ethiopia and requires concerted efforts and mobilization of resources to arrest it. The severely degraded lands are typically characterized by heavily eroded or nutrient deficient soils, hydrological instability, reduced primary productivity and low biological diversity, which are common phenomena in the most parts of Ethiopia. The major causes of land degradation in Ethiopia are the rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production (Badeg, 2011). Inappropriate land-use systems and land-tenure policies have also contributed to enhanced land degradation and loss of agro-biodiversity. Although land degradation is serious in the Ethiopian lowlands, the problem is highly concentrated in the highlands. The Ethiopian highlands cover 44 % of the country's total landmass and about 27 million ha (approximating 50 % of the highland) is already significantly degraded. The soil depth in two million ha of the cultivated lands is so reduced to the extent that these lands are no longer able to support any vegetative cover. Fifty four percent of the remaining highlands are also highly susceptible to erosion hazard. In addition, most of these degraded areas have been under great pressure for a long time, to the extent that they have been changed into wastelands. Thus, at present, remnant forests, woodlands or shrub lands have become restricted to inaccessible areas such as hillsides, mountain tops and around churches, monasteries, mosques or graveyards, particularly in the northern parts of the country.

Currently, there are efforts made by NGOs, government, and communities to rehabilitate and restore deforested and degraded forests, woodlands and bush lands. There are also tree planting campaigns and reports convey planted trees in millions annually. Nevertheless, there are little or no research efforts made to evaluate rehabilitation and characterize community based degraded forest, woodlands and bush land rehabilitation and restoration programmes. However, there is a lack of information on the survival of millions of planted trees and the socio-economic and ecological importance of these programmes. Thus, this study evaluated the socioeconomic and environmental impacts of community-based rehabilitation programs on degraded lands and the impact that the recovery has on the livelihoods of the rural communities.

Materials and Methods

The study site was geographically located at 7° 49 55.9 (7.8322°) °N and 38° 16 7.4 (38.2687°) °E (Figure 1**)** in the Ambaricho Achamo Kebele model watershed found in the Hulbareg district of Silte zone, SNNPR of the Federal Democratic Republic of Ethiopia (Figure 1). It is far away 187 km southwest of Addis Ababa, capital of Ethiopia. The total area of the rehabilitated land is about 278 hectare of communal land.

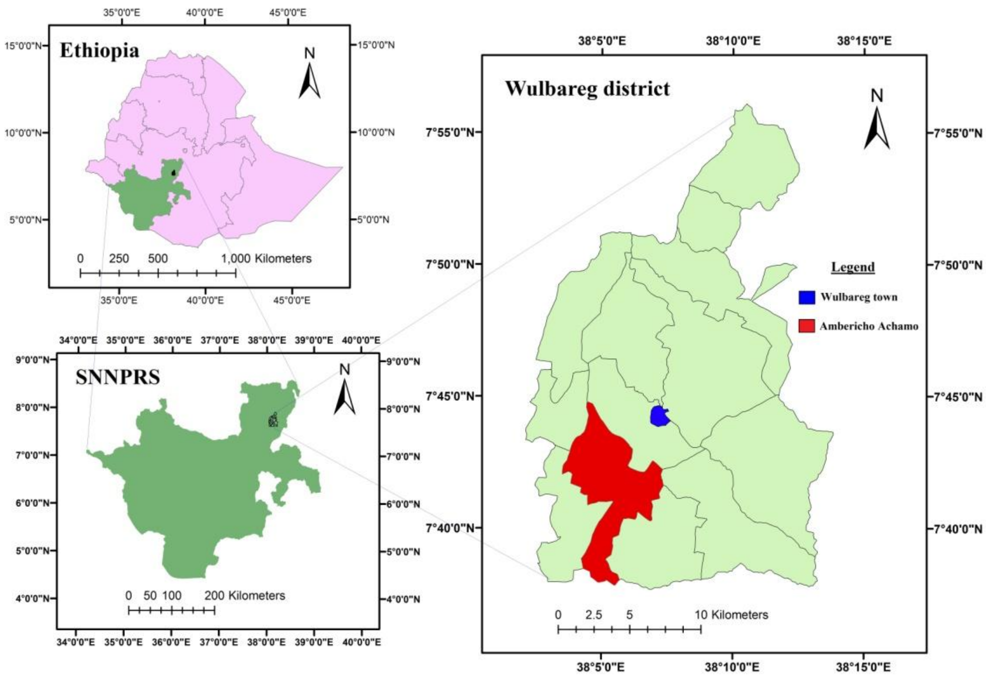

Figure 2Geographic location of study area under map of Ethiopia

The district covers an altitudinal range between 1891 and 2461 m above sea level. The soil property of the *district* was characterized by poor soil fertility having with black soil/Vertisols (60%), red soil/Nitosols (25%), gray soil/Luvisols (15%) because of severe land degradation and high water erosion (resulting in gully formation) exacerbated by recurrent drought and flooding.

The agro-ecological condition of the Hulbareg *distric*t is characterized under the dry *Woyna Dega* agro-ecological category. The rainfall of the study site fallows bimodal rainfall pattern having mean annual rainfall varied between 900 and 1125 mm year^{-1}, with an average of 1012 mm year^{-1}. The mean annual minimum temperature ranged from 19 to 27 ^{o}C, with an average of 23 ^{o}C.

The district is formed by 13 rural Peasant Associations (PAs) and one small town. Based on the 2007 Census conducted by the CSA, this district has a total population of 79,981, of whom 38,284 are men and 41,697 women; 2,198 or 2.75% of its population are urban dwellers with annual population growth rate of 2.7% and population density of approximately 280 persons per km^2. The average family size was 5 per household. The majority of the inhabitants were Muslim, with 98.65% of the population reporting that belief, while 1.04 % practiced Ethiopian Orthodox Christianity.

As far as economic activity is concerned, the people of the Silte communities live in sedentary life based agriculture, involving a complex system of crop rotation and transplanting. They also breed cattle and cultivate crops like Teff (*Eragrostis tef)*, Maize (*Zea mays*), Sorghum, Wheat and False banana). Enset (*Ensete ventricosum*) is also used as stable food crop that considerably support farmers' livelihood.

The study areas have little of their original vegetation cover as a result of the high rate of population growth and also the consequent need of more land for cultivation, more wood for construction and the absence of systematic and continuous efforts of conservation over generations. There are remnants, although few, of the various species of original natural vegetation, showing that they used to be areas of diverse vegetation. Remnants of natural vegetation consists of Tid (*Juniperus procera*), Zigba (*Podocarpus gracillor*), varieties of Acacia species, Weira (*Olea africana*), Sholla (*Fiscus sur*), Warka, Bisana (*Croton macrostachyus*), and Wanza (*Cordia africana*) that also include exotic trees such as Bahir-zaf (*Eucalyptus* species).

Reconnaissance field survey was made to obtain an overview of the study site, followed by detailed preliminary survey, which was made between 4th weeks of January to the end of February, 2014. A cross-sectional survey research design was used to collect primary qualitative and quantitative data from the field.

Purposive and systematic sampling technique methods were used to select study site and households, respectively. A total of 100 households were systematically selected from the list of local community members received from the village administration. Semi-structured questionnaire was administrated to these households to collect data on the impacts of rehabilitation/restoration programs, the role of the area enclosure to rehabilitate degraded lands, and information related to households' benefits gained from it.

Respondents were included using a statistical formula

$$n = \frac{z^2 * p * q * N}{Nd^2 + Z^2 pq} \text{ .... (Eq 1)}$$

Where, n= sample size; N= total population of households in both sites; Z^2= confidence interval (1.96, constant) ; d2= margin of error; p= proportion of population (0.5, constant); q= 1- p ; Assumption: let d= 0.05 and q= 0.5

$$n = \frac{1.96^2 * 0.5 * 0.5 * 135}{135\,(0.05)^2 + (1.96)^2(0.5)(0.5)} = 100$$

On the other hands, review of available literature was used to capture general situation of community rehabilitation programmes to raise general issues. Then preliminary identification of the objective of the program, level of community participation, ownership, intended output or achievement and socio-economic impact was examined based on secondary sources and information from key informants. Both primary and secondary data was collected from relevant sources using combination of different PRA tools. Hence, secondary data on the program and related issues was collected through reports from the office of district agricultural and rural development while the primary data was gathered through a combination of tools such as semi-structured interviews, key informant interviews, group discussion and direct observation.

Data Analysis Procedures

Statistical Package for Social Scientists (SPSS) version 20.0 software was employed to analyze data drawn from the household survey. Descriptive statistics like mean, percentage and frequency distribution were used to analyze quantitative data. Then, analyzed data was summarized and organized in tables and figures. Qualitative data generated from key informant interview, focus group discussion and secondary sources was analyzed by narrative description and interpreted on spot.

Results

Demographic Characteristics of Households

Nearly 91% of the respondents were male headed and the rest 9% represent the female headed households. Regarding the respondents educational status, about half (45.9%) of the respondents were considered to be illiterate (never went to school), 36.7% were attended primary school (can able to write and read) and the rest 16% of respondents were grouped under high school and advanced school level category. Figure 2 describes the age class distribution of interviewed household heads.

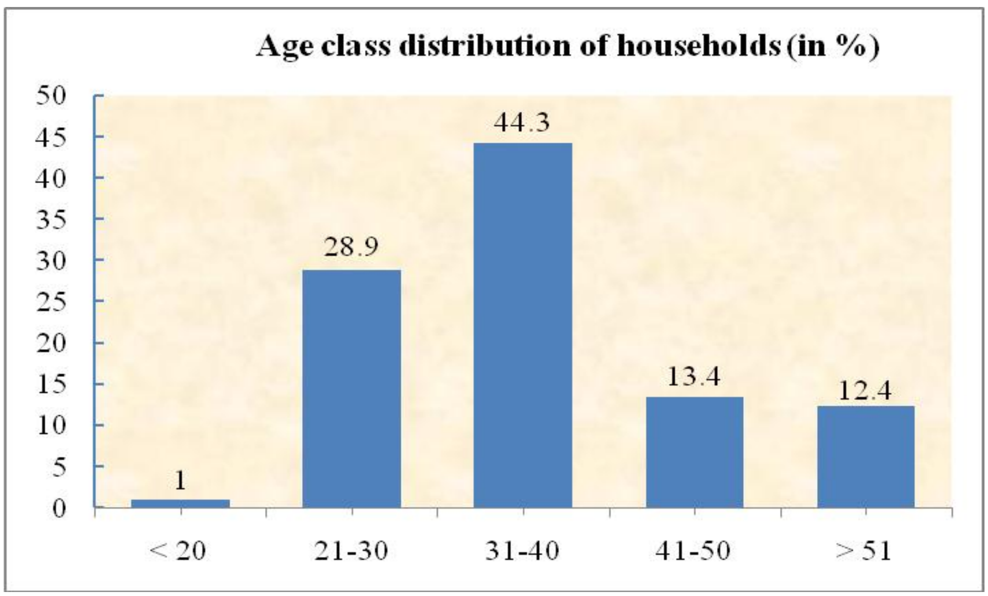

Figure 2: Age class distribution of the households in the study area

According to key informants, major criteria for setting wealth of respondent household were number of cattle and land size; poor (less than two and 0.78 – 1 ha), medium (three to five and 1 – 2 ha) and rich (more than six and 2 ha), respectively. Hence, the wealth status of the selected households was fall under medium class which comprising half of a proportion (58.7%) and the rest were considered under poor wealth class (38.7%) including only 2.7% rich responds according to criteria set by the selected key informants.

On other side, the majority of the respondents (92%) were chosen crop production as their primary livelihood source followed by livestock husbandry (58.2%), casual labor (30%), and tree crops and agroforestry practices as their secondary, tertiary and fourth source of livelihood respectively (Figure 3).

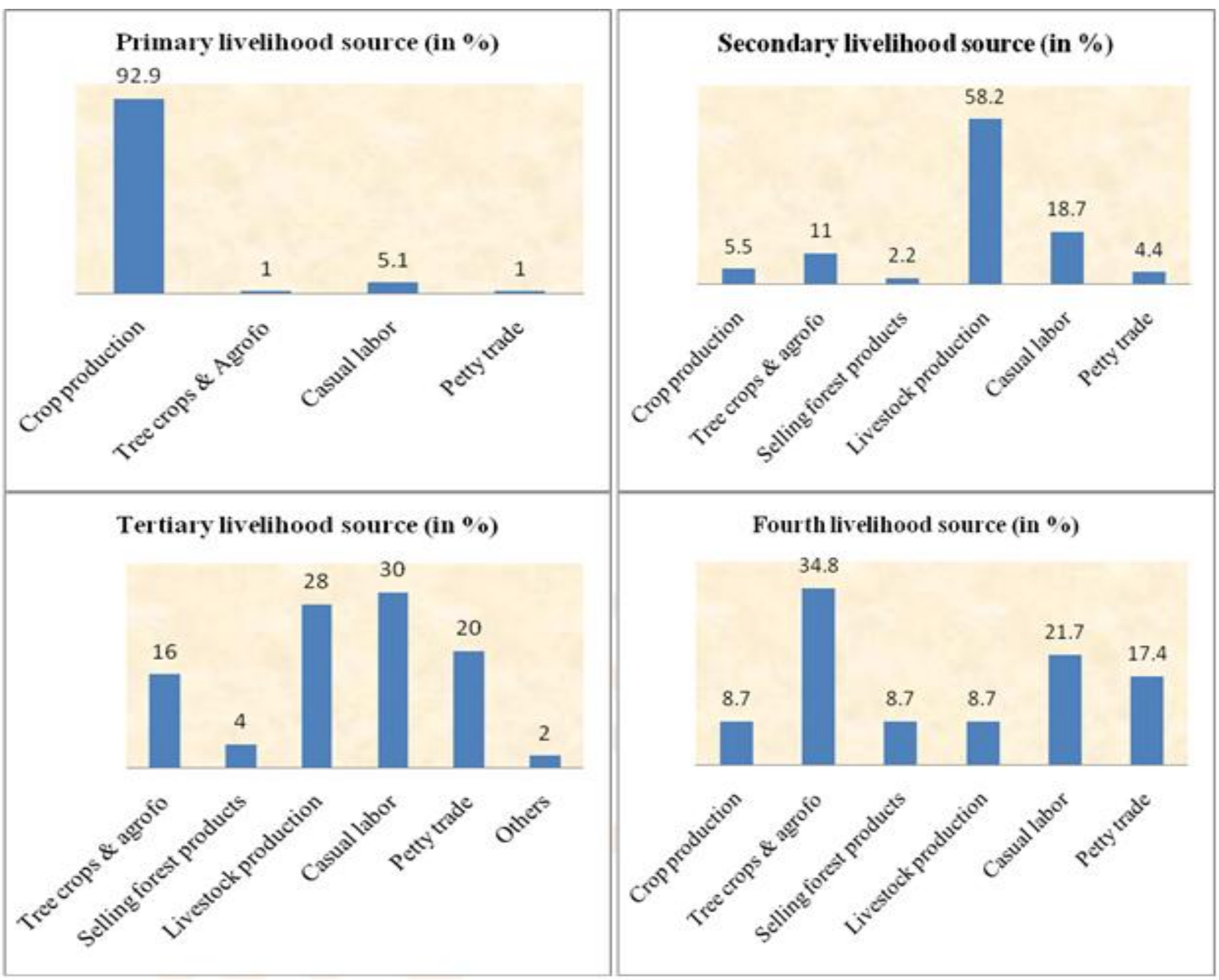

Figure 3: Source of livelihoods for the respondent households in the study area

According to results indicated the majorities of the households have less than one hectare of land. About 35 % of respondents have one hectare of land whereas it was found that nearly 20 % of households manage more than two hectares of land (Figure 4). Hence, the average landholding of the respondent households was 0.75 hectare.

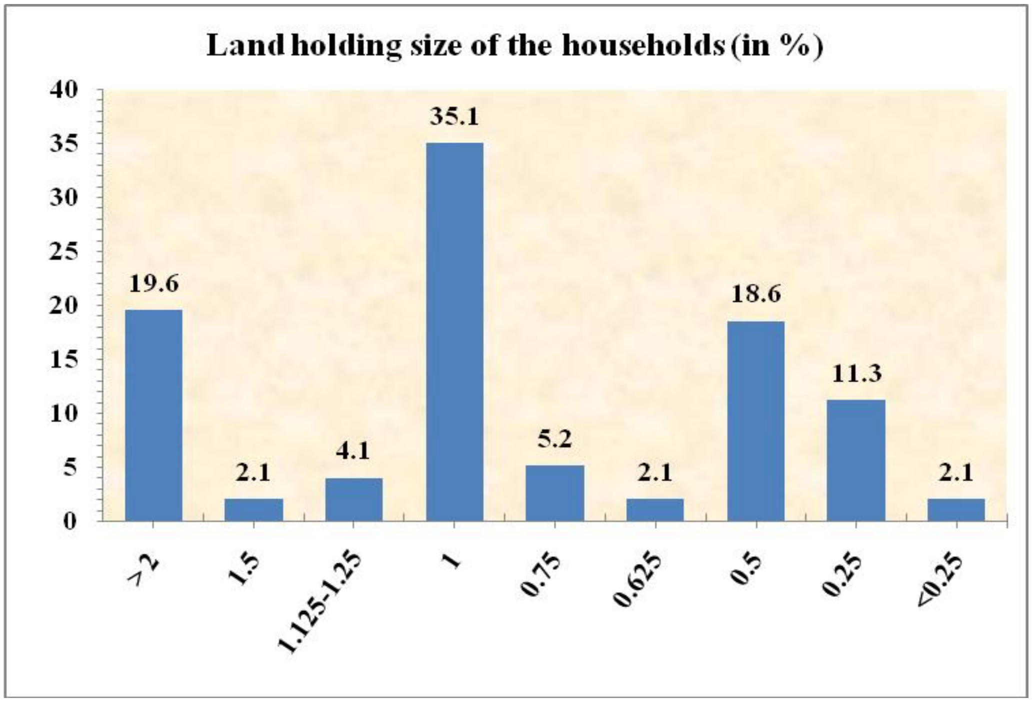

Figure 4: Land holding size of the households in the study area

Socioeconomic Contribution of the Community Rehabilitated Lands

The results revealed that 90.8% of respondents' household income enhanced due to remuneration gained through area enclosure. Meanwhile, 43.3% of respondents agreed that the rehabilitated land created better prospect of employment for the nearby community members. On other hand, 87.2% of the respondents indicated that the enclosure of degraded land contributed for increment of crop yield production (Table 1).

As fuelwood consumption concerned, 8.2% of respondents showed inclination to use firewood/energy saving stove for cooking purpose and about 97% of interviewed farmers have desire to use firewood/energy saving stove in future as well (Table 1). It was found that the respondents' best species preference for the fuelwood consumption include *Acacia species* (37.1%) following *Eucalyptus camaldulesis* (44.6%) in addition to *Cordia africana, Acacia seyal* and *Acacia saligna* shared 3.4%, 2.9% and 2.9% , respectively.

Table 1: Summary on socioeconomic benefits of the community based rehabilitated area

Socioeconomic benefits from area enclosure	Respondents' responses (in %)	
Household income enhanced due to establishment of the enclosed area	Yes	90.8
	No	9.2
Rehabilitated area created prospect in terms of employment for nearby community members	Yes	43.3
	No	56.7
Households attitude towards income generation from the enclosed area	Attractive	5.9
	Fair	47.1
	Not good	47.1
Enclosure of degraded lands contributed for addition of crop yield production	Yes	87.2
	No	11.6
	No change	1.2
Change in households net-income due to different benefits generated from the enclosure	Yes	81.1
	No	18.9
Fuelwood supply from the area enclosure	Increased	25.5
	Decreased	55.3
	No change	19.1
Communities inclination towards use of firewood/energy saving stove for cooking purpose	Yes	8.2
	No	90.7
Farmers preferred to use firewood/energy saving stove in future as well	Yes	97.1
	No	2.9

Results indicated that 27.2% of the households have utilizing unprotected communal land (open resource) to fulfill the daily demand of fuelwood consumption before area enclosure. Meanwhile, 30.3% of the respondents depend on the crop residues as source of fuelwood consumption followed by buying of fuelwood and cow dung, 15.9% and 13.8% respectively (Figure 5). On other hand, the fuelwood supply from the enclosed area substantially decreased to 8.9% but, use of crop residues as fuelwood source increased by 36.3% after establishment of the area closure. Then, the results revealed that the households shifted towards utilization private woodlots (14.4%) and other combinations (12.3%) to fulfill the demand of fuelwood (Figure 6).

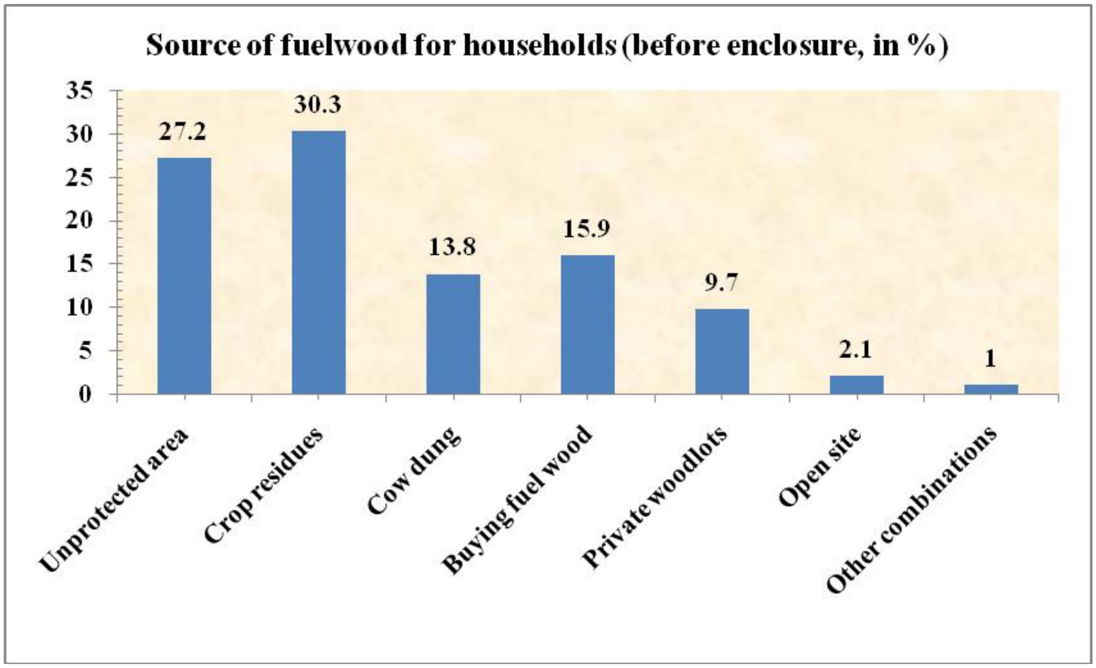

Figure 5: Sources of fuelwood consumption for the households (before enclosure)

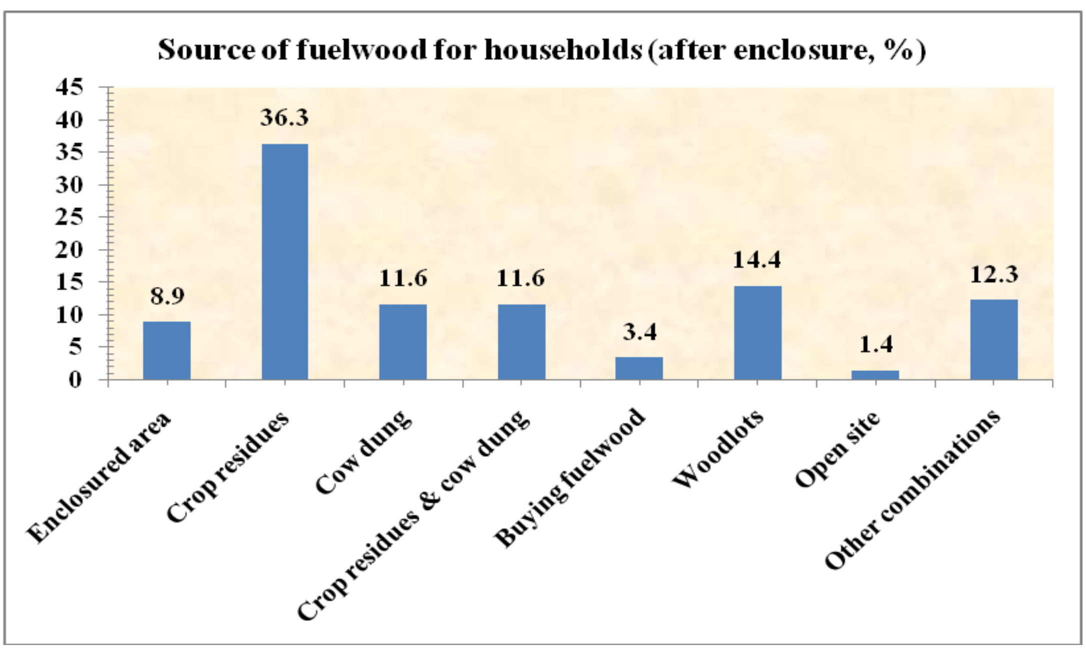

Figure 6: Sources of fuelwood consumption for the households (after enclosure)

It was found that the majorities of nearby beneficiaries (54.5%) share the access to enclosed area commonly followed by 24.8% of respondents share the benefit in group and the rest 20.8% utilize the rehabilitated land individually (Figure 7).

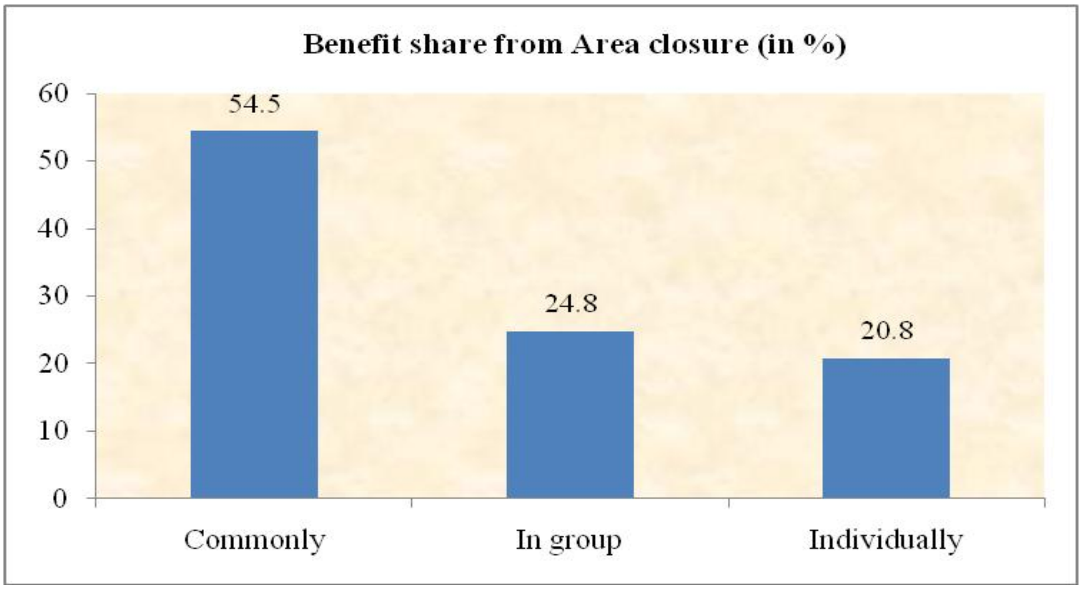

Figure 7: Nearby communities' benefit share from the area enclosure

Ecological and Environmental Benefits of the Rehabilitated lands

Table 2 below describes the ecological and environmental benefits of the community based rehabilitated land. About 95% of the respondents indicated that the vegetation cover in the enclosed area substantially enhanced in terms of species abundance (biodiversity) and density. On other hand, nearly 79% of interviewed farmers confirmed fodder availability increased considerably in the enclosed area that enabled them to feed their livestock that the farmers' stern. Not only this, results showed about 96% of respondent farmers indicated decrease of soil erosion and related devastations around farmers' household near rehabilitated land after area enclosure. In addition, it was found that 49.2% of respondents agreed on considerable increment on availability of medicinal shrubs and herbs in the enclosed area that support farmers customary healthcare system (Table 2)

Table 2: Summary on ecological and environmental benefits from the rehabilitated land

Ecological and environmental benefits	Respondents' responses (in %)	
Vegetation cover in enclosed area enhanced in terms of biodiversity and species density	Yes No	94.7 5.3
Fodder availability increased substantially in the enclosed area that enabled them to feed their livestock that the farmers stern	Yes No No change	78.9 18.9 2.1
Grass availability amplified in the rehabilitated land that would helped the farmers to use it for household consumptions	Yes No No change	77.7 18.1 4.3
Households began placing bee hives in enclosed area for the production of honey	Yes No	17.1 82.9
Honey yield increased due to vegetation cover regenerated in the enclosed area	Yes No	88.9 11.1
Availability of medicinal shrubs and herbs in the enclosed area that support farmers customary healthcare system	Increased Decreased No change Do not know	49.2 11.5 31.1 8.2
Status of soil erosion and related devastations around farmers household near rehabilitated land after area enclosure	Increasing Decreasing	4.2 95.8
Land slide around farmers households near rehabilitated land after area enclosure	Increased Decreased No change	8.3 75.0 16.7
Frequent encounter of flooding trouble substantially decreased due to management of enclosure	Yes No	97.6 2.4
Enclosure contributed for the ground water improvement that farmers found water from deep wells	Yes No	42.6 57.4
Surface water improved due to enclosure of degraded land that enabled farmers to have access it	Yes No	65.1 34.9

Farmers' Perception on Community-based Rehabilitated Lands

The results showed that at the beginning nearly 70% the respondents did not agree for the placement of the enclosure in the open common lands even though the attitude has been changed positively (96.2% of respondents) through time. Therefore, currently

82.2% of households have showed willingness to expand new rehabilitation areas due to the lessons from the existing advantages of enclosure (Table 3).

Table 3: Farmers' perception on community based rehabilitated area

Farmers' perception on rehabilitated area	Respondents' responses (in %)	
Users' insight on area enclosure during the period of initiation and establishment by the local government	Good	29.3
	Terrible	69.6
	Indifference	1.1
Change in attitude of the users on regarding the area closure that those had before	Yes	96.2
	No	3.8
Willingness to protect additional areas so as to adopt learnt lessons from the current enclosure	Yes	82.2
	No	17.8

Management Role of Community on the Rehabilitated Lands

It was perceived that higher portion of the management role was played by the community (39.2%) and peasant association administers (32.4%) (Figure 8) indicting active participation of nearby communities that have major position in management of the rehabilitated land.

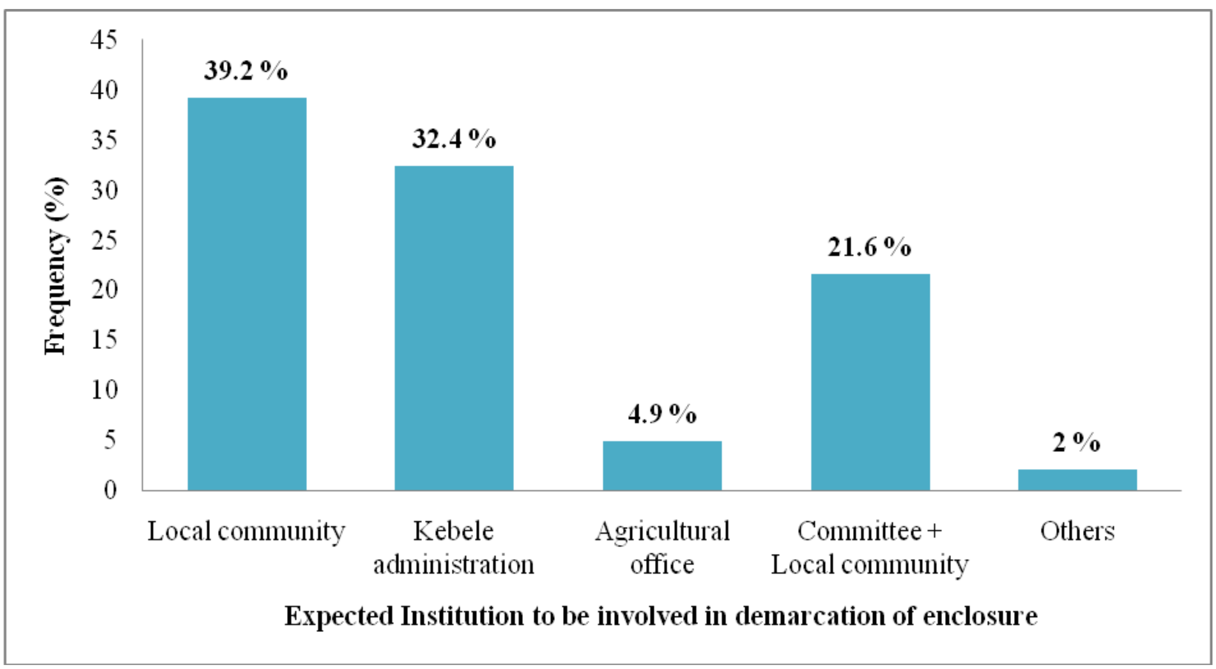

Figure 8: Institutions expected to be involved in demarcation of enclosures as perceived by local communities.

About 94% of respondents indicated bylaws must be placed to manage the area and illegal utilization of resources could be reduced/controlled. The findings also indicated by 81% of respondents confirmed that they are satisfied by the expected outcomes from the enclosure and related ongoing activities (Table 4).

Table 4: Communities management role on the community based rehabilitated area

Communities management interventions on enclosed area	Respondents' responses (in %)	
Active participation of community members' on management process (identification, planning and implementation) is uncompromised	Yes No	97.7 2.3
Availability of bylaws in place and regulations set by the stakeholders to manage enclosed area	Yes No	93.9 6.1
Extension and provision of trainings to raise awareness on management of the enclosure	Yes No	37.9 62.1
Nongovernmental organizations support is encouraged	Yes No	16.7 83.3
Stakeholders' satisfaction on expected outcomes from the enclosure and related ongoing activities	Yes No	81.0 19.0

Discussion

Local Communities' Perception on Land Degradation

The majorities of respondents agreed that humans and livestock should be restricted from enclosed sites for effectiveness of enclosures. In this regards, the studies reported that fencing involves restricting of damaging agents to maintain degraded lands (Hayward and Kerley, 2009) and it is a recommended practice to facilitate land rehabilitation (Girma, 2009). Moreover, research result states that for overall vegetation rehabilitation, excluding of livestocks ensures the growth of woody vegetation, which provides shelter for next generation of succession; as a result a better regeneration could be achieved by excluding of humans and animals from degraded sites (Girma, 2009).

Communities' Attitude towards Enclosure

Respondents stressed that enclosures are effective land management options that promote surface cover and mitigate soil degradation resulting in enhanced land value and productivity (Table 2). This positive attitude of local communities is fundamental for the sustainability of enclosures (Heitschmidt, et al., 2004) and also for future rehabilitation projects (Wolde, et al., 2009). Local communities' attitude towards enclosure is supported by previous study that states irrespective of the increase in population size, soil and water conservation and land rehabilitation efforts such as enclosures resulted in decreased sheet and rill erosion (Nyssen, et al., 2007). Besides, studies concluded that increased vegetation density in enclosures result in increased infiltration, that in turn triggers vegetation rehabilitation through superior biomass production thereby improved land productivity including spring discharge at lower catchments (Nyssen, et al., 2002; Wolde, et al., 2009).

The majorities of respondents are optimistic to the performance of enclosures and reported that enclosures are effective in rehabilitating degraded lands (Table 4); hence, they support vegetation growth on degraded lands. It was also noticed that the enclosed sites were completely covered with vegetation which were regenerated naturally; but open lands were bare sites. In addition, during focus group discussion, they explained that the performance of enclosures could be enhanced with continuous and integrated soil and water conservation mechanisms. This households' perception is in consistence with Wolde et al. (2000) study that states enclosures are effective in controlling soil degradation. Similarly, Vanandel and Aronson (2006) found that re-establishing natural vegetation is an option to reverse land degradation, rehabilitate landscape integrity, and realize the environmental and social benefits of natural resources; it is now widely practiced around the world.

Management Role of Communities on Enclosures

Respondents pointed out that the local community should be involved in decision-making and bottom up approach management of area closures develop sense of belongingness among the community (Figure 8). Consequently, respondents believe that the demarcation should be collaborative (Local community, *Kebele* officials and Agricultural office), and the majorities of the respondents concluded that sense of belongingness could be developed if the management is designated to the local community after demarcation. Households' conclusion is supported by studies that state although establishment of enclosures in Ethiopia have considerable economic and ecological significances, it might be due to top-to-down implementation and limited participation of local community in decision making and utilization of resources during the during past years, the community denied the contribution of enclosures (Dessalegn, 1994). This has significantly affected the sense of ownership and community's commitment for effective protection and sustainable management of land resources (Nedessa, et. al., 2005).

Role of Enclosure for Local Communities

The local communities disclose that enclosures provide three fundamental benefits to the local community. These include (i) Social value: accordingly, they were asking for resettlement due to accelerated soil erosion. However, nowadays the practices of enclosures have enabled them to control soil erosion and have increased land productivity. (ii) Economic value: respondents replied that enclosures provide considerable fodder access for livestocks and are efficient to increase income for households in terms of employment, and crop yield production towards lower catchments (Table 1). Hence, this has helped them to save the cost of grass purchase for fodder and thatching. This optimistic perception of the local community is supported by studies that state enclosed sites provide grass and wood access for local community beyond their aim of establishment (Mengistu, et. al., 2005). Respondents' view of economic benefits of enclosures also agrees with Lovejoy (1985) research result that states resources from area closures contribute to the households' economy, suggesting that economic and social wellbeing is enhanced by focusing on rehabilitation of degraded lands (Lovejoy, 1985). (iii) Environmental value: respondents explained that area closures are effective strategies in controlling accelerated soil erosion and agricultural lands below area closures become more productive than lands below grazing. This agrees with studies that state agricultural lands below free grazing were strongly affected by water erosion than below enclosed sites (Wolde, et al., 2000). In addition, studies concluded that enclosures facilitate natural regeneration thereby reducing surface runoff. This will promote accumulation of soil organic matter and other plant nutrients that excel soil quality and capable of support diverse communities (Girma, 2009).

Conclusion and Recommendation

Community-based rehabilitation programmes in degraded lands i.e. restoration through enclosure of areas) is widely acknowledged as a way of reversing degradation processes and improving , land productivity, environmental services, the resilience of human and natural systems and the livelihood of local communities. The sense of ownership of the technology in the community, and the equitable distribution of benefits among community members, are keys to success. The conversion of degraded land through the deployment of enclosures is considered to be relatively low-cost. It reverses land degradation processes, with many associated advantages: it reduces runoff and soil erosion; improves the microclimate and water infiltration; restores soil nutrients; produces livestock fodder, woodfuel and grass for house construction; and enhances biodiversity. If all benefits are taken into account, enclosures provide a better return than other agricultural land uses such as intensive cultivation and livestock grazing. Surveys of local people showed that more than 96 % of households had a positive view of the effectiveness of enclosure in restoring degraded lands. Therefore, the results in this study revealed that enclosures have significant contributions to the socioeconomic and ecological systems; as they generate ecological and socioeconomic benefits. The majorities of the local communities developed sense of belongingness and developed positive attitude to the performance of enclosures. Such perception is a base mark for future sustainability of the practice.

Promote natural regeneration–assisted natural regeneration and, on farms, farmer-managed natural regeneration are simple and effective restoration measures that require little investment. They also have the potential to be scaled up quickly in areas where tree and shrub species have the ability to re-sprout after harvest and where rights to resource use are appropriate. On other hands, collaboration at the local level among scientists and stakeholders, along with community involvement, were keys to the successful application of the ecological restoration programme in the study area. Monitoring and database development should be intrinsic components of all restoration projects.

It is fact that the previous attempts to improve the rehabilitation and productivity rate of enclosures were constrained by lack of planting technique, silvicultural management of trees, lack of comprehensive bylaws, and absence of management plan. Thus, careful selection of tree species, knowledge of silvicultural management, planting techniques and developing participatory and holistic bylaws will provide the fundamental basis to enhance the rehabilitation and productivity rate of enclosures. Thus, rehabilitation of degraded land activities must be accompanied by technological innovations that will enhance the productivity and rehabilitation rate.

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Chapter Two: Climate Science Research

Traditional Ecological Knowledge System for Climate Change Adaptation and Mitigation: Lesson from Central Rift Valley, Oromia Regional State, Ethiopia

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Abstract

The aim of this research is to assess and document the traditional ecological knowledge system applicable for climate change adaptation and mitigation. The research was conducted in three Kebeles of Adami Tulu Jido Kombolcha District, Oromia Regional State. Data were collected on the environmental and livelihood problems of the area, manifestation of climate change and associated impacts affecting the study area communities, indigenous rainfall prediction system and coping strategies. Data were collected from August to June 2017 using questionnaire survey, key informant interviews, focus group discussion, and observations. Results showed that the main livelihood and environmental problems at the study area were directly or indirectly related to climatic change such as drought, rainfall variability and hotter temperature. The study communities rely on varies indigenous weather monitoring mechanisms and indicators that include: i) meteorological (wind, cloud, tornado and lightning), ii) astronomical (moon, sun and star), iii) animal behavior (frog and cattle) and other environmental and social indicators. They are able to predict weather condition from daily to seasonal basis, and thereby apply their knowledge for land preparation or for early warnings and preparedness depending on the time scale. The major indigenous climate change adaptation and coping strategies include: i) farming along river/lake banks, ii) seasonal migration to wetter area and to towns, iii) collecting and saving crop residue for livestock feeding, iv) destocking of livestock, v) saving, and vi)income generation from fuel wood and charcoal making. The study also depicted that despite the communities heavily rely on their traditional ecological knowledge system in their day-to-day livelihood activities, less recognition is given to the integration of the local knowledge system. This less attention to their knowledge system has increased the vulnerability of the study communities implying the need for careful integration of indigenous knowledge system and conventional knowledge in order to enhance social-ecological resilience of the vulnerable communities.

Key Words: *Climate change, adaptation, Ethiopia*

Introduction

Climate change is among the major environmental challenges the world is facing today. Although climate change affects the whole world, its impact is substantial in least developed countries. The major impacts include frequent and severe droughts, flood, increased pests and diseases, damage on crops and livestock, loss of biodiversity and decline in ecosystem productivity, resulting in households' welfare depletion, massive migration and competition of rural communities for scarce resources (Abaje and Giwa, 2007).

Rural communities in developing countries such as in Ethiopia are known to rely to a greater extent on their indigenous or traditional ecological knowledge system in their day-to-day livelihoods. Traditional Ecological Knowledge (TEK) refers to the evolving knowledge acquired by indigenous and local people over hundreds or thousands of years through direct contact with the environment (Folke, 2006). Despite its marginalization for long time since the industrial revolution, there is a tremendous acknowledgement of TEK system in the recent decades, mainly in areas of natural resource management, climate change adaptation and mitigation, biodiversity conservation, weather forecast, peace building and conflict resolution (Folke, 2006; Parrotta and Agnoletti, 2012; Adefires, 2016).

Similarly, in its fourth assessment report, the IPCC stated that TEK is "an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change" (Raygorodetsky, 2011). TEK system plays important role in short and medium-term weather forecasting (Parrotta and Agnoletti, 2012). Despite the slow move to integrate TEK system in formal sustainable development plans, there are various studies that show the application of TEK system to manage natural resources in rural Ethiopia. For instance, Desalegn et al. (2015) assessed the indigenous biotic weather forecasting system among the Borena herders in southern Ethiopia. Similarly, Abate (2016) studied community climate change coping mechanisms in southern Ethiopia. The aim of the present study was to document the indigenous climate prediction and adaptation/coping strategies of communities in selected Kebeles at Adami Tulu Jido Kombolcha District, Oromia Regional State, in order to promote the re-vitalization of TEK system into the extension system.

Material and Methods

Adami Tulu Jido Kombolcha District is found in Ethiopian Rift Valley system in East Shewa Zone of Oromia Region, Ethiopia. It extends from 38°25′E and 38° 55′E to 7°35′N and 8°05′N. The district shares boundaries with Southern Nations and Nationalities People's Regional State (SNNPRS) in the west and North West. According to the information gathered from the District's Agriculture and Disaster Management offices, currently there are a total of 43 rural and 4 urban (*Kebelle* associations) KAs in the district.

Major livelihood strategy in the district is mixed agriculture (crop and livestock). Most common livestock are large ruminant cattle, goat, donkey, and poultry and major crops cultivated are maize, teff, barley and wheat. Agro-ecologically the district is predominantly 'dry-kola' with small area being woinadega. The annual rainfall varies from 600-800mm and is characterized by bimodal rainfall.

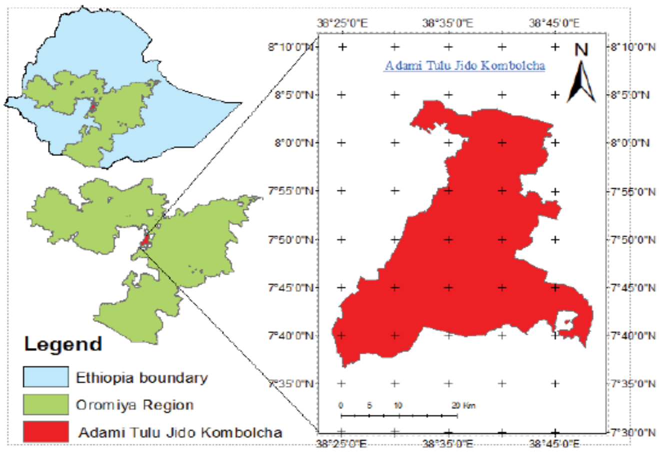

Figure 1: Study area map

The natural vegetation in most central part of the Rift Valley is sparse umbrella shaped woodland dominated by *Acacia etbaica* and *Balanites aegyptica*, and hence, it could be classified as *Acacia-Balanites* woodland (Abera, 2016). The people in the district are dominantly Oromo ethnic group with different clan groups locally called '*gosa*'. These include '*Wege*', '*Abure*', '*Kontoma*', '*Habelose*', '*Koji*' etc.

Data Collection Methods

Primary data was collected on the environmental and livelihood problems in the area and their causes, community manifestations and/or community observations on the change processes such as climate change and associated impacts, rainfall prediction strategies and community-based short-term coping mechanisms and long-term adaptation strategies. Data was collected using guiding questions (checklists and interview) by focus group discussion, key informant interview and field observations. Focus group discussion was conducted to get general overview of the area, community climate change perception, the community rainfall prediction/forecasting indicators and the different coping/climate change adaptation and mitigation practices in the area. Key informant interview was conducted for in-depth understanding of indigenous climate prediction mechanisms/indicators and their meanings. Qualitative data analysis method was used to summarize the information.

Sampling

Sample *Kebele* Administrations (KAs) were fixed to be three due to the limitation of resources. The three KAs out of 43 rural KAs were selected purposively. Key criteria used to sample KAs include vulnerability to climate change, distance from cenetral administration unit, and agro-ecology (*Kola and Woina Dega*). Based on these criteria Haroresa Kalbo, Abine Garmama and Galo Hiraphe were selected for this study.

The major data collection methods in this study were Focus Group Discussion (FGD), Key Informant Interview (KI) and Observation. FGD was organized at each Kebele, where individuals from all age and gender groups, religion and traditional leaders and experts were participants. About 10 to 15 individuals were purposively selected for the KI. Individuals who lived at the study areas for over 20 years and those who directly engage in agricultural activities and were assumed to have knowledge on the environment and climate change were given emphasis during selection.

Results

Environmental and Livelihood Problems

Frequent flood and drought incidences, rainfall variability, livestock and crop diseases, declining crop and livestock productivity, intensive winds that damage crop, landslides, soil erosion, and shrinkage of wetlands, deforestation and local extinction and or scarcity of some tree species were identified as most important environmental challenges at the study area. Respondents mentioned different biophysical and socio-economic factors that led to declining forest resources and total disappearance of some important fodder and food species from the area. Forests were cleared for farmland expansion, which derived by fast growing population in the area. Farmers also clear forestland with the intention of production area expansion for new and fertile land to compensate declining agricultural productivity caused by loss of soil fertility, frequent drought and rainfall variability and the overall increasing livelihood vulnerability and poverty. The livelihood assessment show recent increase of livelihood dependence on forests as alternative means of income such as through sale of fuel wood and charcoal. These on the other hand enhanced severe degradation of the Acacia woodlands and wooded grasslands. Respondents also mentioned declining rainfall and lack of suitable forest management knowledge as factors contributing to poor natural regeneration of various species.

At the study areas, livestock asset is declining mainly due to scarcity of forage and drinking water. As far as water availability is concerned, the participants mentioned that, their established tradition of collecting enough water in the morning after rains in the night was not any more possible. This among others is due to increased temperature that facilitates quick loss of water through evapotranspiration. Rainwater is also lost immediately to erosion as soils have poor water infiltration capacity where vegetation cover is lost. These have resulted in increased competition for water at the study area. The competition is further aggravated by increased interest in diversion of scarce water for irrigation by factories at the study areas. Respondents emphasized their serious concern about continued reduction of the local lake water resource, locally called 'haro', mainly due to unwise use of water for irrigation by the growing number of factories since recently and also siltation problem In summary, despite the contribution of other socio-economic, cultural and policy and institutional issues, environmental problems, mainly those related to climate change were the main factors for increased social-ecological vulnerability at the study areas.

Climate Change Manifestations as Explained Based on Rainfall Condition

Communities explain climate change mainly based on the changes and variability of rainfall and its impact on environment and livelihoods. According to key informants, the study areas were used to get rain for more than six months and four to seven days a week 20-30 years back, but currently the dry season have extended from six to ten months and may rain for one day per week or not at all even during rainy seasons, leaving their water points empty (Figure 2). A respondent mentioned the current situation by saying "current rain has no brother" to mean, it rains one day and may not come at all, or come after many days once the soil and vegetation have already become dry. They also emphasized that rainy season is no more predictable and there is mix of dry and wet seasons. Respondents also explained shift in the rainfall onset, for instance, they mention that, 30 years ago rain used to start in March and end in September. Currently, it is not even known; it may start between May and June or may not rain at all. Unfortunately, late coming rainfall often causes flood and run off when it rains, also resulting in scarcity of soil moisture that is not enough to grow crops or species regeneration.

The study communities also relate forest loss to climate change with change in rainfall and temperature. It was mentioned that forest has become vulnerable to climate change directly due to lack of sufficient rainfalls and indirectly due to deforestation for copping up the loss of crop and livestock productivity. The communities listed (in local names) some of the common plant species currently disappeared and or endangered due to drought and deforestation: '*Ejersa*', '*Tatesa*', '*Wadesa*', '*Hindesa*', '*Badesa*', '*Mancera*'(source of food), '*Garbi*' (cultural spiritual prayer place), '*Habile*', '*Kurkura*' and '*Gunaa*'. Most of these species are known sources of timber, fuel wood, fruits/food and livestock and bee fodder, among others. According to most respondents, most of these species are unable to regenerate after cutting or from soil seed bank or once they regenerate the seedlings are unable to adapt to increased dry spell.

Climate Change Manifestation as Impacting Livelihoods

The study communities also explain climate change and variability through its impacts on their livelihood. For instance, they mentioned change in rainfall amount in terms of its inadequacy for crop, forage and forest productivity as well as by the availability of water for livestock. Respondents also mentioned shrinkage of lakes (Figure 2) over time and due to scarcity of rains. Crop and livestock yield depended on the rainfall; there might be low yield to no yield depending on rainfall sufficiency.

Figure 2: Community indicators, absence of rain in rainy season, left; and shrinkage of lake, right

Change in temperature is manifested by observing plants reproduction or phenology such as drying of leaves, fast loss of water from land and collection points such as "haro" through evaporation and percolation, animals gathering under tree shade for long time and the like. Respondents also mention change in the agro-ecology, for instance previously moderate temperature like climate, locally called 'woinadega' agro-ecology has changed to dry and hotter agro-ecology, locally called 'kola'.

The study communities also mention that, previously they never use improved crop variety, as they were able to produce enough using local races as they used to depend on few races, may be one or two. But, these days, due to uncertainty of rainfall, everybody has to use improved crop variety and more types of crop species so as to minimize risks. Respondents also explain that they would no more depend on their traditional practices as it is not sufficient to cope up and adapt to the alarming environmental changes. This is for instance explained in terms of lack of productivity of crops without input and advanced land management practices that demands high labor and finance. Even with application of technology, livelihood in the study area has become hand to mouth due to severe impact of climate change and variability and landscape degradation that has resulted in poor agricultural productivity and loss of forests. According key informants, when there was more or less stable rain fall and fertile land nearly thirty years ago, they used to harvest 20 to 30 quintals (i.e., 1 quintal is 100 kg) from one 'kertu' (kertu' is local land measurement unit equals to 0.25 ha). These days however, the extended dry season ("bega") has made crop cultivation difficult, leading most households to depend on food support.

The study found difference among livelihood strategies. Livestock production is the most vulnerable livelihood to climate change at the study area. Within the livestock, cattle and sheep are the most vulnerable, while donkey and goat are relatively resilient. According to the key informants, frequent drought and the consequent shortage of fodder and water and associated livestock diseases have dramatically reduced number of livestock per household and also critically reduced the life expectancy of individual animals. Households also have to destock some of their animals during bad seasons such as flood or drought and epidemics, which result in reduction of total livestock per head. As far as disease epidemics are concerned, respondents mentioned that the current climate condition could be optimum for many pests and pathogens causing diseases (Table 1). They elaborated this in such a way that, the occurrence of plant and animal pest and disease is likely when the rain stars to rain and then stops for longer time (short rain followed by longer dry spell). They also mentioned that the likelihood of disease or pest occurrence is high when there is hot weather and when it rains in dry season.

Table 1: Livestock and crop disease occurrence, affected crops or livestock and time of occurrence

Types of livestock affected	Livestock diseases		Types of plants/crops affected	Plant diseases	
	Type of disease /local name	Months of occurrence		Type of disease /local name	Occurrence month
Cattle	'Fura', 'Cine', 'Abansanga'/'Dibe Gala','Cinii'	May	Maize	'Worm'	July
Goat/Sheep	'Luqace'	September, November	Wheat,Barley	Wag','Butukume'	July,August
Cattle	'Manse,Gardo'	June			
Goat	'Ole'	Throughout the year			
Cattle	'Gororsa'	Throughout the year			
Goat	'Dola'	May			
Donkey	'Garagalcha'	Throughout the year			
Chicken	'Figili'	July			
Goat/Sheep	'Finchadimesa'	March			
Donkey	'Sardo'				

Since recently, it was also observed that, spread of livestock and crop pests and diseases were increasing and covering wider areas compared to the previous years. Among others, spread of '*wagi*' (a fungal rust disease that affect wheat, maize and barley) during May to June has become common in the study area. If dry spell extend for two weeks, '*wagi*' attack maize and wheat crops. According to the key informants, the disease start to attack crop fields when cold weather abruptly change to hot and such event has become common these days. In addition, termite spread, locally called 'rirma', has become a serious problem at the study area. This pest spreads when the weather is cloudy, but does not rain for sometimes.

Gender and Climate Change

Climate change doesn't equally affect men and women. Since women are differently affected by climate change, and being burdened by household activities, in addition to agricultural activities, they explain impacts of climate change in other terms. Women in the focus group particularly mentioned how difficult for girls to fetch water. They stated that, in some areas, girls have to leave at 5am in the morning to find water point and may comeback home at 2pm in the afternoon. This along with other factors has been undermining girl's education at the area. Women headed households in particular are victims of climate change as they are unable to produce enough to feed their families under current frequent drought and unpredictable rainfall. UNDP (2013) states that women are charged with securing various livelihood means such as water, food and fuel for cooking and heating and as climate change intensify; they face the greatest challenges to fulfill their responsibilities.

Community Beliefs on Reasons of Climate Change

The study communities give different reasons for climate change specially the change in rainfall amount and variability in their area. One of the main reasons mentioned is diminishing culture of prayer. One key informant explains this as, "previously when the rainy season approached, we used to go to 'melka' (River) and pray hence rain comes timely". According to this informant, the important culture is left behind now and is reason for lack of rain. The other reasons mentioned as reason for lack of rainfall is not abiding with traditional 'gada system', which result in unsustainable natural resources management. Weakening of local institutions such as "*Geda* system" has aggravated deforestation including cutting of sacred tree/forests, traditionally called '*abdari*'. There are also many people who belief that the current change in climate is a punishment from God because of disobedience of people to this rules and regulations, hating each other, lack of justice and respect for each other.

Community Level Climate Change Adaptation

Community level adaptive responses and mitigation strategies, including indigenous rainfall prediction approaches, and their coping mechanisms as assessed from the respondents are summarized in next sections.

Community Rainfall Prediction and Seasonal Forecast Mechanisms

The studycommunities use various indicators to predict the onset of rains and to identify the season's suitability for decision making. Some of the indicators are animal behavior, wind circulation, cloud cover, water bodies, plant characteristics and other environmental and social means (Table 2). They predict the coming of rainfall on daily and seasonal basis (season's condition if it is bad or good). According to their expression, bad season means a season with drought or flood whereas good season is a season, which has optimum rain for crop and livestock production. Communities' prediction of rainfall is for shorter period at the beginning of cropping season for land preparation and, to indicate whether the season is suitable to plan for a crop type and/or for preparedness.

Table 2: Community rainfall prediction strategies

No	Indicators for onset of rain for daily or a few days ahead/ short range forecast	Indicators for suitability of season: Good season indicators	Indicators for suitability of season: Bad season indicators
1	Meteorological phenomenon indicators		
	- wind direction south to north; - presence of cloud if it is not windy; - appearance of strong whirlwinds/ small tornado locally called 'hobombolesa' if it stands and moves slowly to the right, rain is expected in 1 to 2 days; lightening in the sky	-	- rainbow appearance
2	Astronomic indicators		
	-hiding of moon at night -color of sun become red in the morning -star pattern become bigger and many then (rain is expected in 28 days)	-moon's half side directs downward	-moon half side directs upward
3	Animal behavior		
	- cattle behavior of sniffing - a local bird called 'humo' chirping and movement in the area - frogs croak laader	- bees migrate to land	- bees migrate to river; - cattle loss grazing and drinking appetite, unusually eat bone, refuse to get out and in from their pen
4	Others		
	coming of rain in nearby area (from south direction)	Timing of rainfall-at the onset of rain if it rains at morning and then night	Timing of rainfall at the onset of rain if it rains in noon
		color of water/lake such as when it becomes black	

The study community also followed tree phenology to predict rainfall. They stated that flowering of a tree locally called '*harbu*', which is now extinct, indicated the coming of rainfall few days ahead. In addition to indicators shown (Table 2), they use social means to forecast the next season. They forecast next good and bad season by naming the day the rain stars. Accordingly, if it rains on women's '*ayana*' day, then the coming season is interpreted as kind and good season. If it rains on 'ayana' of horse, then it will rain erratically. If it rains on '*ayana*' of elephant, heavy rain is expected and on '*ayana korma*' drought is expected. Other social indicators, such as coffee spoiling and children unusually cry for food, are used to indicate the coming of bad season.

There are similar situations in other parts of Africa. Before the advent of modern scientific methods, rural communities must have realized that some animals, birds, insects and plants had the capacity to detect and respond to changes in atmospheric conditions. They also mastered the positions of stars, the sun and associated shadows and the moon, the wind strength and direction and the cloud position and movement and the lightning patterns (Makwara, 2013). Indigenous knowledge system also use different indicators to predict the quality of the season before the onset of the rains, these climate indictors includes birds, wild fruits, trees and worms (Soropa, et al. 2015). The behavior of animals such as livestock, birds, insects and amphibians is also used by farmers to predict the onset of the rainy season (Mafongoya and Ajayi, 2017). Frogs in swampy areas croaking at night is indicator for onset of rains. According to the authors, the songs and movements of different birds to signal the onset of rains has been reported in Mali, Nigeria, Swaziland, Tanzania and Zimbabwe, among other countries in SSA.

While the indigenous communities are almost dependent on indigenous rainfall prediction methods, there are potential constraints or threats to their forecast. The constraints were criticism from religious people who don't accept such method, rather trust that rain is from God, lack of trust of young generation on the traditional forecast method due to increased awareness about the modern forecast methods and also due to degradation of various indigenous indicators that have been undermined due to environmental degradation, climate change, and due to absence of documentation.

Community Adaptation Practices

The study communities practice different climate change adaptation practices by themselves as well as by support of the extension system. Indigenous practices identified as means of coping and adaptation to climate change include planting trees and protecting existing patch forest, farming near and along river/lake banks, crop diversification, change in planting dates, migration to wetter area, collecting crop residue for livestock feeding (Figure 3), collection and sale of forest products and the like. According to studies conducted in Africa, in developing adaptation strategies to climate change, one of the first steps to take is to know what the affected people are already doing to cope with the changes that they have observed (Benjamin and Winston, 2011).

Figure 3: Crop residue for livestock (left) and application of cow dung on farmlands (right)

As shown in figure above (Figure 3), the indigenous people practice various activities to restore degraded landscapes by way of collecting and spreading cattle dung on their farm lands and by constructing animal/cattle stall in marginal land for rehabilitation. They dig shallow wells to collect water for dry seasons (Figure 4). Due to the water in the shallow well, the tree 'bekenisa' could survive which in turn enabled them to produce honey (Figure 4). They also request support from relatives, borrow and/or share goods and services from each other during bad seasons. Other coping and/or adaptation mechanisms include requesting local government for supplementary food aid, selling livestock such as goat and poultry to buy food, saving food and cash, migration to town for search of daily job, reducing food consumption, and selling of forest products such as fuel wood and charcoal. The study communities also have short term early warning system in place. For instance, when there is heavy rain in the upstream, people at downstream are informed by various means, so that they will be prepared to cop up with flood.

Figure 4: Application of different adaptation strategies such as digging shallow pond (left) and traditional bee hive near the pond (right)

The study communities also have established social mechanisms to resolve environmental other conflicts. They enact '*Sirna Gada*'/*Geda* system/ to formulate and implement laws to forest and water uses. For instance, a person who cuts a tree is penalized to pay a livestock or up to 500 birr per tree. In addition, a person who cuts a tree is believed to be a cursed person in the social systems.

There are informal local institutions established and managed by the communities themselves, which have great role in enhancing social-ecological adaptive capacity. These include '*edir*', '*ekub*', youth and elders environmental protection group, traditional women group locally called '*wiijoo*' and the like. Their role is to help each other in time of difficulty and occurrence of drought and flood. If livelihood is lost by flood or a woman has nothing to live with due to drought, the women group collects money and gives her to buy a goat.

Conclusions and Recommendations

Communities observe climate change and variability mainly through its impacts on their environment and livelihoods. Results also demonstrated interdependence between crop, livestock and forest productivity and management and rain and/or water availability. When the rain is sufficient for agriculture, there is usually good crop yield and also enough crop residues for the livestock which again reduces pressure on forests. In other words, reduction in agricultural crop yield causes forest degradation, since forest resources become last resort and coping options for most households.

This study disclosed the various coping and or adaptation mechanisms at the study area. Among others, the study communities developed skills that monitor and give feedback about status of their environment, while also predicting weather and climate condition from daily to seasonal time scale. They almost depend on their traditional forecast to plan their agricultural activities. Despite the various adaptation practices, current scale of climate change and variability has been undermining the performance of most of traditional practices, resulting in greater social-ecological vulnerability. It is also observed that, there are no many proactive climate change adaptation strategies in the long term as most interventions are as such coping responses. Unfortunately, some of the practices have caused drying up of rivers and lakes and resulted in environmental degradation. The overall assessment shows that, unless supported by technology and other alternative means, existing traditional coping mechanisms may not be enough to support livelihood in the face of future climate change.

One valuable resource in the coping and adaptation process of the study communities is the evolution of their local knowledge system and how this knowledge is applied to monitor current status and predict future changes of the climate. Particularly, their climate prediction method is crucial to support scientific forecasts as it enhances accuracy which is tend to decrease with decreasing area under consideration. Local forecast also improve in resolving limited and inequitable access to climate information in rural areas where there is no or scarce infrastructure.

The current piece of work strongly suggests further research to understand how the future climate unfold, correlate local forecast method with scientific method and identify and strengthen community based adaptation strategies

Acknowledgments

We would like to thank the smallholder farmers who participated and freely shared their wealth of indigenous knowledge on climate change that has been used in this study. In addition, we thank staffs in study areas' Agricultural and Disaster Risk Management offices.

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Teleconnections between Ocean-atmosphere Coupled Phenomenon and Droughts in Northern Ethiopia: The Case of Alamata

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Abstract

Existing limited understanding on the teleconnections between ocean-atmosphere coupled phenomena and drought occurrences in Ethiopia has been undermining the decisions and interventions related to climate change adaptation and mitigation. Two drought indices Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) were usedfor correlation and lag correlation with global indices (El-Nino Southern Oscillation (ENSO), Oceanic Nino (Nino3.4), Indian Ocean Dipole (IOD) and Pacific Decadal Oscillation (PDO). The indices were obtained from their respective database websites of the National Center for Environmental Prediction (NCEP). Historical EL-Nino and La-Nina years and Ethiopian drought years were collected from literatures. Meteorological data for seasonal mean rainfall, maximum and minimum temperatures and Potential Evapo-transpiration (PET) of stations (1916-2016) were collected from Tigray regional meteorology agency. In addition, the Cru/Model data was collected from KNMI climate explorer. The analysis shows that the deficiency of (July-Sept) rain in 1972, 1982, 1987 and 1997 is linked with ENSO events. Likewise, deficient and abundant rains in Apr-June appeared to be influenced by the ENSO events. The July-Sept and Apr-June seasonal mean of Southern Oscillation Index (SOI) is positively and negatively correlated to the July-Sept and Apr-June rains in the region, respectively. The Sea Surface Temperature (SST) of central and eastern Pacific (Nino 3.4) is negatively correlated to July-Sept rains and positively correlated to Apr-June rains. In addition to El Nino impacts, other events such as PDO, SOI and IOD are important factors for triggering meteorological and agricultural droughts in Tigray region. The information in this study will serve as inputs to improves seasonal forecast.

***Key Words**: Teleconnections, ENSO, IOD, PDO, SPI and RDI*

Introduction

Climate change is the sever problem that the whole world is facing today which is manifested by changing the intensity, duration or time of climate variables. Incidences of extreme weather events and large fluctuations in precipitation patterns, and shortening of the lengths of growing periods have been occurring with increasing frequency (Hassan, 2009). These extremes in climate variability may lead to droughts and floods. It is now widely accepted that climate change is already happening and further change is inevitable. Assessments that are carried out by the IPCC (2007) states the projected global surface warming lies within the range 0.6 to 4.0^{o}C.

Drought is a normal, recurring feature of climate; it occurs in virtually all climatic regimes (Wilhite, 1992a). Recent droughts have illustrated the vulnerability of people and environment due to extended periods of precipitation deficiency. Stafford and McKeon (1998) stated that drought is a normal feature of any climate and it is a temporary, recurring natural disaster, which originates from the lack of precipitation and brings significant economic losses. It is not possible to avoid droughts. But drought preparedness can be developed and drought impacts can be managed. The success of both depends, amongst the others, on how well the droughts are defined and drought characteristics quantified.

Drought varies with regard to the time of occurrence, duration, intensity, and extent of the area affected from year to year. It is broadly classified into different categories. Meteorological drought indicates the deficiency of rainfall compared to normal rainfall in a given region. Hydrological drought indicates the scarcity of water in surface and underground resources. Agricultural drought occurs when the rainfall and soil moisture are inadequate to meet the water requirements of crops.

Drought studies are important because of their influence on the society and the economy of any nation. It differs from other natural hazards by its slow accumulating process and its indefinite commencement and termination. Drought assessment involves analysis of spatial and temporal water related data. Several methods were developed to assess the drought quantitatively. Over the years, various indices have been developed to detect and monitor droughts. Hence, characterization of different droughts using different indices is important to devise and use alternative early warning mechanisms to manage drought impacts and to implement adaptation and mitigation options and technologies. Drought preparedness planning has become a widely accepted tool for governments at all levels to apply to reduce the risks to future events. Drought plans should contain three basic components: monitoring and early warning, risk assessment, and mitigation and response. Because of drought's slow onset characteristics, monitoring and early warning systems provide the foundation for an effective drought mitigation plan. A plan must rely on accurate and timely assessments to trigger mitigation and emergency response programs.

Atmospheric and oceanic teleconnections govern the variability in our climate system on a broad range of time and spatial scales, in both the tropics and extra-tropics. On inter-annual time scales, the connection between El Niño–Southern Oscillation and the Asian monsoon system influences rain amounts in regions particularly sensitive to floods/droughts. On inter-annual and decadal time scales, rainfall variability in the Sahel region of West Africa appears to be governed to a large extent by teleconnections patterns related to the Pacific Ocean, the Indian Ocean, and the Atlantic Ocean. Yamagata et al. (2004) states that the seasonally stratified correlation between the indices of IOD and ENSO peaks at 0.53 in September–November. This means that only one third of IOD events are associated with ENSO events.

The decadal behavior of the North Atlantic Oscillation (NAO), influencing climate in Europe, Asia, and northern Africa, is also likely to be connected to both tropical and extra-tropical sea surface temperatures in the Indo-Pacific and Atlantic regions. The first panel discussion focused on general issues related to teleconnections and mechanisms connecting tropical and extra tropical regions. One of the main questions raised during this discussion was whether teleconnections are useful for climate predictions. The panel agreed that teleconnections can be used as a predictive tool and to aid the understanding and improvement of predictive skill in seasonal forecasts.

The association between the above coupled ocean atmosphere phenomenon and droughts in Ethiopia have not been well examined. This project is initiated to investigate the relationship between the changes in these global phenomenon and droughts in Ethiopia to point out the implications in early warning system.

Material and Methods

Tigray region is situated between 12015′ and 14^{0}57'N latitude 36^{0}27'E and 39^{0}59′E longitude, is in the northern part of the nine regions of Ethiopia (Figure 1). The language mainly spoken in the region is Tigrigna. Mekelle is the capital city of the region. Alamatawereda is located in the southern zone of Tigray bordered by Raya Azebo in the North, Ofla in the west, the Amahara National Regional State in the south and the Afar National Regional State in the East at 12°15'N latitude and 39°35'E longitude. It is situated 600km north of Addis Ababa and about 180km south of the Tigray Regional capital city, Mekelle.

Topographically, Alamata is divided into western highland and eastern lowland. The western part (*Tsetsera* and *Merewa*) is categorized under the northern highlands of Ethiopia, having an altitude range of 2000 to 3000 meters above sea level (m.a.s.l). It is characterized by steep slopes, gorges and undulating terrain having scattered flat lands used for grazing livestock and farming. It covers 25% of the woreda. The topography of the area dominated by steep slopes has induced erosion. The eastern lowland with its eight tabias is generally plain in topography with an altitude ranging from 1450 to 1750 m.a.s.l. The plain landscape of this area makes the area suitable for agriculture and it covers 75% of the woreda (Census, 2007). This study will be extended to the whole Tgiray region.

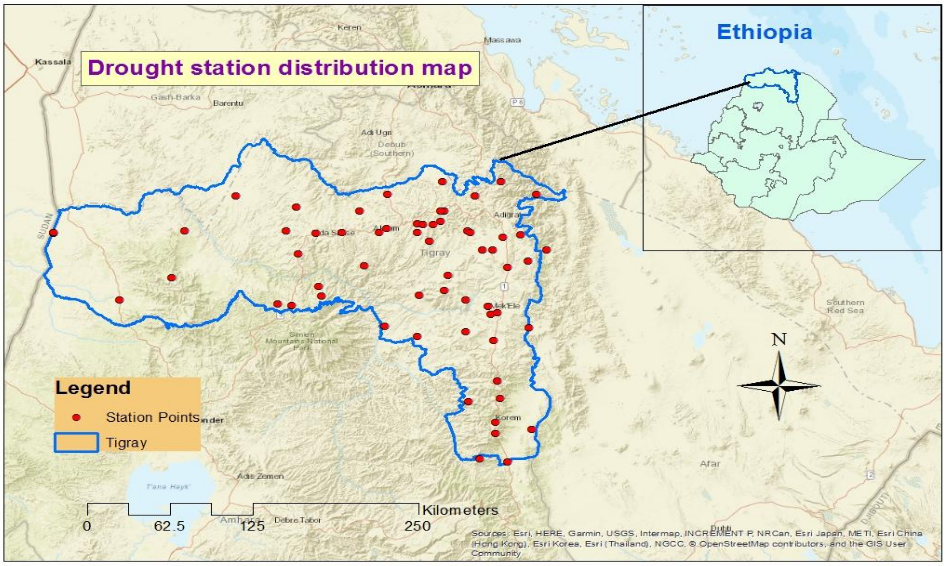

Figure 1: Station distribution map of the study area

Data and Data Source

Data for this study was collected from different sources. El-Nino 3.4, Southern Oscillation Index (SOI), Pacific Decadal Oscillation (PDO) and Indian Ocean Dipole (IOD) indices were downloaded from their respective database websites of NOOA and National Center for Environmental Prediction (NCEP). Stations data on seasonal mean rainfall, max temperature, min temperature and Potential Evapo-transpiration (PET) for the years 1916-2016 years were obtained from NMA and Cru/Modeled data was obtained from KNMI climate explorer http://www.esrl.n oaa.gov/psd/enso/index.html.

Data Analysis Methods

To investigate teleconnections between ocean-atmosphere coupled phenomena and local drought occurrences, two drought indices that is Standardized Precipitation Index (SPI) (Mckee, et al., 1993) and Reconnaissance Drought Index (RDI) were used. Seasonal mean rainfall, max temperature, min temperature, Potential Evapo-transpiration (PET) of stations for the years 1916-2016 years were used as an input to calculate and characterize meteorological droughts (SPI) and Agricultural drought (RDI) using DrinkC software (Tigkas, 2015). Then SPI and RDI were correlated with global climate indices (ENSO, SOI, PDO and IOD) for different seasons (July to Sept and April to June). Missing data (very few) are filled up using long term mean. The study also used the Cru/Modeled data from KNM climate explorer in addition to the observed datafor SPI and RDI analysis.

Historical EL-Nino and La-Nina years and Ethiopian drought years were collected to investigate if El Nino events trigger droughts in Ethiopia or not. El Niño years are identified to be 1965, 1966, 1969, 1972, 1982, 1986, 1987, 1990, 1991, 1992, 1993, 1994, 1997, LaNiña years to be 1964, 1971, 1973 1974, 1975, 1988, 198 and 1999, and finally normal years were identified as 1967, 1968, 1970, 1976, 1977, 1978, 1979, 1980, 1981, 1983, 1984, 1985, 1989, 1995 and 1996 based on IPCC (2000b). The LaNiña and El Niño category include years with weak, moderate and strong events of the corresponding episode.

A correlation analysis and regression analysis (Equation 1) was made to investigate Teleconnections between ocean-atmosphere coupled changes and droughts in Ethiopia. In the linear regression analysis the drought indices were considered as dependent variable and the ENSO, SOI, PDO and IOD indices were considered as independent variables.

$$y = bx + a + e \qquad \text{(Eq 1)}$$

Where, y is the dependent variable (drought indices), x is the independent variable (ENSO, SOI, PDO and IOD indices), b is the slope, a is the y intercept when x is zero and e is the error if the regression equation

The least square method was used to fit the data that minimizes the sum of the squared residuals. The slope b of the least square line is given by equation 2 and the intercept of the least squares line is given by equation 3.

$$b = \frac{SS_{xy}}{SS_{xx}} \quad \text{(Eq 2)}$$

Where, SSxy is the sum of the cross-products andSSxx is the sum of the squares for the variable x.

$$a = \bar{y} - b\bar{x} \quad \text{(Eq 3)}$$

Based on the findings of relations between droughts and ocean-atmosphere coupled changes (the strength of relationships and the time lag), were identified.

Reconnaissance Drought Index (RDI)

RDI is a new index that involves precipitation and temperature, which are key factors to characterize the climate of a region. The indices calculation uses precipitation and evapo-transpiration which incorporates temperature variable in its computation. RDI has 3 forms: the intial value (α_k), the normalized form (RDI_n), and the standardized form (RDI_{st}). However, the standardized form would be used for the characterization of droughts. The initial value (α_k) is calculated for the i-th year in a time basis of k (months) as follows:

$$\alpha_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} PET_{ij}}, \; i=1(1)N \text{ and } j=1(1)k \quad \text{(Eq 4)}$$

Where, Pij and PETij are the precipitation and potential evapotranspiration of the j-th month of the i-th year and N is the total number of years of the available data. The normalized form (RDI n) is computed using the following equation(8):

$$\mathrm{RDI}_{\mathrm{n}}^{(\mathrm{i})} = \frac{a_k^{(i)}}{\overline{a_k^{(i)}}} - 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 5)}$$

in which $\overline{\mathrm{a}_{\mathrm{k}}^{(\mathrm{i})}}$ *is the arithmetic mean of the* $\mathrm{a}_{\mathrm{k}}^{(\mathrm{i})}$

By assuming log normal distribution, the standardized RDI values were calculated as follows:

$$\mathrm{RDI}_{\mathrm{st}}^{(\mathrm{i})} = \frac{y^{(i)} - \overline{y}}{\hat{\sigma}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 6)}$$

in which yiis the $\ln\left(\mathrm{a}_{\mathrm{k}}^{(\mathrm{i})}\right)$, $\overline{\mathrm{y}}$ *is its arithmetic mean and* $\hat{\sigma}_{\mathrm{y}}$ *is its standard deviation.*

For real world applications RDI (Reconnaissance Drought Index) is calculated as a general indicator of meteorological drought and it was calculated for 3, and 12 months scale. The drought classification in SDI (Stream Flow Drought Indices) is similar to that of SPI (Standardized Precipitation Index) (Table 1). Intensity of the droughts was characterized using the value of RDI in Table 1. Duration of droughts was analyzed based on the period in which the RDI values are below zero.

Table 1: Classification of droughts based on standardized SDI values

$\mathrm{RDI}_{\mathrm{st}}$	Category
2 or more	Extremely wet
1.5 to 1.99	Severely wet
1 to 1.49	Moderately wet
0 to 0.99	Normal condition-wet
0 to -0.99	Normal condition-dry
-1 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 or less	Extreme drought

Source: Tigkas (2015)

Standardized Precipitation Index (SPI)

SPI (standardized precipitation index) has the advantages of being easily calculated, having modest data requirements, and being independent of the magnitude of mean rainfall and hence comparable over a range of climatic zones. It does, however, assume the data are normally distributed, and this can introduce complications for shorter time periods.

The study showed the relationship between drought duration and drought time scale using the SPI (Komuscu, 1999) (Table 2).

$$SPI = \frac{\mathrm{X}_{ik} - X_i}{\eth i} \text{.. (Eq 7)}$$

Where,

$ó_i$= standardized deviation for the i_{th} station; X_{ik}= precipitation for the i_{th} station and k_{th}observation

X_i= mean precipitation for the i_{th} station

Table 2: Classification of droughts based on standardized SPI values

1	Drought class	SPI value
2	Non-drought	SPI≥0
3	Mild drought	−1 < SPI < 0
4	Moderate drought	−1.5 < SPI≤−1
5	Severe/extreme drought	SPI≤−1.5

Along with the analysis of Standardized Precipitation Concentration and Reconnaissance Drought Index, El Nino Southern Oscillation (ENSO) and related pacific and Indian Ocean Sea surface temperature (SST), PDO and IOD patterns are shown to have potential influence on seasonal precipitation.

Deciles

Deciles approach suggested by Gibbs and Maher (1967) were widely used method was applied. Monthly precipitation totals from a long-term records are first ranked from highest to lowest to construct a commutative frequency distribution. The distribution is then split in to ten parts (tenths of distribution or deciles).The first deciles is the precipitation value not exceeded by the lowest 10% of all precipitation values in a record is between the lowest 10 and 20% etc. According to the author classification (Table 3) deciles are grouped in five classes, two deciles per classes

Table 3: Classification of Deciles Indices values and justification

Precipitations falls	DIs Ranges (%)	Justification
10 – 20%	1 to 2	Much below normal
30 – 40%	3 to 4	Below normal
40 – 60%	5 to 6	Near normal
60 – 80%	7 to 8	Above normal
80 – 100%	9 to 10	Much above normal

Results and Discussion

Teleconnections of SPI and RDI with Global Indices in Alamata

Figure 2 (b and c) below shows that the positive SPI values indicate greater than mean precipitation and negative values indicate less than mean precipitation. A drought event starts when SPI value reaches -1.0 and ends when SPI greater or equal to 0 becomes Non-drought positive again. As the analysis result of the station indicates, the SPI values for years 1988 and 1999 was ranged extremely wet non drought years for July to Sep rain seasons but in years 1984, 1986 and 2008 SPI value was below -1 which indicates moderate drought years. This is also similar for April to June rain seasons.

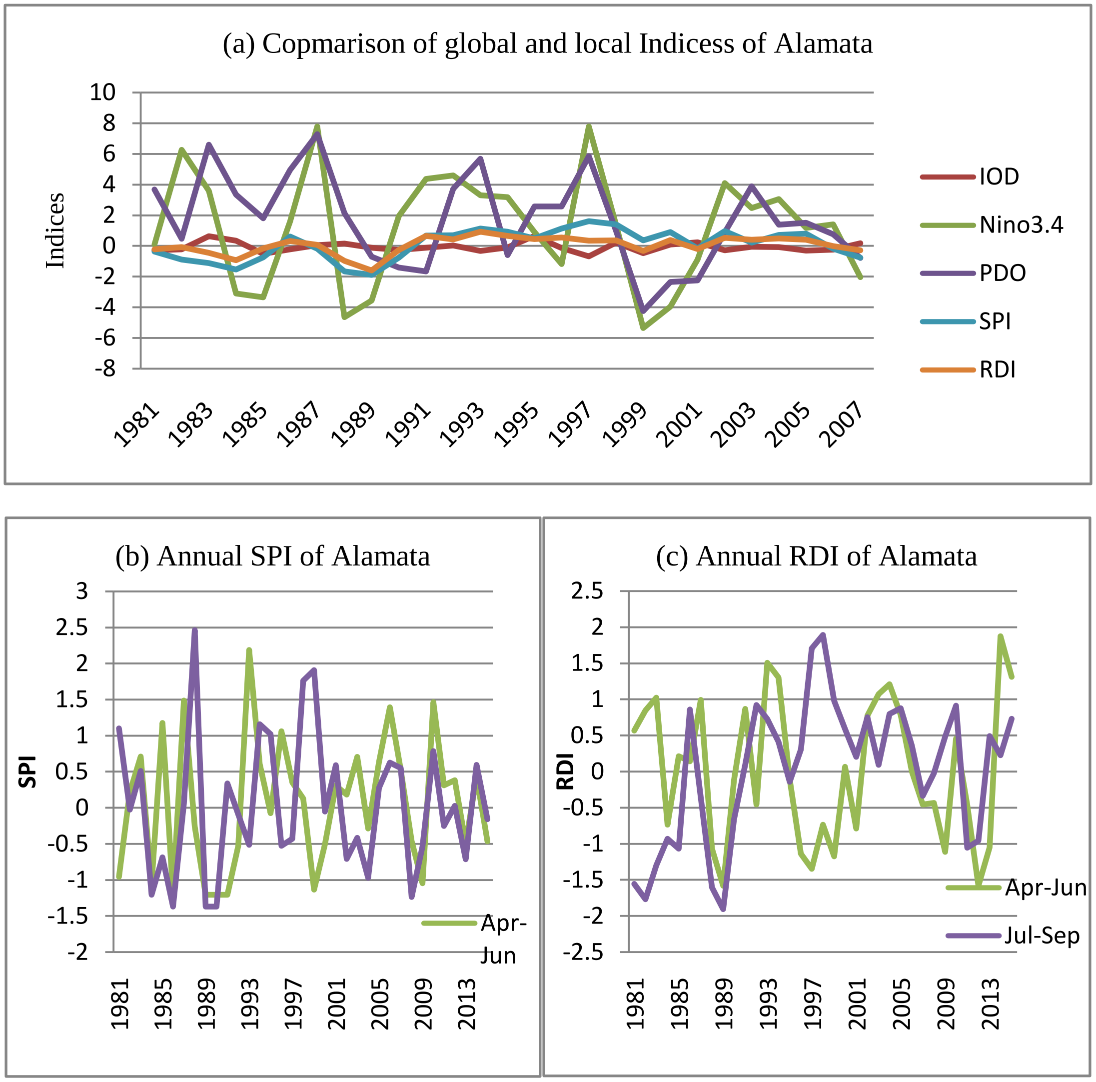

Figure 2: a, b and c Global indices, SPI and RDI of Alamata

The Figure (2a) above shows that the global indices Nino 3.4 and PDO has positive relation or concedes with local drought SPI and RDI but the IOD more relies with SPI than RDI for years 1982, 1983, 1986, 1988, 1991, 1992, 1995, 1999, 2001,2002,2003,2005 and 2007/8. This shows that SOI is not the only factor for drought of the area but also PDO and IOD do. The annually stratified correlation between the indices of IOD and ENSO peaks concede and the events are associated in few years. But for many years IOD events are not associated with ENSO events. This means the independent natures of IOD weaken the drought nature and the combined effect of global indices made strength the drought nature.

Among the above RDI years according to IPCC (2000b) the years 1982, 1986, 2008 and 2009 are categorized as Elino years which means the local droughts are more linked with the global indices made teleconnections with local indices. In other hand the global indices (Nino 3.4, IDO and PDO) are consider as another factors that alters climate of the region.

The correlation result in the Figure 3 below indicates that global indices Nino3.4 and PDO are strongly correlated with local SPI of April to June rain. Similarly, SOI and IOD work the same for July-Sep rainfall. The lag correlation also shows that PDO and IOD are strongly correlated with Lag 3 and lag 6 months of April to June and July to Sept rain season respectively.

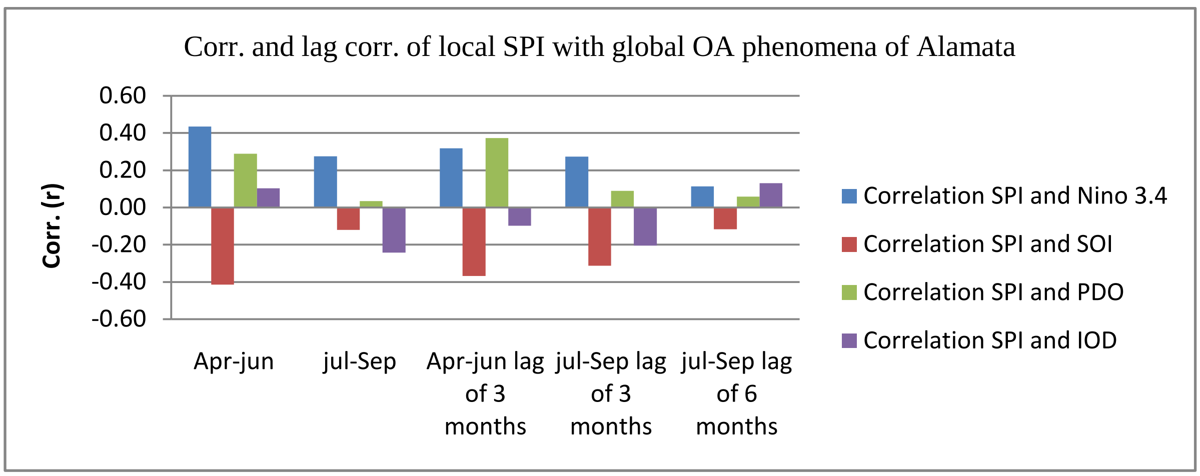

Figure 3: Correlation and lag correlation result of Global Ocean Atmospheric Phenomena with local SPI of Alamata

The correlation result in the Figure 4 below indicates that Nino 3.4, PDO and IOD are positively correlated with local RDI for both rainy seasons. Global indices SOI and IOD are negatively correlated with July to Sep rain season. The lag Correlation shows that PDO and Nino 3.4 strongly correlated with Lag 3 and lag 6 months of April to June and

July to Sept rain respectively. In fact there are also numerous mountains and valleys which could influence the weather of Ethiopia that made it more complicated. The examined correlation and lag correlation shows that after happening of the global phenomena (Nino 3.4, IOD, SOI and PDO) the influence will persist until three and six months but weak for lag6 than lag 3. Hence, global ocean atmospheric phenomena associated other important factors which have not got credit.

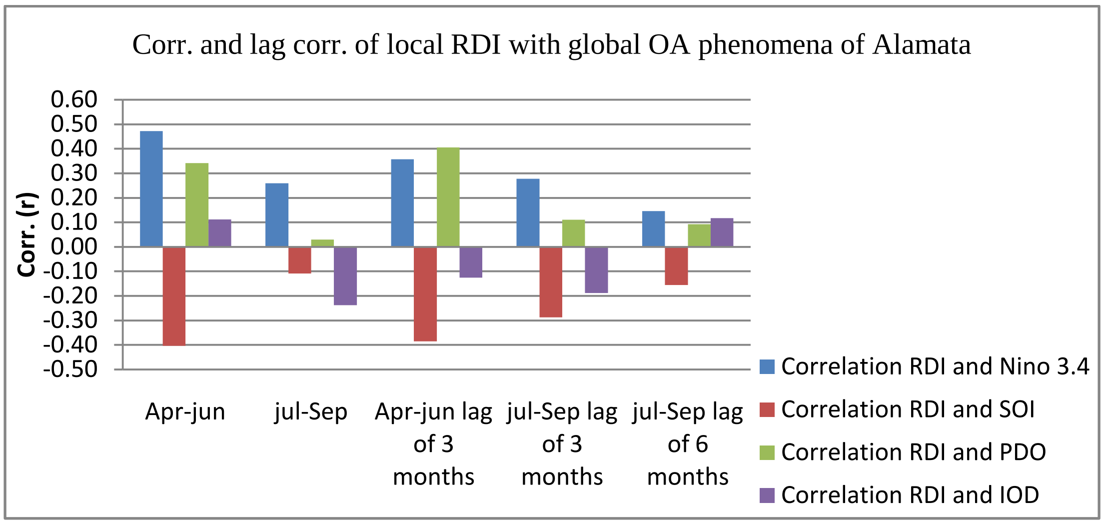

Figure 4: Correlation and lag correlation result of Global Ocean Atmospheric Phenomena with local RDI of Alamata

Another investigation about the precipitation conditions of the study area with the two droughts Meteorological (SPI) and Agricultural (RDI) drought indices indicates below normal rain/ SPI drought of Kiremt (July-Sept) rains in 1972, 1982, 1987 1991, 1997, 2002 and 2004 has been associated with ENSO events. Consequently, deficient rains in (July-Sept) and abundant rains in (Apr to Jun) seasons appear to be influenced by the ENSO events. The (July-Sept) and (Apr to Jun) seasonal mean of Southern Oscillation Index (SOI) is positively and negatively correlated to (July to Sep) and (Apr to Jun) rains respectively. Similarly, Sea surface Temperature (SST) of central and eastern Pacific (Nino 3.4) is negatively correlated to (July to Sep) rains and positively correlated to (Apr to Jun) rains. This means that during El-Nino years, the atmospheric circulations particularly in the tropics would be disturbed. As a consequence, the rain-producing components for Kiremt would be weakened and/or dislocated, while those systems in Belg would be enhanced. Not only the Nino 3.4 but also SOI, PDO and IOD have also both positive and negative influence depending on the season.

The first decile's precipitation value not exceeded by the lowest 10% of all precipitation values in a record is between the lowest 10 and 20% etc. According to the Deciles classification in Figure 5 below the years 1983, 1984, 1988, 1989, 2011, 2012 and 2016 are classified as much below normal distribution of precipitation.

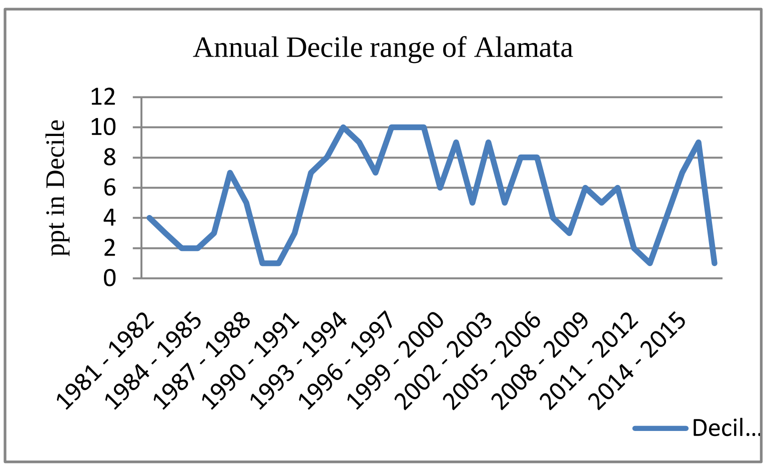

Figure 5: Annual Deciles values of Alamata

Conclusions and Recommendations

The correlation results of the stations indicated that Nino3.4, PDO and IOD are positively correlated with local RDI for both rainy seasons. Global indices SOI and IOD are negatively correlated for July to Sep rain season for the rest stations. The lag Correlation shows that PDO and Nino3.4 strongly correlated with Lag 3 and lag 6 months of April to June and July to Sept rain season respectively for most stations.

Which indicates that the influence of the global phenomena persist over several months after its occurrence.

The results of analyzed stations indicates that not only Elnino3.4 but also other global ocean atmospheric phenomena teleconnections (PDO, SOI and IOD) are important factors of Meteorological drought (SPI) and Agricultural drought (RDI). Thus the independent as well as combined effects of global indices have their own influence that requires consideration in seasonal rainfall forecast for early warning.

We have shown here that the independent and individual influences of global indices on the local indices (SPI and RDI) such climate signals also alarming peoples for alternative adaptation options and interventions for well reasonably influences of PDO and IDO. Finally, in fact there are also numerous mountains and valleys which could influence and make the weather of Ethiopia more complicated. It is believed that, the study will be continued with additional meteorological stations to map and correlate the teleconnections of global indices with local SPI and RDI.

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The Roles of Dry Forests for Climate Change Adaptation in Liben District, Southern Oromia, Ethiopia

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Abstract

Dry forests play important socio-economic and ecological roles in climate change adaptation and mitigation across the world. However, the diverse contribution of these resources has given less attention in the national and regional development planning. The aim of this study was to evaluate the roles of dry forests for climate change adaptation in Liben district. Qualitative and quantitative research approaches were employed. Data was collected using household survey, key informant interviews, focus group discussion, and observation. From three kebeles, a total of 74 households were randomly selected for the survey and 30 and 15 purposely selected individuals for focus group discussion and key informant interviews, respectively. The results showed that the average total households' income in Liben district was 11,209 ETB birr, out of which, dry forest income constituted 15%. Analysis of risks related to climate change revealed increasing vulnerability of households to frequent and severe droughts and rainfall variability. Among the survey households, 75% of them claimed that drought was the main threat to their livelihoods, resulting in increased failure of crop production and massive death of livestock, and eventually, undermined households' adaptive capacity. In response of increasing social-ecological vulnerability, respondents mentioned growing dependence on dry forests as means of coping with and adaptation to drought and rainfall variability. Key informants responded that frequent drought has undermined the quality and productivity of major rangeland types, mainly grasslands. Dryforest based fodders are relatively available and serve as last resorts for the livestock production at the study areas. Respondents also mentioned increasing dependence on dryforests for construction wood, traditional medicine and forest based food for subsistence and sale. Relative to crop and livestock based income, income from dryforests products were mentioned as less affected by drought and hence, sources of livelihood during drought periods. About 48.6% of the respondents mentioned increasing income from dry forests in recent years. Similarly, the trends of livelihood dependency on dryforest of the respondents were strongly increasing indicating that dryforest income is now becoming essential along the frequent occurrence of drought in the area. Therefore, it is important to improve management of dryforests for livelihood enhancement as well as maintaining their long-term ecological functions.

***Key words**: Drought, Dry forests, Livelihood Strategies, Vulnerability*

Introduction

Climate change is already taking place now, thus past and present changes help to indicate possible future changes. Over the last decades, the temperature in Ethiopia has increased at about 0.2°C per decade. Precipitation, on the other hand, remained fairly stable over the last 50 years when averaged over the country. However, the spatial and temporal variability of precipitation is high, thus large-scale trends donot necessarily reflect local conditions (Keller, 2009).

Ethiopia is an agrarian country where traditional crop and livestock production employs over 85% of the population (Ethiopian NAPA, 2007; MoFED, 2012). Crop production is the major livelihood strategy in the highlands, where rainfall is relatively high. The vast majority (over 70%) of the landmass of Ethiopia is dryland, characterized by low and unpredictable rainfall patterns (ECA, 2007). These regions are poorly developed and suffer historical, political and economic marginalization (Fekadu, 2009). Traditional pastoralism and agro-pastoralism are the major livelihood strategies in the drylands, where households depend on livestock production for a significant proportion of their food, income and traction power (FAO, 2009). Pastoralism and agro-pastoralism employ an estimated 14% of the human and 40% of the livestock population in Ethiopia. Pastoral areas cover some 60% of the total land area in Ethiopia and the country stands fifth in the world in its pastoral and agro-pastoral population size (Bekele and Amsalu, 2012).

Despite the long standing adaptation practices, recent trends indicate an increase in drought incidence in the dry land eco-regions in the Horn of Africa in general and in Ethiopia in particular (IPCC, 2007; NAPA, 2007). Increasing in frequency and intensity of drought leads to rise in the vulnerability of pastoral and agro-pastoral communities (Homann, 2008) as pastoral and agro-pastoral communities are continuously losing a significant proportion of their livestock assets (Kassahun, et al., 2008).

A continued severe environmental degradation, shrinking resource bases and transhumance mobility routes are becoming major problems facing these production systems (Fekadu, 2010; 2013). A post drought livestock re-stocking, a common phenomenon in the drylands, has become a difficult process due to protracted drought, alarming rangeland degradation and diseases (Homann, 2008). The gradual depletion of livestock assets, exacerbated by existing limited alternative coping strategies is therefore putting additional pressure on livelihood systems. According to Fekadu (2013), increase in the frequency of violence, political insecurity and a decline in the capacity of customary authority in conflict management, on the one hand and the lack of enforcement of formal institutional framework, on the other hand, gradually exacerbated the vulnerability of these communities.

According to Davies et al. (2012), such complex socio-ecological problems facing the pastoral and agro-pastoral livelihoods call for informed policy interventions to achieve solutions to environmental and livelihood related challenges. The increasingly uncertain climatic conditions and related impacts across the drylands demand for new and integrated resource management approaches that facilitate more resilient land use planning (IPCC, 2007). Promotion of sustainable forest management is a key strategy put forth in recent international and national negotiations to reduce the negative impacts of climate (CIFOR, 2005).

The role of forests in climate change adaptation and mitigation is important (FAO 2010); the sustained provision of ecosystem goods and services can help people adapt to the local consequences of a changing climate, while the carbon stored in these ecosystems, if well managed, can contribute to climate change mitigation (Robledo, et al., 2012). According to FAO (2010), the role of forests and woodlands is even more important, both biologically and socio-economically; in arid lands than it is elsewhere, where rangelands, agroforestry parklands and trees outside forests play vital roles in the livelihood of communities in Africa's drylands.

Forestry managers and professionals recommend integration and responsible management of the currently marginalized dry forests in Africa (FAO, 2010; Mulugeta and Habetemariam, 2011). In case of Ethiopia, there are various socioeconomic, ecological and political reasons to sustainably manage its dry forests. For instance, value added commercialization of gums and resins produced from dry forests would offer access to additional income for the drought prone pastoral and agro-pastoral households and the national and regional economy at large (Mulugeta and Habetemariam, 2011; Adefires, et al., 2011). Demonstrating the ways through which dry forests contribute to increasing income and reducing poverty, would lend additional weight and relevance to forest management initiatives that also contribute in combating desertification (FAO, 2010; Mulugeta and Habetemariam, 2011).

However, despite their values, dry forests are caught in a spiral of deforestation, fragmentation, and degradation (FAO, 2010). Until recently, dry forests in Ethiopia and elsewhere in the Horn have had less attention in the national as well as regional planning, their potential to enhance the local and national economy has been overlooked, and their contribution to sustainable environmental management has not been recognized (FAO, 2010; Mulugeta and Habetemariam, 2011; Adefires, et al., 2011). Therefore, this study assessed the socio-economic contribution of dry forests and forest products to climate change adaptation in Liben district, Ethiopia.

Materials and Methods

The study was conducted in Liben district of Guji zone, Oromia Regional State of Ethiopia (Figure 1). It is at about 630 km south of Addis Ababa (Figure 1). Geographically, it located between 5^0 5' 10 " to 5^0 7' 50" N and 39^0 32' 30" to 39^0 36' 30" E. Except for the central mountain range and scattered volcanic cones and craters, the landscape has dominantly gentle elevation between 1000 and 1600 m.a.s.l (Coppock, 1994).

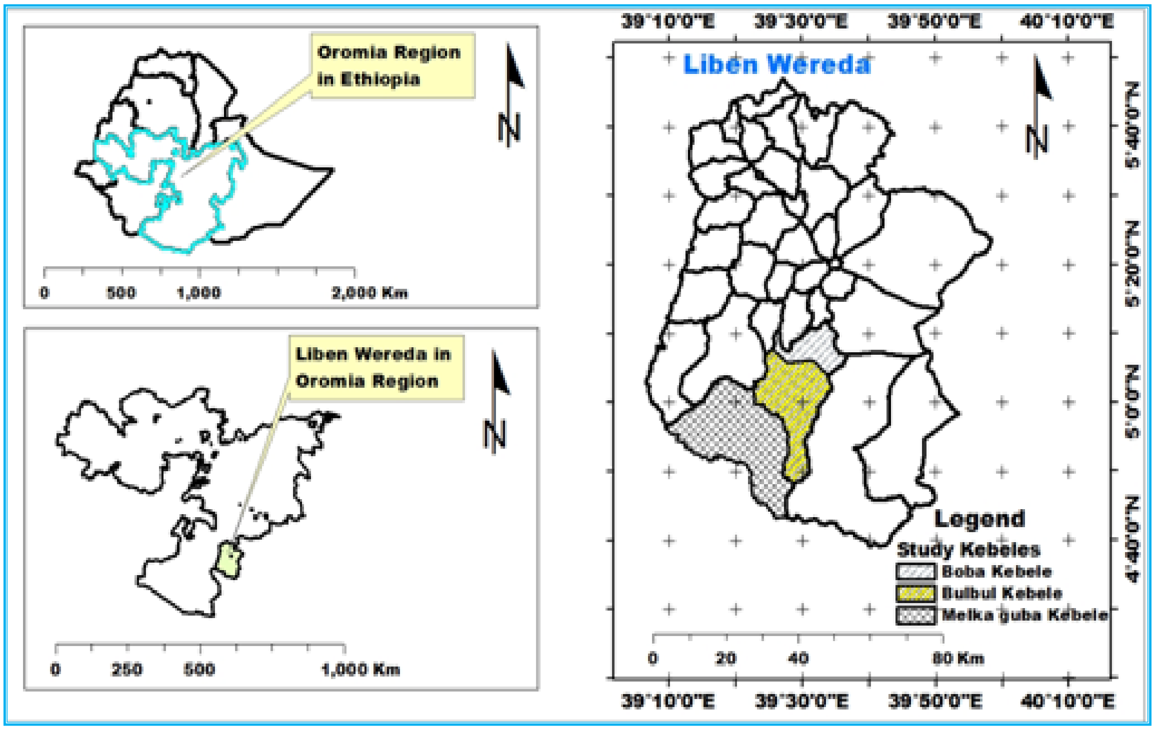

Figure 1: Map of the study area.

Agro-ecologically, the Liben district is categorized under "*dry kola*". The mean monthly minimumand maximumtemperatures for the period 2000-2014 were16 °C and 28 °C, respectively. The rainfall pattern is bimodal and total annualrainfall ranges from 460 to 790 mm with an average of 609 mm. The main rainy season in the district occurs from February to June that accounts about 55% and a minor rainy season from September to December that accounts 41% (Coppock, 1994). Based on the population Census of Ethiopia (CSA 2007), Libendistrict has a total population of 79,981, of whom 38,284 are men and 41,697 women; 2,198 or 2.75% of its population are urban dwellers with annual population growth rate of 2.7% and population density of approximately 280 persons per km^2. The average family size was five per household.

Woodlands of the study area are mainly characterized by *Combretum-Terminalia* dominated woodland (Haugen, 1992). Besides, species of the genera *Combretum, Terminalia, Acacia, Pistacia, Commiphora, Lannea Euclea, and Olea* are common in the study area.

Materials and Methods

Sampling Methods

Random sampling was employed to select study villages and respondents. Three administrative kebeles (local administrative under district) i.e., Melka-Guba, Bulbule and Boba, were selected based on their accessibility, dry forest dependency of the community and relative availability of prior studies on dry forests. Liben district is mainly characterized by pastoral and agro-pastoral livelihoods. Two villages from each kebele were randomly selected. A total of 74 households (30, 24 and 20 households from Bulbule, Boba and Meleka-Guba respectively, covering 5 to 25% of village residents), were randomly selected for a household survey. In addition, 30 individuals (10 from each kebele) were participated in focus group discussion and 15 key informants (5 from each kebele), were purposely selected for an in-depth case study and interviews. Population sampling followed procedures described in Campbell et al. (2002) and Zenteno et al. (2012).

Research Design

Reconnaissance field survey was made to obtain an overview of the study site, followed by detailed preliminary survey, which was made between the end of January to the end of February, 2017. Guided by principles of social–ecological co-evolution theory (Colding, et al., 2003), mixed quantitative and qualitative research design (Creswell 2009) was employed to collect data.

Data Collection

The primary data were collected through household survey, focus group discussions (FGDs), key informant interviews (KIIs) and a guided transect walk for observation (Campbell, et al., 2002; Cavendish, 2003). Data from household heads was collected based on a detailed questionnaire formulated in lined with the prototype developed by the Poverty Environment Network (PEN) (CIFOR, 2010). A structured questionnaire that includes both close and open-ended questions were designed and employed to generate quantitative and qualitative data from respondents. The main secondary data sources that were used in this research were both hard copies and online materials such as published and unpublished articles, proceedings, project reports and other data available at district, zonal, regional, national and international levels. Three local enumerators who can understand English and *"Afan Oromo"* language were hired and trained on how to administer the questionnaire. Pre-testing of questionnaire was conducted to see about inclusiveness, its validity, relevance and comprehensiveness. Based on the pre-testing feedback, final questionnaire was prepared and administered accordingly. Data were collected on a number of variables including: household characteristics, livelihood strategies, household asset and income composition (subsistence and cash), expenditure, preference of dry forest management system, dry forest products collected, push and pull factors conditioning dry forest income dependence, drought trend and the consequent vulnerability, and ex-ante risk and ex-post coping and adaptation strategies of dry forests.

Data Analysis

The household survey data was analyzed by SPSS Ver.20. Descriptive statistics like mean, percentage and frequency distribution were used to analyze quantitative data. Then, analyzed data was summarized and organized in tables and figures. Qualitative data generated from key informant interview, focus group discussion and secondary sources was analyzed by narrative description and interpreted on spot. On other hands, the Multinomial Logit Model (MLM) was used to analyze factors that influence for immediate action of sample households for climate extreme events and factors that influence for coping capacity of sample households for climate extreme events. Moreover, univariate analysis of variance was done to analyze factors of mean total annual income and mean total forest income in the study area.

Results and Discussion

Demographic Characteristics of Sampled Households

The results showed that the majority of the sampled households (75.7%) were male-headed, while the rest were female-headed. The mean respondents' age was 43.54 with minimum and maximum of 22 and 74 years, respectively.

In educational level, only 3% of respondents completed the secondary level of education and nearly 66% of them did not followed formal education to write and read. Others, constituting 22% have got access to attended primary level of education. Although educational background of household heads is believed to be an important feature that determines the readiness of households to choose adaptation strategies to climate change and variability through accepting new ideas and innovations, the survey result showed majority of the household who did not attend formal education perceived climate change and respond to adapt to the change. This is probably because societies have age-old indigenous knowledge to understanding their living environment and solve their problem by themselves (Meseret, 2013).

Nearly 96% of the respondents were married. The mean family size was 6.95 with minimum and maximum of 2 and 13, respectively. The results showed that about 89% of the respondent households were agro-pastoralists and only near to 7% of them were crop cultivators. The mean land holding size of the respondent households was 3.95 with maximum of 15.0 hectare of land. The mean livestock holding of the surveyed households was about 10.21 TLU (Tropical livestock unit) with maximum of 57.6 TLU. Camel, cattle, goat, sheep and donkey were the major livestock species in the study areas. A considerable proportion of the households are managing diverse livestock composition. In this case, 45.2% (4.61 TLU) of the survey households reported owning cattle, followed by camels, goats, sheep, and donkey constituting 25.3% (2.58 TLU), 15.3% (1.56 TLU), 7.4% (0.75 TLU) and 6.8% (0.69 TLU), respectively. Provided that livestock ownership is an indicator of wealth and social status in the study area, the results showed the existence of large wealth gaps between respondent households (Table 1).

Table 1: Summary of Socio-economic characteristics of the sampled households

Socio-economic characteristics	Descriptions
Gender	*Male: 75.7% and Female: 24.3%*
Age	*Mean: 44 and Range: 22-74*
Literacy level	*Illiterate: 66.2%; Primary: 22%; Secondary: 3%*
Family size	*Mean: 7 and Range: 2-13*
Occupation	*Agro-pastoralist: 89%; pastoralist: 7%*
Land holding size (Ha.)	*Mean: 4 with max. of 15*
Livestock (TLU)	*Mean: 10.21 with max. of 57.6*
Livestock composition (%)	*Camel (25.3), Cattle (45.2), Goat (15.3), Sheep (7.4) and Donkey (6.8)*
Religions (%)	*Muslim (50), Wake feta (28), Christianity (12.2) and Others (9.8)*

Dry Forest Income Contribution to Household Income

The results showed that the average total annual income of sample households was 11,209.7 ETB and of which 12.3% was income from dry forest products such as gum and resin, firewood, charcoal and others (Figure 2). The study by Frederik et al. (2015) indicated that mean annual forest income from sub-Saharan Africa was $158 and forest cash income was $82. Other study by Busha et al. (2015) in Ethiopia showed that mean annual income from forest product was 1740 ETB. In addition, Dagm et al. (2016) explored that mean annual income of households in Southeastern Ethiopia (Hammer district) was 12,450 ETB by which livestock, forest and crop contributed 29.7%, 21.4%

and 15.7% of the mean annual income, respectively (Table 2).

Table 2: Factors influencing total annual income and dry forest annual income

Explanatory variables	Significance level at alpha 0.05	
	Total annual income	Dry forest annual income
Corrected Model	.003	.007
Intercept	.693	.685
Age	.768	.807
Number of family	.547	.189
Livelihood	.458	.759
Kebeles	**.000**	**.008**
Sex	.861	.581
Education	.156	.358
Livelihood * Kebeles	.	.
Livelihood * Sex	.649	.674
Livelihood * Education	.746	.368
Kebeles * Sex	.035	.813
Kebeles * Education	.085	.375
Sex * Education	**.015**	.365
Livelihood * Kebeles * Sex	.	.
Livelihood * Kebeles * Education	.	.
Livelihood * Sex * Education	.	.
Kebeles * Sex * Education	**.015**	.261
livelihood * Kebeles * Sex * Education	.	.

Amount of total annual income of sampled household statistically significant at alpha 0.05 *by kebeles*, combined effect of sex and education level and combined effect of *kebeles*, sex and education level of sample households. And also from the factors which affect for dry forest annual income of sample households *kebele* affect statistically significant at alpha 0.05 as shown in (Table 2). Other studies also indicate that household size, non-forest income, distance from forest, cooperative membership could influence forest income (Jumbe, et al. 2008; Busha, et al., 2015). To the study by Dagm et al. (2016), showed that site, sex, household size, land size, access to extension and farm activity were the major factors that have influenced dry forest income. In addition to manage forests as sources of range, the study households collected different types of forest products, such as gum and resins, firewood and charcoal, wood for construction and farm tools, medicinal plants and forest food, both for subsistence and cash income (Adefires, 2015).

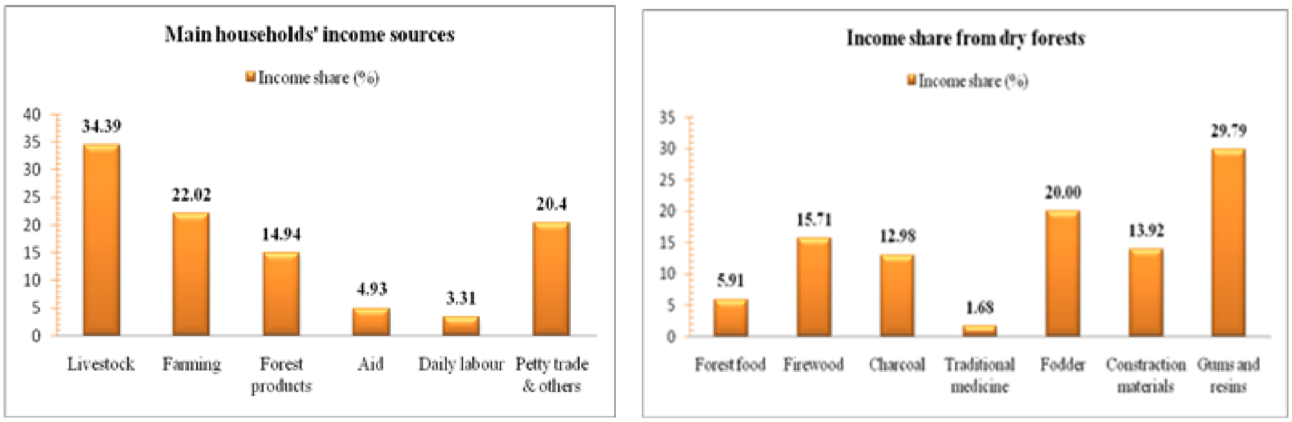

Figure 2: Households' annual income share from main livelihood strategies

The results showed that the cost encored to satisfy the demand of household food consumption and purchase of fodder for livestock during a drought season took the lion-share of household's expense with birr 9,118.33 (34.0%) and 5,919.64 (22.1%), respectively (Figure 3).

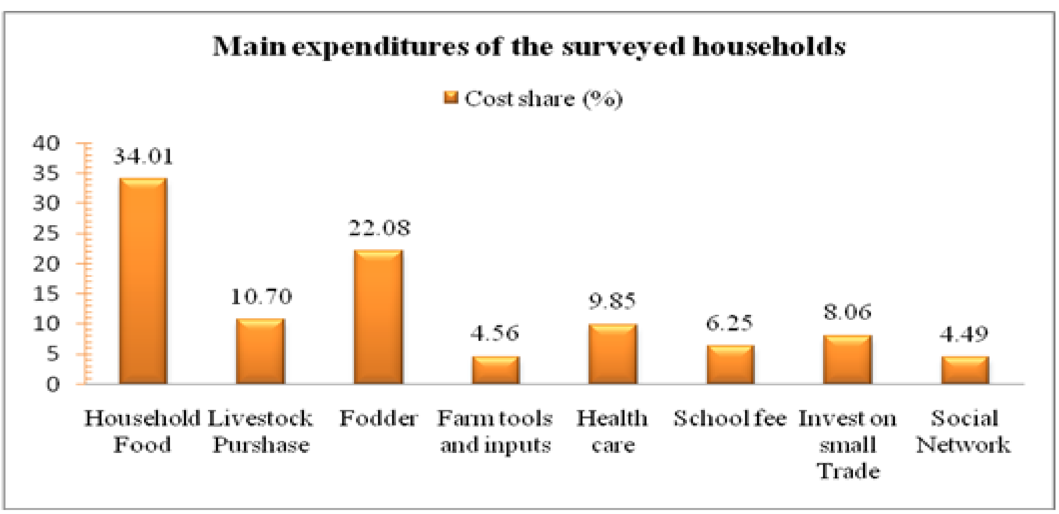

Figure 3: Expenditure items of the surveyed households

The Roles of Dry Forests for Coping Strategy to Climate Extreme Events

To cope with climate change impacts, households have used different strategies like livestock destocking (82.2%), off-farm activities (48.6%), sale of gum and resin (69.8%) and other forest products (81.9%), aid support (76%), migration (84.8%) and others (9%). Temesgen (2010) highlighted that farmers in the Nile Basin of Ethiopia have used sale of livestock (26%) and borrowing of money from relative (10%) as coping mechanisms to climate change impacts while 51.3% of them did no action. A study in Kenya by Andrew et al. (2007) also showed thathouseholds have used food aid, reliance on friends and relatives, sales of asset diversifying income source, casual labor and migration as a coping strategies in order of priority.

Among the major coping strategies with indication of frequent drought phenomena for the respondents, the dry forest contribution was high, which shows with different indicators from respondents, such as trends of livelihood dependency on dry forest during drought period 69.4% strongly increase. The other indicators were 48.6% of the respondent's income generation from dry forest product during drought period increase and 84.7% increases in time of participation in use of dry forest products during drought period.

Immediate action with destocking of livestock was one means of reactive measures by households and the sample respondents have seven choices (none, first, second, third, fourth, fifth and sixth preference and their weight were 18.3%, 33.8%, 31%,7%, 2.8%, 1.45%, and 5.6% respectively). Among the major factors influence for immediate action with destocking of livestock in order to resilient the impacts of drought were total annual income, family size, livelihood strategy, education level, kebeles of the study area, sex of sample households statistically significant at alpha 0.05 significant levels as shown in (Table 3).

The study also found that immediate action for drought of sample households held with off farm activities in order to cope the drought effect in preference of sample households; were none, first, second, third, fourth, fifth, and sixth and their weight were 51.4%, 5.7%, 2.9% 11.4%, 7.1% 8.6% and 12.9%, respectively. And factors influence statistically for immediate action to drought with off farm activity were annual dry forest income and education level of sample household at alpha 0.05 significant level as shown Table 3. While aid also used as a means of immediate action with preference of none, first, second, third, fourth, fifth, six in weight of 22.9%, 7.1%, 12.9%, 17.1%, 12.9%, 5.7%, 21.4% respectively. In addition, for immediate action to drought with aid statistically influenced factors to sample households were family size and sex of head of family at alpha 0.05 significant levels as shown table 3. According to Temesgen (2010), factors affect statistically significant for chose of different coping strategies were educational level, sex of head of family, farm income, livestock ownership, access to extension service positively influenced and non-farm income, farm size, agro ecology with *kola* and precipitation negatively influence for the use of one or combination of the coping strategies of farmers in the Nile Basin of Ethiopia.

Table 3: Factors for immediate action and trends of coping capacity for drought

Explanatory Variables	Significance level at alpha 0.05			
	Immediate action with destocking of livestock	Immediate action with off farm activities	Immediate action with aid	Trend of coping capacity to drought
Intercept	.	.	.	.
Annual dry forest income	.825	.001	.087	.619
Total annual income	.010	.586	.101	.367
Age	.240	.999	.191	.140
Number of family	.000	1.000	.005	.992
Livelihood	.024	.000	.870	.586
Education	.024	.042	.442	.669

Kebeles	.002	1.000	.853	.462
Sex	.001	1.000	.000	.028
Source of information	.081	.997	.084	.569
Formal health access	.180	1.000	.083	.

Household Livelihood Vulnerability and Roles of Dry Forests for Adaptation

Perceived Patterns of Household Livelihood Vulnerability

The majority of the respondents (94%) perceived that the livelihood vulnerability of the community has shown a highly increasing trend due to the impacts of extensive and frequent drought in the last three decades. Only less than 10% of the respondents perceived a lower vulnerability in the mentioned period. More than 75% of the respondents agreed that drought has resulted in the failure of food crops and massive death of livestock in recent years, which is also supported by the study of Meseret (2013). This has been exacerbated by un-stable.

Reasons of Livelihood Vulnerability

The survey households claimed various reasons of livelihood vulnerability that are related to changes in climate and ecology. The results showed that 35.3% and 29.4% of the respondents have perceived an increase in temperature and substantial decrease in annual rainfall, respectively. On the other hand, 17.7% and 11.8% of the households perceived increasing variability in distribution and erosive nature of the rainfall. According to key informants and focus group discussions, the recurrent drought of 2016/17 could be considered as the most severe ever that devastated their livestock and triggered crop failure in the region as a whole. Moreover, over-exploitation of the resources, deforestation and rangeland degradation lead to social stability interruption and institutional weakness.

Similar studies conducted by Adefires (2015) showed that majority of the survey households 68.5% perceived rain has become erratic, erosive and highly localized.

About 58% of the survey households mentioned a deceasing overall rainfall volume, whereas 53.2% perceived a highly rising temperature. This shows that increasing frequency, duration and severity of drought phenomenon in the study areas become the most disruptive factor that affecting the livelihood strategies and ecosystem services and hence, aggravating other factors threatening livelihoods of the households.

Effects of Drought on Households' Livelihood Vulnerability

Climate change has already brought about observable changes in East Africa, such as declines in rainfall, changing rainfall seasonality, and increasing frequency of droughts (Williams and Funks 2010; Williams and Funk 2011). Evidence for declining rainfall has also been documented for Ethiopia (Cheung, et al., 2008; Viste, et al., 2013) with a significant decrease in the long rains in the southern part of the country.

In this study, despite the slight variations between localities, respondents have categorized major livelihood strategies into different vulnerability scales, ranging from less to high vulnerability. According to Adefires (2015), the categorization was based on their accumulated knowledge on the exposure of a particular livelihood strategy to drought risks as well as its adaptive capacity. A particular livelihood strategy was said to be "*highly vulnerable*" when it has already reached its threshold and hence further exposure such as extended drought might lead to its total abandonment. "*Moderate vulnerability*" refers to a situation where the livelihood strategy seems to be resilient despite its exposure to risk and shocks. The trend of the households' livelihood vulnerability has increased significantly from low to high due to climate related hazards, for instance; drought events. Nearly 95% of the respondents agreed that their livelihood vulnerability is highly increasing and 4.1% respondents perceived increasing vulnerability while the rest perceived no visible vulnerability change in the past 30 years. About 77% of the respondents indicated that combined effect of livestock death and decline in farming activities in surveyed households could be triggered by susceptibility to drought. Almost all respondents perceived that annual income generated from their livelihood strategies; especially from livestock and crop production substantially reduced due to prevailing drought effects in the area (Table 4).

Table 4: Households' response on effects of drought on livelihood strategies

Livelihood strategies	Respondents' responses on trend in annual income (N=74 (%))		
	Increasing	Decreasing	No change
Livestock	0.0	100	0.0
Crop farming	0.0	98.1	1.9
Forest products	10.6	78.8	10.6
Off-farm activities	17.2	56.3	26.6

Similarly, in the last three decades, the trend of households' coping capacity has destabilized due to drought. The majority of the respondents (62.8%) perceived that their coping capacity has *"highly destabilized"* due to frequent drought events and 11.6% claimed as it has *"destabilized"*. In contrast, 25.6% of respondents perceived their coping capacity to drought has *"improving"* in the past 30 years.

Table 5: Mean livestock population lost per household due to drought

Livestock Species	Livestock Population Lost Per Household in 2017	
	Mean (TLU±SD)	Max. (No.)
Camel	2.12±3.22	15
Cattle	11.86±12.38	89
Goats	1.26±1.33	50
Sheep	0.84±0.86	38
Total	16.08	192

97.3% of respondents perceived that the trend and status of desertification has highly expanding in the past three decades and become the main threat for communities' livelihood. Furthermore, key informants and focus group discussion indicated that the effect of drought manifested on decline in crop production in terms of quality and quantity, less availability of fodder, low productivity and death of livestock that could be factors affecting the household vulnerability.

A study conducted in Borana Zone by Kejela et al. (2007) also corroborate with the findings of this study. The study showed a decline in livestock production and productivity over the past three decades in Borana exacerbated by increasing frequency and intensity of drought. A similar study by Dewit and Stankiewicz (2006) and IISD (2007) cited by Meseret (2013) also indicate that disruption of sufficient supply of feed and water systems as the result of invasive plant encroachment is impacting development in general and livelihoods of pastoralists' and agro-pastoralists' in particular. These problems are expected to exacerbate under climate change.

In other studies, droughts has been anticipated to occur five to six years in the Borena rangeland (Desta and Coppock 2002), but both their frequency and severity may be rising. Droughts deplete cattle population through heightening mortality and forced off-take. A warming and drying trend in climate negatively affects the rangeland productivity by lowering the quantity and nutritional quality of forages besides causing water scarcity (Thornton, et al., 2009; Nardone, et al., 2010).

Role of Dry Forests for Households' Adaptation

The results indicated an increasing trend of household livelihood dependency on the dry forests in the last three decades. The majority of surveyed households (67.6%) perceived *"strongly increasing"* and 14.9% perceived *"increasing"* trend of livelihood dependency on dry forests. In contrast, 5.4% of the respondents claimed *"decreasing"* trend of dependency on forests while only 9.5% of respondents felt *"no change"* on their livelihoods. More than 83% of the respondents indicated that there was an increment in terms of the level of engagement, participation of family members and time of participation in the dry forests management and utilization. Similarly, 48.6% of the households agreed that the income generated from dry forests increased substantially (Table 6).

Table 6: Trend of engagement in the dry forests during drought periods

Indicating parameters	Respondents' response on the trend of engagement in the dry forests (N=74 (%))		
	Increasing	Decreasing	No change
Level of engagement in dry forests	84.7	5.6	9.7
Number of families	83.3	4.2	12.5
Time of participation in dry forests	84.7	4.2	11.1
Income generated from dry forest products	48.6	27.1	24.3

The respondents agreed that dry forests are less vulnerable to the impacts of climate change and hence help in adaptation strategies of households (Table 6).

Table 7: Respondents' response of on the vulnerability level of different livelihood strategies against the impacts of climate change

Livelihood strategies	Respondents' response of on the vulnerability level (N=74 (%))		
	Highly vulnerable	Moderately vulnerable	Less vulnerable
Livestock	52.8	44.4	2.8
Crop production	47.2	43.1	9.7
Gum and resin	2.8	1.4	95.9
Other forest products	1.4	5.6	93.1
Off-farm activity	2.8	4.2	93.1

Surveyed households identified the most resilient livelihood strategies against both climate- and environment-related risks. Close to 40% of the respondents perceived that off-farm activities (35.8% for petty trade and 3.8% for daily labor) become more resilient during drought periods. Results from key informant interviews and focus group discussions indicated that off-farm activities has climate-independent and simple to exchange and generate daily income for the households.

On the other hand, 35.8% of the respondents agreed that livestock rearing; particularly, *camels and goats* are the most resilient strategies against drought impacts. Key informants were also agreed up on the shift in diversity of livestock species towards *camels and goat* that mainly depend on browsing tree leaves during drought seasons. Climate change, especially increasing frequency and intensity of droughts, accentuates the impact of these stressors, undermining the traditional coping strategies and deepening the vulnerability of the pastoralists. Cattle are the livestock species most susceptible to water and feed shortages engendered by climate change (Seo, et al., 2010). Moreover, the study by Meseret (2013) indicated that Borena herders who have historically been cattle pastoralists are reportedly responding to environmental changes by adjusting their herd composition, i.e., keeping more tolerant species such as camels and goats (Zander, 2011). In other words, the shift is due to the fact that cattle and sheep are found to be more vulnerable to drought. Relatively, camel is better dry season tolerant, offer milk for sale even when cow is not milking, high price when sold (Figure 4).

Similarly, 9.4% of respondents agreed that dry forest products (7.5% for gums and resins, 1.9% for charcoal sell) become resilient in drought and the rest, 13.2% of households considered the combination of petty trade and forest products as resilience livelihood strategies in the study area.

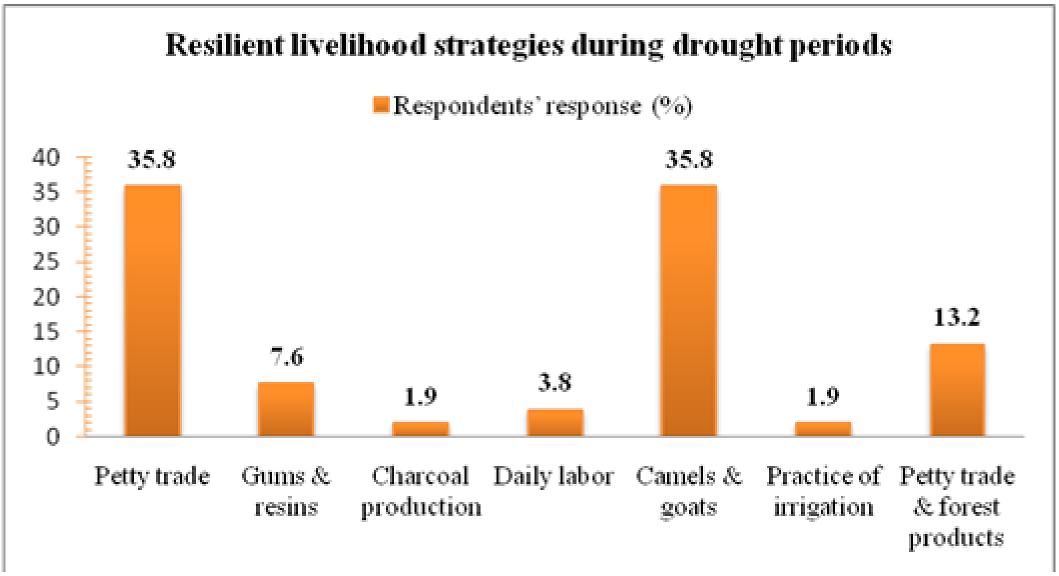

Figure 4: Respondents' response on resilient livelihood strategies during drought

Status and Traditional Dry Forests Management Systems

About 90% of the respondents perceived that dry forest are highly declining and only 10 % of the respondents perceived that dry forests in Liben district are moderately decreasing in the past three decades. Moreover, the status of high valued woody species found in the dry forests showed notable shrinkage in terms of forest cover, species abundance, and regeneration rate. For instance, nearly 97% of respondents perceived notable decrease in high valued species in the dry forests while the remaining perceived either increase or no significant change in species composition and density in the dry forests.

Climate change could be the trigger of increased extinction rates in many regions, especially in the tropics (Thomas, et al., 2004; Fischlin, et al., 2007), and land-use change, such as deforestation, is also an important and synergistic driver (*cf.* Sala, et al., 2000, for a recent, comprehensive review see Fischlin, et al., 2007). Deforestation and degradation through infrastructure development, plus non-sustainable practices, result in fragmented forests and biomass losses at large spatial scales, which could be greater in

CO_2-induced climate change (Zhao, et al., 2005). The results are again impoverished forests with reduced productivity.

On the other hand, the major driving factors that triggered the change in forest cover, species diversity and regeneration include; population increments, deforestation and degradation, over-exploitation of the forest resources, and decrease in amount of annual and distribution of rainfall in the area (Figure 6).

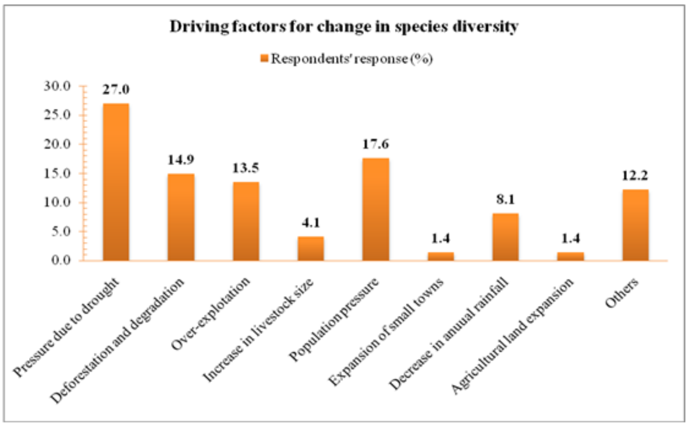

Figure 5: Driving factors that triggered change in species diversity

The results indicated that the main purpose of managing the dry forests for rangeland, source of food, source of non-timber forest products and means of combating desertification (Figure 7).

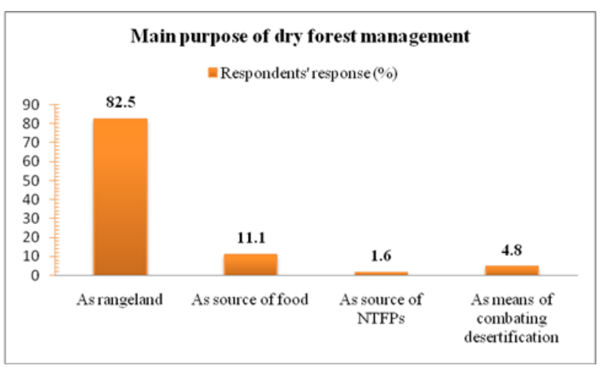

Figure 6: Respondents' response on purpose of dry forest management

Conclusion and Recommendations

Conclusion

Drought, desertification and forest degradation are among the major challenges hindering development of drylands. Findings indicated that frequent and persistent drought in recent years has a negative effect on the availability of food and on the nutritional status of people through loss of assets (especially livestock and crops) and dry forest products. The trends of households' livelihood dependency on dry forest were strongly increasing indicating that dry forest income is now becoming essential withthe occurrence of drought in the area. The results indicated that dry forests are playing crucial role in improving the adaptive capacity of drought prone communities through enhancing their socio-economic and ecological resilience. And also dry forest income has its own contribution for the total annual income of households and thereby for adaptive capacity of communities.

The major factors which have an effect on total annual income in the study were combined effect of sex and education level, and combined effect of location, sex and education level. In the study area, households were used various strategies for coping climate extreme events, among these were destocking of animals, off-farm activities, sale of gum and resin and other forest products, aid support and migration. Overall, the results showed that dry forest has high contribution for household income and hence help for coping strategies in climate extreme events.

Recommendations

Pastoralist communities are expected to be among the most affected groups by climate change impacts. Hence, there is a need to access the resources and services that help them cope with impending catastrophic shocks, protect their livelihood assets and increase their resilience. The adverse impact of climate change is thought to be more severe in developing countries because of their heavy dependence on natural resources and constrained capacity to adapt to climate-induced shifts.

Local forest knowledge and traditional forest management practices have developed over a long time frame that encompasses considerable climatic variation. This knowledge can, therefore, has a considerable value in contemporary climate change adaptation, particularly when applied to forest rehabilitation, restoration and the adaptive management of forests. However, while local and indigenous knowledge has been shown to be dynamic, its capacity to adapt quickly enough to the more dramatic climate change impacts cannot be assumed, especially in many parts of the world where it is already disappearing for a number of reasons. The recognition and preservation of traditional forest-related knowledge and its translation into the language of formal forest science are important steps towards adaptation and application of traditional forest-related knowledge to new or changing environmental, social and economic contexts. Strengthening traditional ecological knowledge (TEK) to promote local dry forest management; for instance, "*Kalo*" system and raising the communities awareness to reduce the livestock, i.e. destocking, and diversification. And also sustainable forest management is essential for reducing the vulnerability of dryforests dependent community to climate change. The current failure to implement traditional ecological knowledge it limits the capacity of forests and forest-dependent people to adapt to climate change. To meet the challenges of adaptation, commitment to achieving the goals of sustainable forest management must be strengthened at both the international and national levels.

It is important to improve management of dry forests for livelihood enhancement and a win-win approach of maintaining their long-term ecological functions. These could be achieved via promoting their integration into the national, regional and local development planning. And also there is a need of strengthening ecosystem service of dry forest for communities including income source with appropriate management plan of dry forest ecosystem to increasing the coping capacity of the local community for climate extreme events like drought.

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Chapter Three: Ecosystem Management Research

Woody Plant Diversity: The Case of Liben and Yabelo Districts Woodland Vegetation, Southern Ethiopia

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Abstract

Biodiversity directly or indirectly touches the day-to-day livelihoods of human being. Conserving and utilizing biodiversity sustainably especially in climate vulnerable areas implies that ensuring food security of the pastoral and agro pastoral people in dry land areas. The aim of this study was to know diversity, structure and carbon stock of woody plant species in woodland of Liben district in Guji and Yabelo district in Borena Zones of Oromia Regional State, Southern Ethiopia. Vegetation sample was taken using systematic sampling method. Three plots having a sizes of 30mx30m were laid at one transect line having 200 meter interval between them. Transects lines were laid by dropping 50 meter elevation gradient starting from 1600 to 800 meter at sea level in Guji Zone of Oromia Regional State. Whereas at Borena Zone, transects were laid systematically at every 2 km interval due to the existence of plain land escape. A total of 65 species belonging to 36 genera and 24 family and 49 species belonging to 37 genera and 23 families were recorded from Guji and Borena Zones respectively in the study area. At higher elevation in Guji zone of the study area higher species (50) were recorded as compared to (35 and 21) at lower and medium elevation gradients respectively in the study area. The dominant woody plant species at one of the stratum becomes absent on the other stratum and vise versa. The DBH structure of woody plant species in the study area revealed inverted- J shape structure. The total carbon stock of the woody plant species in the study area was 34.46 t h^{-1}. Acacia mellifera which is one of the encroaching woody plant species in the study area was recorded as dominant species in the lower altitude than higher and medium elevation. Therefore, any prior controlling mechanisms of this species would be done at lower altitude in the study area.

Key Words: *Woody plant species, diversity, woodlands, Elevation gradient*

Introduction

Woodlands found in Africa are rich in biodiversity that include woodland, bush land, thicket and wooded grassland. The definition of woodland is not consistent and a little bit varies from author to author. For example, CIFOR (2010), defined it based on dominant plant species (woody plants species and wooded grassland) and crown cover in percent (>10). On the other hand, Ethiopian Panel on Climate Change (2015) defined it based on crown cover (20-80), matured stem number (1) with layered under-stories of immature trees, other assemblages (bushes, shrubs and grasses or forbs) height of trees (<20 meters) and tree densities (between 150-400 stems per hectare). But, in any of the cases, it satisfies the definition of dry land vegetation which have an aridity index (P/ETP) of less than 0.65 or length of growing period of 1-179 days.

Biodiversity directly or indirectly touches the day-to-day activities of human being. They are the source of foods and fodders, energies, medicines, industry additives, exporting materials, handicrafts, construction materials and other intangible uses. Management of woodland vegetation sustainably implies that supply of adequate and sustainable water can be insured. Because, all the major river basins in sub-Saharan Africa are either located or have most of their headwaters in the woodlands (CIFOR, 2010). Therefore, the main challenges of dry land areas (lack of enough water supply) can be avoided through managing the woodland vegetation sustainably.

On the other hand, this vegetation types are the source internationally traded goods like frank incense, gum Arabic, and myrrh and many other locally used non forest products. Most of the land area of the country is occupied by dry land vegetation. Moreover, people lived in dry land areas led their lives through livestock production. For this, the woodland play great role for grazing and sheltering the livestock population. Besides of all these usages the vegetation is disappearing in an alarming rate due to a number of factors. Therefore, study the pattern of woody plant diversity, their composition, structure, density and sequestered carbon stock of such vegetation has great role to know and manage the vegetation sustainably.

Prior studies conducted in the study area by Adefirs et al. (2012) and Gemedo et al. (2005) reported woody plant and floral diversity of Borena woodland respectively. The current study attempt to know the altitudinal distribution of woody plant species and sequestered carbon stock of the woodland vegetation at the Guji Zone of southern Ethiopia. MoreThe aim of this study was to study woody plant diversity, structure and carbon stock of woody plant species at Liben district in Negele Borena and Yabelo district in Borena Zone, southern Ethiopia.

Materials and Methods

The study area is about 600 km far away from South of Addis Ababa. Rainfall distribution is bimodal with the long rains between April and May, and the major dry season between December and February (Gemedo, 2005). The Liben district in Negele Zone received higher rainfall than Yabelo. The mean monthly minimum and maximum temperature is 16 ^{o}c and 28^{o}C, respectively. Total annual rainfall ranges from 460 to 790 mm with an average of 609 mm. The main rainy season in the district occurs from February to June and a minor rainy season from September to December

Sampling Technique

Preliminary survey of the area was carried out to understand the overall vegetation type of the area. Then the vegetation was stratified in to three homogenous representations. These are the vegetation in the higher altitude/broad leaved mixed woodland (1600m-1450 m at sea level), the vegetation in the middle altitude/Acacia dominated woodland (1451-1200 m above sea level) and the vegetation in the lower altitude/Commiphora dominated woodland (1201-700 m above sea level) in Liben Wereda of Guji Zone.

Sampling sites were laid by dropping 50 m altitudinal gradient starting from 1600 m above sea level to capture the diversity of woody plant species in the study area. From each sampling site three quadrants having the size of 30mx30m were established which are 200 meter apart from each other from the centre of two consecutive quadrants. While the vegetation type in Yabelo was classified as one, because the slope of the terrain in this area is almost negligible. Therefore, sampling sites were selected by considering distance between sampling sites unlike that of Guji. Accordingly, sampling sites were selected two kilometres apart from each other.

Results and Discussions

Woody Plant Species Richness and Diversity

A total of 65 species belonging to 36 genera and 24 family and 49 species belonging to 37 genera and 23 families were recorded from Guji and Borena Zones respectively in the study area (Table 1). In Guji Zone in the study area revealed more richness, diversity and evenness than that of Borena Zone. Sixty five and forty nine species were recorded at Guji and Borena zones respectively.

Table 1: The diversity of woody plant species at Guji and Borena Zones of Oromia Regional State, Southern Ethiopia.

Zones	Richness	H	Evenness
Guji	65	3.30	0.79
Borena	49	2.63	0.69

The current study showed higher number of species by two folds at Borena and three folds in Guji Zones of the study area than the previous studies (Adefires, et al., 2012). This might be derived from the presence of environment gradient like altitude in the Guji Zone and other associated environmental factors like rainfall. But, when compared with Gemedo et al. (2005) research report, it was lower by almost more than two fold of species. This can be the outcome of forest degradation by a number of factors like over grazing and the over dominance of encroaching species like *Acacia drepanolobium* and *Acacia mellifera*.

Research reports in similar vegetation type in other parts of the country revealed more diverse woody plant species than the current study by Haile et al. (2012) at Metema, north Gondar; and by Samson et al. (2010). This may be due to the presence of better management regime of the vegetation and other associated biophysical factors than the current study areas. On the other hand, similar results were reported from similar vegetation types in other parts of the country (Yohannes, et al., 2013) and lower species richness was reported from South Omo area woodland by Muhamed et al. (2014).

A*cacia busei* was the dominant tree species followed by *Acacia mellifera* and *Terminalia browinii.* Fabaceae was dominant family represented by 5 genera and 16 species. The dominant woody plant species at one of the stratum becomes absent on the other stratum and vise versa (Table 2).

Table 2: The dominant woody plant species and their ecological index at elevation gradient in Guji Zone of Oromia Regional State, Southern Ethiopia.

No	Botanical name	Elevation gradient	RD	RDO	RF	IVI
1	*Terminalia browini*	Higher	11.64	14.93	80.39	106.97
2	*Chionothrix latifolia*	Higher	0.05	0.09	80.39	80.53
3	*Combretum molle*	Higher	16.10	19.81	27.45	63.36
4	*Pistacia lentiscus*	Higher	8.46	12.67	37.25	58.38
5	*Commiphora africana*	Higher	1.85	2.85	47.06	51.76
6	*Acacia bussei*	Medium	32.56	33.18	85.00	150.73
7	*Commiphora africana*	Medium	8.64	8.24	65.00	81.88
8	*Acacia etbaica*	Medium	5.98	6.07	65.00	77.05
9	*Acacia mellifera*	Medium	18.94	16.87	35.00	70.80
10	*Commiphora kua*	Medium	5.98	6.89	50.00	62.87
11	*Acacia mellifera*	Lower	27.78	29.06	91.67	148.51
12	*Acacia bussei*	Lower	12.00	11.97	83.33	107.31
13	*Grewia bicolor*	Lower	8.89	8.78	66.67	84.33
14	*Acacia etbaica*	Lower	4.00	3.74	66.67	74.40
15	*Chionothrix latifolia*	Lower	6.22	6.17	58.33	70.73

Higher number of species were recorded at higher elevation (50) as compared to the lower (34) and medium (21) elevation gradients in Guji Zone respectively (Table 3).

Table 3: The diversity of woody plant species along elevation gradient in Guji Zone of Oromia Regional State, Southern Ethiopia.

Elevation gradient	No of plots	Elevation range	Richness	H	Evenness
Higher	17	1600-1400	50	2.96	0.76
Middle	20	1400-1200	21	2.25	0.74
Lower	12	<1200	34	2.62	0.74

Vegetation Structure

The population structure curve of woody plant species in Guji Zone showed that there was problem with natural regeneration. From the three strata better natural regeneration was observed at lower strata. The woody plant species with DBH > 2 cm in this stratum showed inverted-J shape (healthy) population structure. From the population structure figure serious problem was observed in lower DBH class at middle altitude.

The overall population structure figure of the two zones of the study area indicated that Borena Zone had better or healthy population structure except at seedling stage. The diameter distribution graph indicates that the structure of the woody plant species in the study areas were looks like healthy (Figures 1 and 2). That means if there is greater number of the juvenile or young woody plant species in given vegetation than that the adult one then the given vegetation will be considered as ecologically healthy.

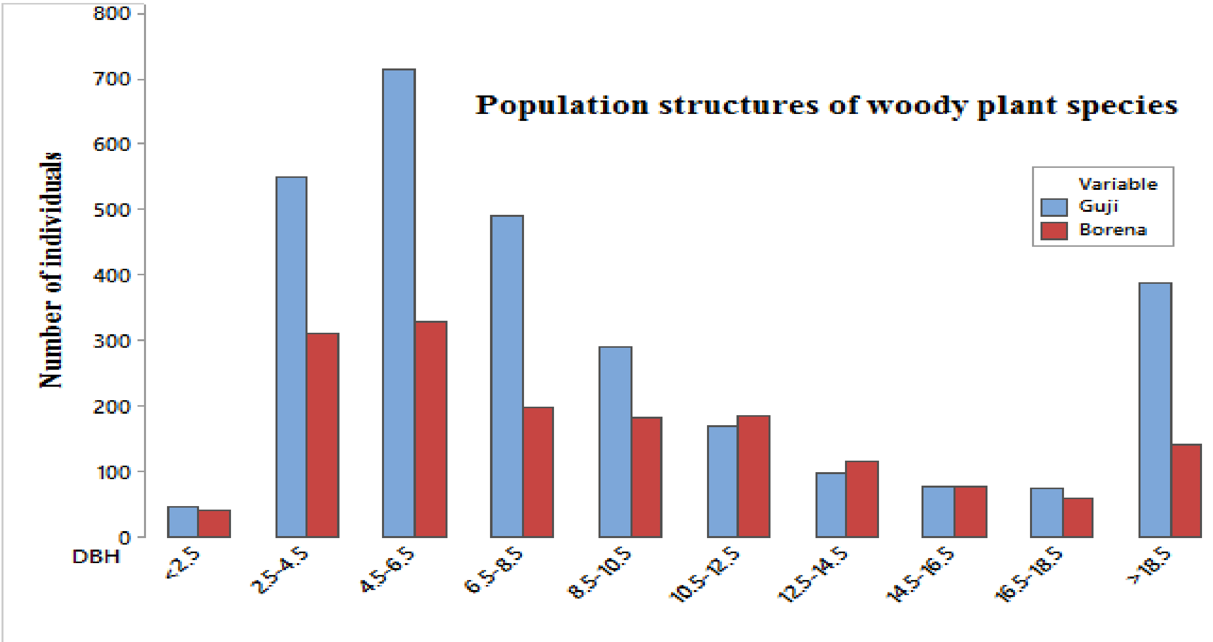


Figure 1: Woody plant population structures in Guji and Borena Zone of Oromia Regional State, Southern Ethiopia

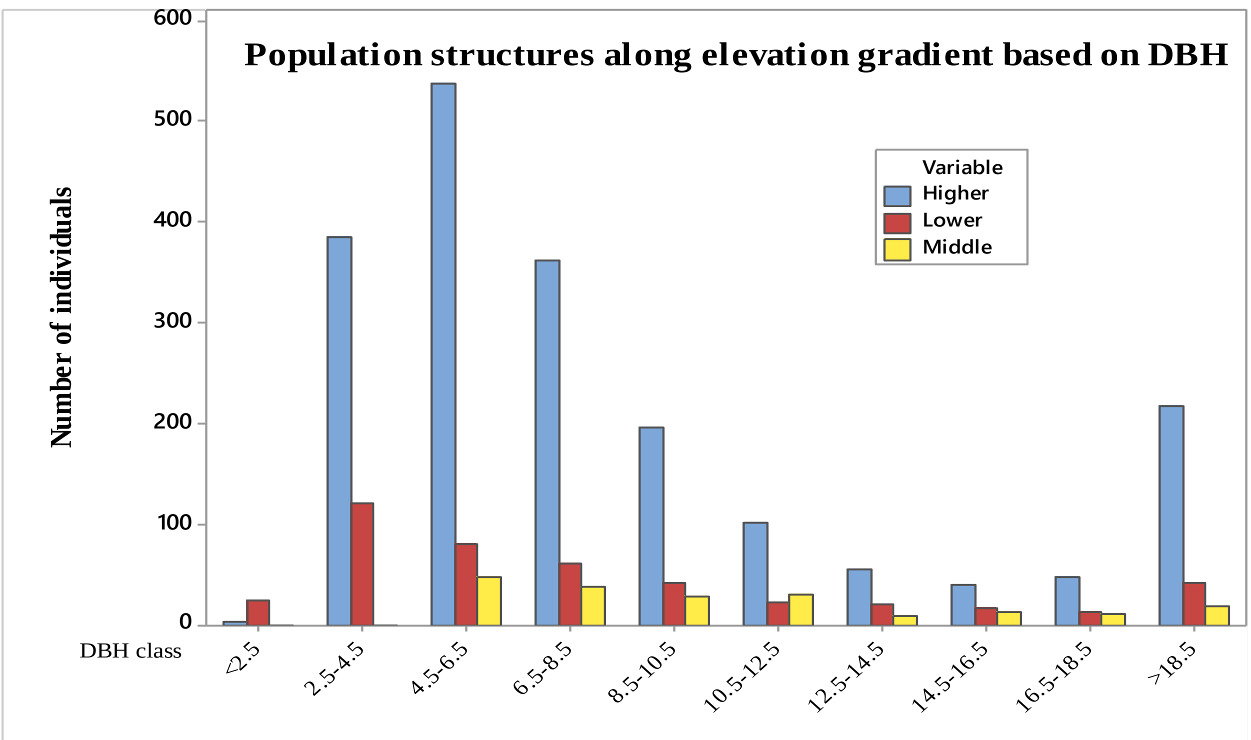
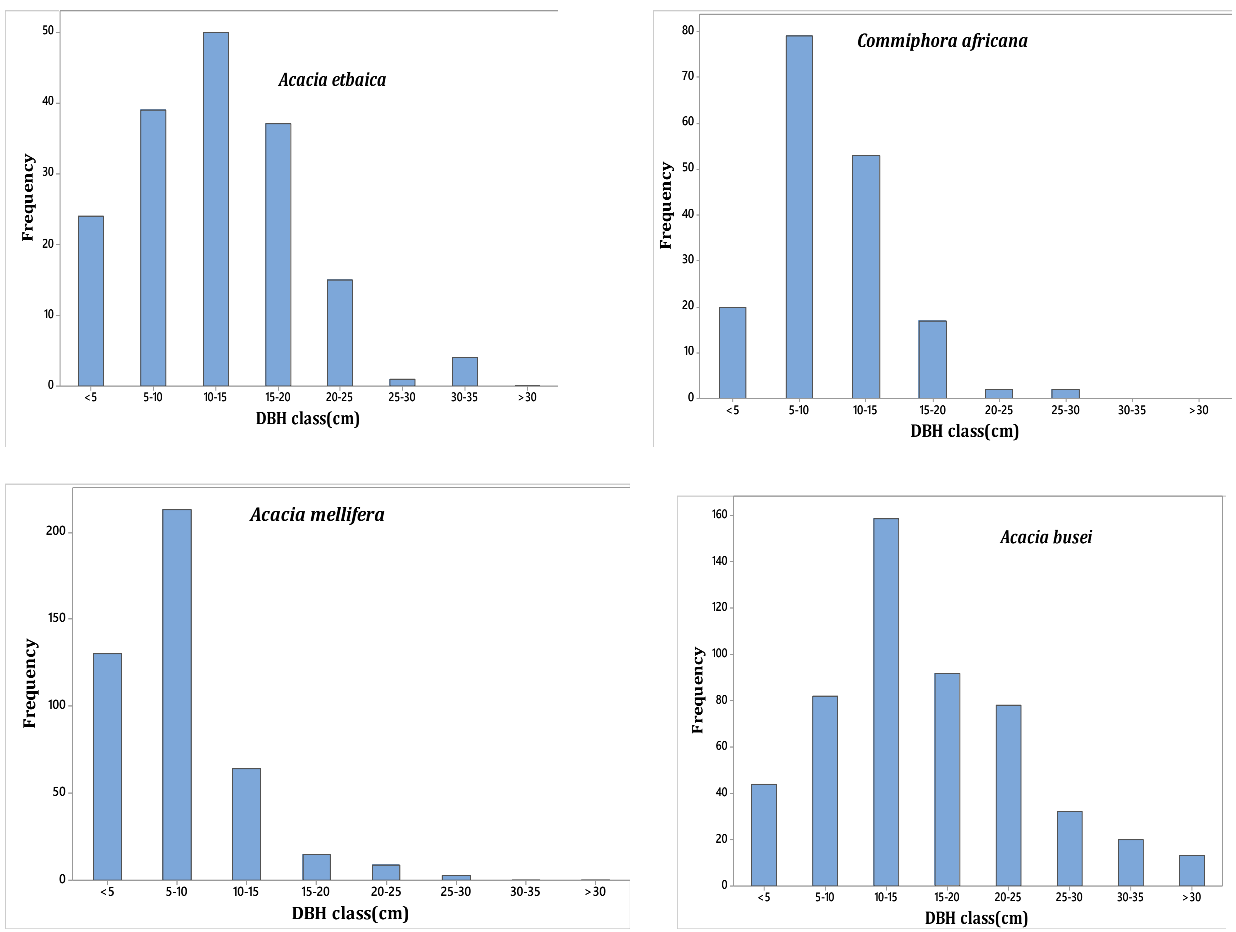


Figure 2: Woody plant population structures along elevation gradient in Guji Zone of Oromia Regional State, Southern Ethiopia

The population structure of the top seven dominant woody plant species encountered in the study area revealed more or less the same structure except *Grewia bicolor*, which shows a clear inverted J-shape structure (Figure 3). The population structure of *Acacia mellifera* did not revealed individuals at higher DBH class. This may be the factor that enabled it became encroacher species in the study area. The population structure of *Terminalia browinii* revealed that it has problems with regeneration followed by *Combretum molle*. This may be due to high level of human disturbance in the form of trembling and browsed by domestic animals at higher elevation.



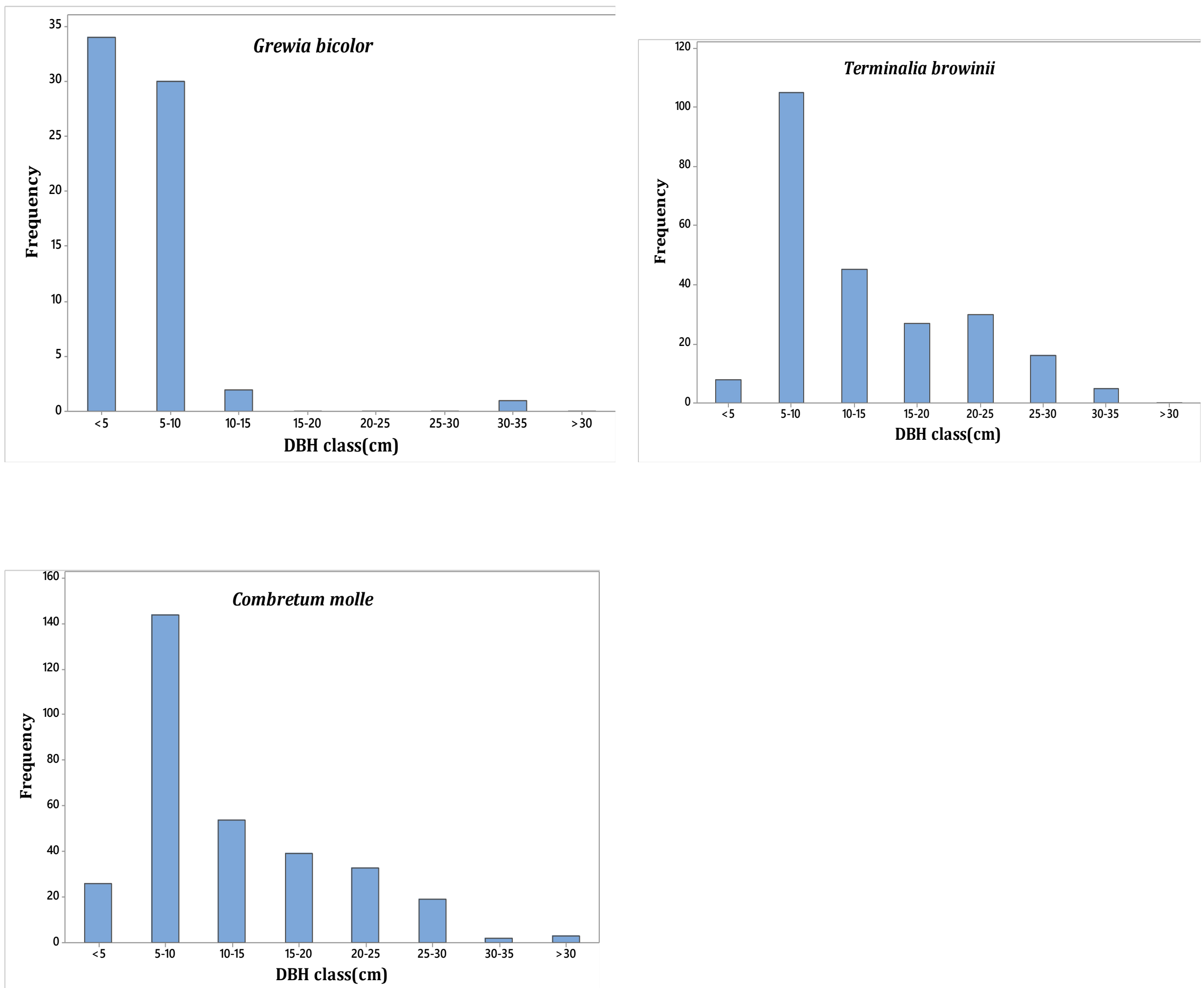


Figure 3: The population structure of dominant woody plant species in Guji and Borena Zones of Oromia, Southern Ethiopia

Carbon Stocks

Deforestation and forest degradation altered from woodlands they can sequester 18% of the global carbon dioxide (Munishi, 2014). The carbon stock of the vegetation was calculated by using Chave et al. (2014) biomass calculating equation. This equation demands three parameters such as; DBH, height and specific basic wood density to calculate the biomass of the tree. Collection of specific basic wood density data in the field is not as simple task as that of DBH and height, therefore it is convenient to collect it from some available global data base like that of Global Wood Density Data Base and

World Agro forestry Wood Density Data Base. Accordingly, the wood density of woody plant species collected from the field was taken from these two databases.

Table 4: Carbon stock along altitudinal gradient in Guji Zone of Oromia Regional State, Southern Ethiopia

Strata	Altitude range(m)	AGB (t/h)	AGC (t/h)	BGC (t/h)	TC (t/h)
Higher	1600-1400	14.32	7.16	1.43	8.59
Middle	1400-1200	19.22	9.61	1.92	11.54
Lower	<1200	20.14	10.07	2.01	12.09

Besides, of the provision of different goods and services that the local people gain from the woodland, it can also sequester paramount level of carbon dioxide during photosynthesis process. The carbon stock of the vegetation in Yabelo area is approximately lower by three tons per hectare from Liben area (Table 5).

Table 5: The carbon stock content of the woody plant species in Borena and Guji zones of Oromia Regional state, Southern Ethiopia

Wereda	Mean AGC.t.h	Mean BGC.t.h	Total
Yabello	12.93	2.58	15.51
Liben	15.74	3.15	18.89
Total	28.67	5.73	34.4

The total carbon stock of the two districts of the study area was higher than similar vegetations in other part of the country. Whereas the carbon stock of the vegetation in each districts are lower than other areas like Kafta Humera, Metema and Sherkole reported by Ethiopian Panel on Climate Change (2015).

Conclusions and Recommendations

A total of 65 species belonging to 36 genera and 24 family and 49 species belonging to 37 genera and 23 families were recorded from Guji and Borena Zones respectively in the study area. *Acacia busei* was the dominant tree species followed by *Acacia mellifera* and *Terminalia browinii.* Fabaceae was dominant family represented by 5 genera and 16 species. The over all population structure figure of the two zones of the study area indicated that Borena Zone had better or healthy population structure except at seedling stage.

The population structure curve of woody plant species in Guji Zone showed that there was problem with natural regeneration. From the three strata better natural regeneration was observed at lower strata. The woody plant species with DBH > 2 cm in this stratum showed inverted-J shape (healthy) population structure. From the population structure figure serious problem was observed in lower DBH class at middle altitude. At higher elevation in Guji zone of the study area, the highest species richness (fifty) was recorded as compared to (thirty five and twenty one) lower and medium elevation gradient respectively.

The current study showed higher number of species by two folds at Borena and three folds in Guji Zones of the study area than the previous studies (Adefires, et al., 2012). But, when compared with Gemedo et al. (2005) research report, it was lower by almost more than two fold of species. The population structure of *Terminalia browinii* revealed that it has problems with regeneration followed by *Combretum molle*.

From the result, population structure at seedling stage were very limited when compared with the population structure of the adult stage. Therefore, proper forest management mechanism should be set to enhance the natural regeneration of the woodland. On the other hand, in Guji Zone at middle altitude no individuals observed at the DBH class ≤ 4.5 cm. So that the factors should be investigated and appropriate measure should be taken for future.

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This research work was found by the contribution of many researchers of ecosystem management directorate. Therefore, we would like thank all those previous and the current members of the directorate for their respective contribution in that harsh environment. Mahdere Mulugeta, Amdemichael Mulugeta, Dr. Tesfaye Bekele, Dr. Alemu Gezahegn, Gizachew Zeleke and others needs to get appreciation for their effort.

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The Contribution of Soil Seed Benk for the Regeneration of Aboveground Plant Species in Wof - Washa Forest, North Shewa Zone, Amhara Region, Ethiopia

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Abstract

The soil seed bank provides an indication of the regenerative potential of forest ecosystems following disturbances. The present study was conducted to examine the spatial distribution of soil seed bank (SSB) in Wof-Washa forest with the aim of exploring the diversity characteristics of SSBs and the relationships between SSBs and forest vegetation. Systematic sampling design was used to collect vegetation data. The soil samples were spread on seed beds in a glasshouse and emerging seedlings were counted and identified. Jaccard and Sorensen's similarity coefficient of were used to measure species similarities among community types and soil seed bank layers of Wof-Washa forest. Seed beds were maintained for nearly 10-11 months until no seedlings emerged. The results revealed higher number of germinable seeds was recorded. A total of 76 plant species, 5549 seedlings per m^2 (2948 in the 0-3 cm layer, 1494 seedlings in the 3-6 cm layer and 1107 seedlings in the last 6-9 cm layer) were recovered from soil samples collected beneath the Wof - Washa Forest. Herbs dominate the soil seed flora, represented by 63 species (82.9%) followed by trees species 8 (10.53%), liana of 3 (3.95%) and shrubs with 2(2.63%). Thirteen woody species with 67 seedlings were identified from soil seed flora of Wof-Washa forest. 51% of soil seeds were identified in the upper three centimeter of soil seed layer followed by the (3-6 cm) with 26% while the deeper layer (6-9 cm) contributes only 19% of the total seed bank of the forest. The result of soil seed bank and field survey identified that human induced pressures especially free grazing and human encroachment are the most pressing and persistent driving factors among others. Thus, application of integrated forest management strategies using both in situ and ex situ conservation and participation of local communities, social institutions in collaboration with local governmental development agents is an urgent issue.

***Key Words**: Distribution pattern, regeneration, seed density, seedling emergence, soil depth*

Introduction

The tropical montane forests are highly diverse ecosystems providing important ecosystem functions and services. Habitat heterogeneity together with anthropogenic and natural disturbances can make these forests very complex systems. Forest areas of northern and central Ethiopia is highly fragmented and is facing rapid deforestation and degradation due to high demand of population for agricultural land expansion, grazing, fuel wood, fodder, construction materials and timber (Tamrat, 1993). Human induced pressure in combination with environmental variables explains the spatial and temporal vegetation distribution patterns and dynamics (Ellenberg, 1988).The frequent anthropogenic impacts and droughts have contributed to the further deterioration of the natural resource and genetic erosion of biodiversity. Soil seed banks play a significant role in primary and secondary plant succession and to a large extent to determine the composition and structure of existing vegetation. Soil seed banks are also very important in the restoration of native vegetation following disturbance (Van der Valk and Pederson, 1989). Therefore, the present study focuses on soil seed banks to identify species of high regeneration potential for the management of vegetation restoration and rehabilitation. Therefore, the conservation of these valuable and highly vulnerable ecosystems could be of high priority that needs due attention from the conserned stalkholders.

Materials and Methods

Description of the Study Area

This study was conducted at Wof-Washa Forest in North Shewa Zone of Amhara Region, in central Ethiopia (Figure 1). Wof-Washa Forest is a dry afromontane forest and extends between 9^{o} 43' 46.3'' N to 9^{o} 46' 26.2'' N latitude and between 39^{o}01'10.78 '' E to 39^{o}47'15.8'' E longitude with the total area ~ ca. 3600 ha (Tamrat Bekele, 1993). Topographically, the study area is highly dissected, undulated by frequent stream incisions with slopes ranging from 1900 to about 3700 m a.s.l. Extreme slope nature, remoteness to main roads and towns and the meagre infrastructure situation make Wof-Wash forest highly inaccessible (Tamrat, 1993).

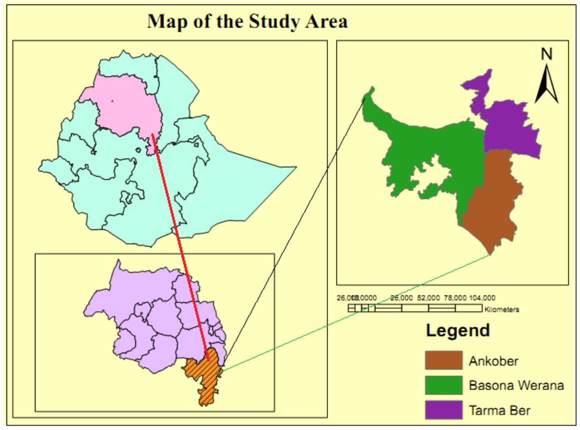


Figure 1: Map of Ethiopia showing Regional States and the Study Area

According to the climate data (1992-2010) obtained from the National Meteorological Agency, the mean annual rainfall of Ankober Woreda is 1254 mm. The mean annual rainfall of Tarmaber is 1, 250 mm (falling in two wet seasons from February to March, and July to September. The mean monthly temperatures of the daily maxima in Debre Sina range from 15.5 to 24.2°C, and the corresponding minima from 1.2 to 11.8 °C. The mean monthly temperature ranges from 8.35 to 18 °C (Figure 2). There are often dry winds during the day, frosts may occur at night, and snow sometimes settles on the summit of Eme Mihret, Kundi and Wuti.

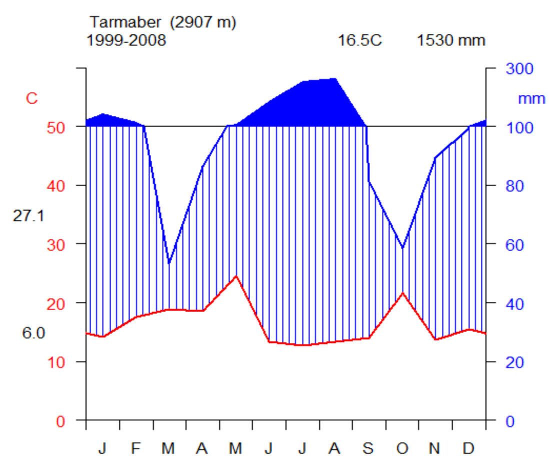


Figure 2: Climate diagrams showing Annual rainfall and temperature distribution patterns (Source: National Meteorological Service Agency, 2014)

Wof Washa forest can best be described as dry evergreen afro montane forest in the eastern escarpment of the NW Highlands (Tamrat, 1993). The main characteristic species at the higher altitudes are *Hagenia abyssinica, Juniperus procera, Maesa lanceolata* and *Ilex mitis. Podocarpus falcatus, Allophylus abyssinicus, Halleria lucida, Euphorbia abyssinica, Polyscias fulva, Prunus africana* and *Olinia rochetiana* occupy the middle altitude. At and above 3,000 m*, Erica arborea, Hypericum revolutum,* and *Lobelia rhynchopetalum are* the most dominant species with a few individual trees of *Hagenia abyssinica* and *Pittosporium viridiflorum* on the inaccessibly cliffy and steep slopes.

Reconnaissance Survey

Reconnaissance survey was carried out from March 20 to 30, 2014. During the survey, study sites were selected, sampling method was determined, accessibility of the study area was assessed, and altitudinal gradient and topography of the study area were inspected. Generally, reconnaissance survey provides an impression on the general vegetation physiognomy, landscape and sampling sites of Wof – Washa forest.

Sampling Design

Soil seed bank samples were collected from each plot in five replicates (15 x 15 cm) with 9 cm depth four at each corner and one at the center of a square plot established for the vegetation study and is composited for analysis. The composite sampling provides average values for each respective sampled plot for further laboratory work.

Data Collection

Soil seed bank field data were collected at the end of small rain (May-June, 2015) and at the end of major rainfall season (October - November 2015) at 95 plots prepared for vegetation data collection in five subplots (15 cm x15 cm). Three successive layers (0-3, 3-6, and 6-9 cm) consisting of the litter layers were carefully removed with a hollow 15 cm x

15 cm square metal frame into the soil at each subplot . Soil layers of each subplot were separated by using a sharp knife and spoon along gradient. Soil samples of the corresponding soil layers from the five sub-plots of each plot was mixed uniformly in a plastic bag and later divided into three equal parts of which one was randomly taken as the working sample for incubation in a glasshouse. Accordingly, 285 different soil seed layers were sampled with 95 soil seed samples from each layer. Taking the soil samples from the soil layers could enable to examine the variations in the depth distribution of seeds and the adjacent natural forest in the soil (Mulugeta and Demel, 2006). The basis for taking sub-plots is to have spatial heterogeneity of soil seed distribution. The soil samples were transported to the Forestry Research Center (FRC) for laboratory analysis. The most common and applicable techniques are seedling emergence and manual seed extract methods for identification and isolation of seed bank (Demel and Granstrom, 1997), to determine and compare seed density and species composition in the soil of natural forests. Despite large differences between the two approaches, seedling emergence is the most commonly used method (Johnson and Anderson, 1986) and the current study also used this approach.

Seedling Emergence Method*:* in the laboratory the seedling emergence rate was observed over a period from October 2015 to September 2016 for 11 months after starting to water the soil samples for the first phase and from March 2015 to January 2016 for the second phase. The soil samples were first sieved using a mesh size of 1.6 mm, 2.5 mm and 3.15 mm to recover seeds of the different plant species. The seeds recovered by sieving were collected into paper bags and identified using local reference material (Hedberg, et al., 2003). The viability of seeds was determined by germination and grinding method (Feyera and Demel, 2002). The collected samples were transported to a glass house in FRC (Forest Research Center, Addis Ababa) and spread on trays. Watering of the samples was done every morning until the incubation was terminated. The maximum number of seedlings was emerged within the first four months of examination. Earlier to the fiveth month onwards the emerging rate gradually decreased until the end of the examination period. There was no germination of new seedlings for the last two months in both phases. Seedling germination was checked every seven days and seedlings readily identified were recorded and removed from the trays to reduce shade effect following the methodology by Getachew et al. (2004).

Unidentifiable seedlings were transplanted into pots and let to grow until species identification is possible. Soil samples were maintained and checked for emerging seedlings for eleven month, (Baskin and Baskin, 1998). After 11 months, when there was no further seed germination, the trays were left to dry for two weeks. This allowed the samples to be crumbled to expose deeper buried seeds to the light. Species identification were done in the green house by the supervision of advisors, using taxonomic keys and authenticated herbarium collections placed in the national herbarium (ETH) at Addis Ababa university and Flora of Ethiopia and Eritrea.

Data Analysis

Overall species richness and evenness of the soil seed bank in each soil layers was determined by Shannon-Wiener diversity index. Jaccard and Sørensens similarity coefficients were used to analyze the similarity between the soil seed bank and the above ground vegetation (Kent and Coker, 1992). Two-way Analysis of Variance (ANOVA) was used to analysis species composition and density of the soil seed banks among the study sites and between soil depths. Species diversity, richness, evenness and total value for the similarity between the above ground vegetation and the soil seed bank of the study area were calculated taking the pooled seeds from three layers of 95 study plots.

To analyze the density of seeds in each soil layer, the numbers of seeds recovered in similar layers were combined and divided by the area in meter square, each area were multiplied by sample size (number of study plots), so that the density of seeds (number m^{-2}) at that particular soil depth was determined following the methodology used by (Taye, 2006).

Results and Discussion

Soil Seed Bank Species Composition

A total of 76 plant species, 5549 seedlings per m^2 (2948 in the 0-3 cm layer, 1494 seedlings in the 3-6 cm layer and 1107 seedlings in the last 6-9 cm layer) were recovered from soil samples collected beneath the Wof - Washa Forest. Herbs dominate the soil seed flora, represented by 63 species (82.9 %) followed by trees species 8 (10.53 %), liana of 3 (3.95 %) and shrubs with 2(2.63 %) (Table 1). The dominant families were Poaceae and Asteraceae with seven species each followed by Brassicaceae (five species), Apiaceae and Polygonaceae with four species each while the rest 30 families were represented by 1-3 species. Thirteen woody species with 67 seedlings were identified from soil seed flora of Wof-Washa forest (Table 1). 62.68 % seedlings of the woody species were identified in the upper layer (0-3 cm) followed by 22.37 % in the bottom layer (6-9 cm) (Table 1).

Table 1: Seedling composition of woody species in the seed bank layers

Species	0-3 cm	3-6 cm	6-9 cm	Total	Habit
Maesa lanceolata	18	0	3	21	T
Solanum bundrianum	4	0	5	9	L
Vernonia amygdalina	4	1	3	8	T
Eucalyptus camaldulensis	1	0	5	6	T
Juniperus procera	1	3	0	4	T
Calpurnia aurea	3	0	1	4	S
Ficus sur	3	0	0	3	T
Smilax aspera	1	2	0	3	L
Eucalyptus globulus	2	0	0	2	T
Hypericum revolutum	2	0	0	2	T
Clutia abyssinica	1	1	0	2	S
Urera hypselodendron	1	1	0	2	L
Olea europaea subsp.*cuspidata*	1	0	0	1	T
Total	**42**	**8**	**17**	**67**	

Soil seed density

The total seed density in the upper nine centimeters and litter fall using seedling emergence and direct seed counting method were 5549 and 263 seeds/m^2 respectively. *Juniperus procera and Discopodium penninervum* were relatively represented in the litter seed bank in higher density among other tree species with 192 and 36 seeds respectively. The highest density of seeds were due to five most abundant species of herbs (*Crasula alsinoides, Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii* and *Callitriche oreophila*) contributed 52.51 % of the seed densities in the soil seed banks of Wof-Washa forest (Table 2).

Table 2: Species with abundant seedlings from soil seed bank in Wof-Washa forest

Species	Soil seed bank layers(cm)			
	0-3	3-6	6-9	Total
Crasula alsinoides	495	445	427	1367
Nephrophyllum abysssinicum	322	175	112	609
Oxalis corniculata	177	84	97	358
Eragrostis schweinfurthii	132	96	78	306
Callitriche oreophila	213	47	14	274
Agrocharis melanantha	189	34	21	244
Dichondra repens	144	75	10	229
Eragrostis racemosa	117	41	54	212
Spilanthes costata	151	34	8	193
Trifolium repense.	74	48	53	175
Cyperus costatus	86	33	27	146
Cotula abyssinica	57	19	35	111
Galinsoga quadriradiata	73	30	5	108
Silene burchellii	87	15	0	102
Subtotal	2317	1176	941	4434
Other species	631	318	166	1115
Total	2948	1494	1107	5549

Seedling density was highly variable among study plots and community types. The maximum numbers of seedlings were observed in plot nine and community type one with 348 and 1949 Seedlings respectively. Plot 82 was exhibited by single species and single individual while the remaining 14 plots are not represented by soil seeds. At species level *Crasula alsinoides* contributes the maximum seedlings/m^2 1367 (24.64%) followed by *Nephrophyllum abysssinicum* with 609 seedlings/m^2 (10.97%) and *Oxalis corniculata* 359 seedlings/m^2 (6.45%) (Table 2).

Spatial Distribution of Seeds in the Soil

There were great differences in the spatial, horizontal and vertical distribution in both the number of species and seeds densities in the soil seed bank.

Vertical Distribution of Seeds in Soil Profile

Seed densities and number of species in soil profile showed similar vertical distribution in almost all plots and community types with the highest number of seed densities and number of species in the upper three centimeter of the soil and gradually declined with increasing the soil depth (Figure 3). Fifty-one percent of the recorded seedlings were identified in the upper three centimeter of soil seed layer followed by the second soil depth (3-6 cm) with 26% while the deeper layer (6-9 cm) contributes only 19 % of the total seed bank of the forest.

At species level, highest densities and number of seeds were in the most superficial soil layer, particularly *Crasula alsinoides, Nephrophyllum abysssinicum, Callitriche oreophila, Eragrostis schweinfurthii, Eragrostis racemosa, Agrocharis melanantha, Silene burchellii, Cyperus costatus, Oxalis corniculata, Galinsoga quadriradiata, Uebelina abyssinica,Cotula abyssinica* and *Spilanthes costata.* Few species *Umbelicus botroides, Ajuga integrifolia, Stellaria media, Geranium arabicum, Crepis rueppellii* and *Datura stramonium* revealed their maximum seed density at the 3-6 cm soil depth. *Cardamine trichocarpa, Plectranthus lanuginosus, Arabis thaliana, Sonchus bipontini, Plantago lanceolata* and *Conyza bonariensis* were also represented in the deepest layer (6-9 cm) (Table 2).

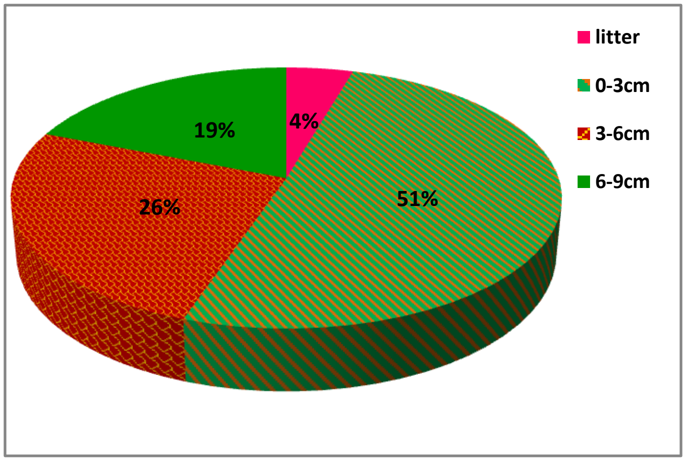
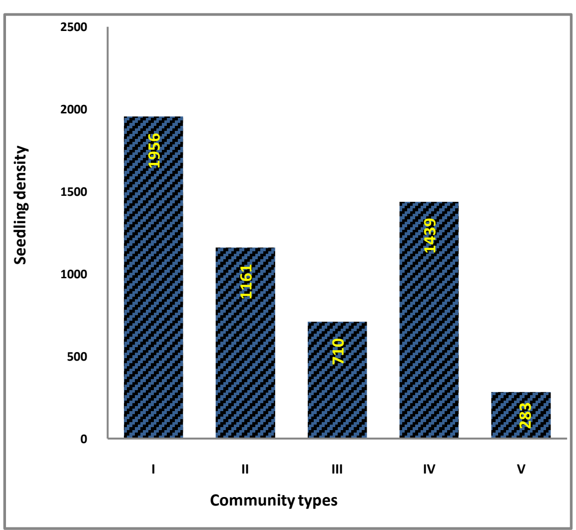


Figure 3: The density of seeds (number of seeds m^{-2}) recorded from the four layers

The vertical distribution seedling densities exhibit variation in both study plots and identified community types. Seeds of *Discopodium penninervum, Galiniera saxifraga, Rosa abyssinica* and *Osyris quadripartita* were entirely confined to the litter layer only. On the other hand, seedlings of *Crasula alsinoides, Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii, Callitriche oreophila, Agrocharis melanantha, Dichondra repens, Eragrostis racemosa, Spilanthes costata, Trifolium repense* were relatively well distributed in all the three seed bank layers. The seedlings of *Conyza bonariensis, Plantago lanceolata, Arabis thaliana, Plectranthus languinosus* and *Cardamine trichocarpa* were distributed in the deeper soil seed bank layers.

Horizontal Distribution

Horizontal distribution of seeds were treated by community type and study plots and showed considerable variations among both community types and sampled plots. The highest seed density 1956 (35.2 %) were identified from community type one followed by community type four of 1439 (25.9%). The least soil seed density was collected



from community type five, 283 (5.1%) (Figure 4)

Figure 4: Density of seedlings along the respective community types

Jaccard's and Sørensen's similarity coefficient were used to compare soil seed species composition among communities types. The result of the two similarity coefficient indicates, that the highest seed bank species similarity was found between community type one and community type four with (JSC=0.553) and (SSC=0.712) values (Table 3). These community types share the maximum number of species (73) than the rest pairs of community types. Community type two and four exhibits the second shows the subsequent higher species similarity with (JSC=0.473) and (SSC=0.642) values. The lowest seed bank species similarity was also found between community type two and five (JSC= (0.213 and SSC=0.351) (Table 3). The similarity in species composition of the soil seed bank was generally low among community types.

Table 3: Jaccard's (JSC) and Sørensen's (SSC) similarity coefficient of soil seed species composition among community types

Community type	C1	C2	C3	C4	C5
C1	1	0.449	0.453	0.553	0.407
C2	*0.619*	1	0.367	0.473	0.213
C3	*0.624*	*0.537*	1	0.373	0.268

C4	*0.712*	*0.642*	*0.543*	1	0.308
C5	*0.578*	*0.351*	*0.423*	*0.471*	1

Key: values indicated in bold and Italized refers to the Jaccard's (JSC) and Sørensen's (SSC) similarity coefficient respectively

Relation between Stand Vegetation and Soil Seed Bank of the Forest

As a total 405 species were recognized in the vegetation and soil seed banks of Wof-Washa forest, of these 65 species (16%) were common in both vegetation and soil seed bank, 3 % and 81 % were found only in the soil seed bank and vegetation respectively (Figure 5). The forest plant diversity was mostly represented by herbaceous species confined to different families. Asteraceae (48 species), Poaceae (30 species), Cyperaceae (15 species), Fabaceae and Lamiaceae (each 14 species), Apiaceae (13 species) Brassicaceae (9 species) and Polygonaceae (8 species) among other families and contributed, the highest species richness (64.7 and 82.9 %) in both above ground and soil seed bank species of Wof-Washa forest respectively. The least species richness were Shrub in soil seed bank (2.6 %) and liana in above ground vegetation (4.6 %) (Table 4).

Sixity five soil seed species were common to both soil seed bank and above ground vegetation, only 12 (15.8%) were exclusive to the soil seed bank species. Among the woody species (*Juniperus procera, Maesa lanceolata,Olea europaea* subsp. *cuspidata, Ficus sur,Vernonia amygdalina,Urera hypselodendron, Sparmannia ricinocarpa, Hypericum revolutum, Calpurnia aurea* and *Eucalyptus globulus* were represented both in the above ground vegetation and soil seed banks.

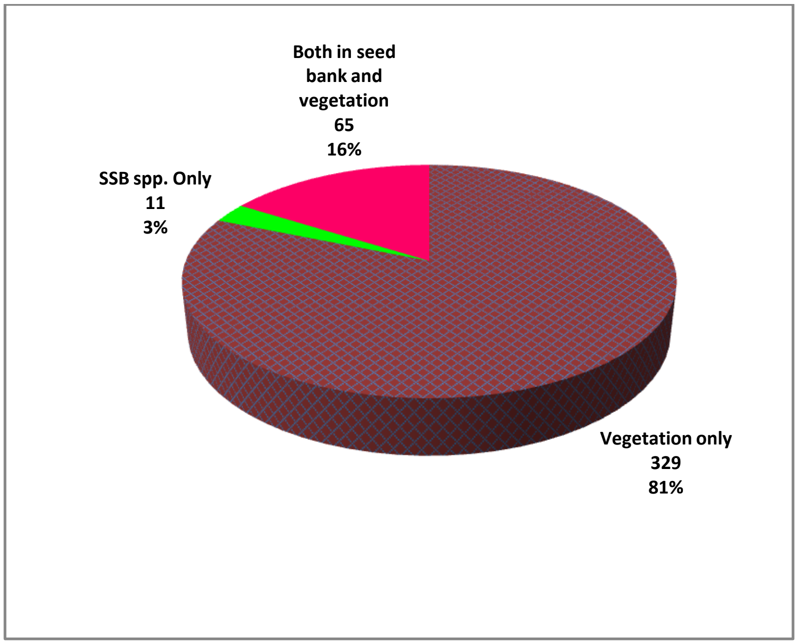


Figure 5: Proportion of vegetation, soil seed bank and common species in Wof-Washa forest

Table 4: Classification of soil seed bank and above-ground vegetation

No	Habit	Soil seed bank		Above ground Vegetation	
		Number of species	%	Number of species	%
1	Tree	8	10.5	49	12.4
2	Shrub	2	2.6	72	18.3
3	Herb	63	82.9	255	64.7
4	Liana	3	3.9	18	4.6
Total		76	100	394	100

Moreover, among the most abundant species in the above ground vegetation (*Erica arborea, Myrsine africana, Podocarpus falcatus, Ilex mitis* and *Galiniera saxifraga*) are not represented in the soil seed bank and vice versa for (*Callitriche oreophila*, *Centella asiatica* and *Eragrostis racemosa*).

Specie similarity between the soil seed bank and above ground flora was very low (ranging from values of 0.06 to 0.08 in JSC and 0.12 to 0.16 in SSC). The least species similarity was recoreded in community type three and the highest was in community type one (Table 5). Although there are more common species in seed bank and above ground vegetation, high species richness of above ground vegetation reduces the specie similarity between the soil seed bank and above ground flora.

Table 5: Jaccard's and Sørensen's coefficient of similarities (JSC and SSC) of soil seed bank and above ground vegetation species

Community type	SSB species richness	Spp. Exclusive to SSB	Vegetation species richness	SPP. Exclusive to Vegetation	Common to both (a)	JSC	SSC
I	50	42	88	67	10	0.08	0.16
II	36	30	74	63	8	0.08	0.15
III	29	23	86	78	7	0.06	0.12
IV	44	35	115	101	10	0.07	0.13
V	23	21	68	62	6	0.07	0.13

Discussion

A total of 76 plant species, 5549 seedlings with large density of herbs (82.9 %) were recovered from soil samples collected from the soil seed bank of Wof - Washa Forest (Table 1). The high accumulation of viable seeds of herbs and low proportion of woody species in the soil seed bank were reported by Demel and Granstrom (1995) and Feyera and Demel (2001).

The seed sizes of most herbs are small and easily dispersed by different mechanisms and small amount of requirement such as water and minerals may be enough to complete their lifecycle which increase the opportunity to be persistent with high density in the soil seed bank in different local climate and topography. Furthermore, seeds of large trees are susceptible for predation, the remaining easily decomposed and delayed reproduction cycle of tree species. Seedling density was highly variable among study plots and community types. The total seed density in the upper nine centimeters and litter fall using seedling emergence and direct seed counting method were 5549 and 263 seeds/m^2 respectively. The five plant species with the highest number of seeds in Wof-Washa forest (in decreasing order of number of seeds) were *Crasula alsinoides,* *Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii* and *Callitriche oreophila*. *Discopodium penninervum, Galiniera saxifraga, Rosa abyssinica* and *Osyris quadripartita* were entirely confined to the litter layer only.

Herbaceous species were dominant in all the plots sampled for the study while woody species are fewer (Table 1). Seed decay, mode of seed dispersal and predation by both wild and domestic animals may reduce the number of viable seeds of woody species. Similar result and explanation for low seed density of woody plants were given by Demel and Granstrom (1996).

There were great differences in the spatial, horizontal and vertical distribution in both the number of species and seeds densities in the soil seed bank of Wof-Washa forest. The relation between species richness and soil depth showed that the number of species did not increase significantly beneath 9-cm depth. All species corresponding to the deepest buried seeds were also found in the most superficial layer with a higher density in Wof – Washa forest.

The highest densities and number of seeds were found in the most superficial soil layer. The vertical distribution of seeds were almost similar in all the study plots with the highest number of seeds and seed density in the upper three centimeter of the sampled soil and show gradual decreasing of number and density of seeds as the soil depth increases (Figure 5 and 6). The litter layer has lower density and number of seeds than the upper layer. At species level, there were variations in distribution patterns. For enstance, some species were recorded in all the layers, others also in one or two layers. Seeds of *Discopodium penninervum, Galiniera saxifraga, Rosa abyssinica* and *Osyris quadripartita* were entirely confined to the litter layer only while seeds of *Crasula alsinoides, Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii, Callitriche oreophila* were distributed in the three layers. The seedlings of *Conyza bonariensis, Plantago lanceolata, Arabis thaliana, Plectranthus languinosus* and *Cardamine* *trichocarpa* were distributed well in the deeper soil layer. Such type of distribution pattern of seeds in the soil was reported in several previous studies in Ethiopia (Mulugeta and Demel, 2005).

Horizontal distribution of seeds in the soil exhibited considerable variations both at community and plot levels. The highest seed density1956 (35.2 %) were identified from community type one followed by community type four of 1439 (25.9 %). The least soil seed density was collected from community type five, 283 (5.1 %) (Figure 7). Most species were found in a few samples and very few species were common and distributed in most samples. The microhabitat differentiation causes spatial variation in abundance and distribution of soil seeds. Such a site to site variation may be attributed to variation in vegetation cover burial depth, seed density and predator pressure.

Jaccard and Sørensen's coefficient of similarities values of soil seed bank and above ground vegetation species values showed low floristic simiarity with the highest (JSC=0.08) and lowest (JSC=0.06) respectively that is a feature of most vegetation types(Table 5). The large discrepancy or weak association between the seed bank and the standing vegetation showed that, the above-ground vegetation is highly represented by most abundant species that were absent from the seed bank (*Erica arborea, Myrsine africana, Podocarpus falcatus*) and vice versa for abundant soil seed species which are not found in the above ground vegetation (*Callitriche oreophila*, *Centella asiatica* and *Eragrostis racemosa*. Some of the vegetation species also may partly be derived from seeds outside the forest for instance *Senna multiglandulosa* and *Senna occidentalis*. The scarcity of most above ground species in soil seed banks may be attributed to seed size. The current results show that most aboveground species had large and heavy seeds for successful recruitment in stress associated forest environments but cannot be able to incorporate in the soil seed bank which contribute to the scarcity of the species in the soil seedbank while small seeded species especially herbs had the largest contribution in the seedbank that supports the negative correlation between seed size and seed longevity. This result is consistent with numerous previous studies that have shown a poor correspondence between species present in the above ground flora and in the seed bank (Feyera and Demel, 2002).

Conclusion and Recommendations

The soil seed bank flora analysis result indicates that Wof-washa forest posses a considerable population of buried soil seeds of herbs, grasses and sedges. The most dominant tree species are not represented inthe seeds bank. This suggests, the removal of mature individuals restrict the regeneration of primary tree species from seeds. Furthermore, most woody species of dry afromontane forests have relatively large sized seeds that make them vulnerable to predators, seed collectors and prevent long distance dispersal of seeds. The density of seeds in the soil was high to few most abundant herbs (*Crasula alsinoides, Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii* and *Callitriche oreophila*). Horizontal soil seed distribution pattern was highly variable among study plots and community types. This is due to variation in topography that creates opportunity to have different microhabitat for soil seeds of the forest.

Similarity analysis result indicates that the soil seed bank and above ground vegetation have shown low floristic similarity. The main reason for this discrepancy between soil seed and above ground is that the most abundant above ground species (*Erica arborea, Myrsine africana, Ilex mitis, Podocarpus falcatus* and *Galiniera saxifraga*) were not represented in the soil seed flora and the vice versa. The low species similarity between soil seed flora and above ground vegetation and very few woody plant species representation in the soil seed bank suggests that most woody species of the forest have other alternative means of regeneration than using soil seed bank. In general, the contribution of soil seed bank in the restoration and regeneration of the forest vegetation is very low and could not be considered as an important source for woody species diversity and recovery. Thus, future survival and existence of the woody species relay on the sustainable management and conservation of the remnant forest and plant species.

Recommendations

Wof - Washa forest comprises biodiversity with high numbers of endemic and rare species. The forest contains high carbon stock potential due to large, old and abundant *Juniperus procera, Ilex mitis, Polyscias fulva* and some other tree species. The forest harbors different wild animals including the endemic *Serinus ankoberensis,* the most common wild animals in the forest such as *Jib* (*crocuta crocuta*), *Guereza* (*Colobus guereza*), *Tota* (*Cercopithecus aethiopes*), *Gelada djingero* (*Theropithecus gelada*), *Yeminilk Dikulla* (*Teragelaphus scriptus meneliki*), different bird species and other rare species such as *Jigira* (*Numida meleagris*), *Gugut* (*Coraias abyssinica*), *Shelemetmat* (*Genetta abyssinica*), and *Jart* (*Hystrix cristata*). Despite the ecological and economical importance of the forest, the forest is under severe anthropogenic pressure threating the forest biodiversity. Therefore, based on the findings, discussion and conclusion, the following recommendations are forwarded for effective conservation and sustainable management of the forest which integrate biodiversity conservation, local people interest and livelihood needs.

- Link the livelihood activities of the local people in an organized manner such as (apiary and newly established lodge) with the forest resourse conservation to increase the benefit of the local interms of (service, materials and monetary) and conserve the biodiversity by reducing anthropogenic pressure;
- The local community has indigenous knowledge and system of self resourse management. Therefore, the local people should be involved in the planning, design, and immplementation of forest management and biodiversity conservation activities. Thus,integration of indigenous resourse conservation knowledge and

modern conservation approaches are indispensable and mandatory for this particular forest area;

- Rehabilitation of degraded forestl area in and around the forest using multipurpose and environmentally friendly tree species that will create alternative livelihood to the local communities and to develop a buffer region in the sustainable management of the forest;
- Implementation of agroforestry in the homegardens and rural agricultural areas where subsistence farming is practiced;
- Finally, giving conservation priority for identified multipurpose species by designing *in situ* and *ex situ* conservation strategies that should move towards coordinated effort for community based conservation and sustainable utilization of species.

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Socio-economic Importance and Threats of Lake Ziway, Ethiopia

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Abstract

Lake Ziway is one of the rift valley lakes found in Ethiopia and it has played a significance role on the socio-economy of the local community and to the country. Despite these facts, many considered that it is under threat which is caused by different factors. Therefore, the objectives of this paper were 1) to assess the socio-economic contribution of Lake Ziway to the local communities 2) to identify the major threats of Lake Ziway. To achieve the objectives a *structured questioner was developed and used for data collection. In the study, a total of 297 household are from six kebelesresiding around the lake, 12 individuals who are members of two fish cooperatives, and 47 key informants working in different offices were participated. Descriptive statistics was used to analyze the data. The result indicated that the average income of households is $US 1918.15 per year. Out of these total income from different sources, their average yearly income from Irrigation farming using the lake water and Fishing were $US 834 and $US 77.6, respectively. The result further indicated that, the fish cooperatives on average they sell 39375 Kg fishes per year and gate an average yearly income of $US 39152.35 from the sale of this quantities of fish. Despite such importance of the Lake, the respondents ranked that floriculture farm expansion around the lake, water pumping for irrigation from the lake, agricultural expansion, pollution from different sources, sedimentation etc. are the major threats of Lake Ziway. The participants of the study recommended the following management options to be practiced for the sustainable management of the Lake; these are to reduce chemical released from floriculture; to reduce agricultural expansion around lake; to protect and conserve the existing natural forest; to create buffer zone around the lake; to reduce over irrigation and use the lake water wisely and efficiently; to reduce over fishing; to develop integrated management plan to the lake and its resources; to reduce agricultural expansion; to formulate a policy and establish a local institute that will control the use of the water from the Lake.*

Keywords: *Lake Ziway, households, key informants, cooperatives, socio-economy, biodiversity*

Introduction

Ethiopian Central Rift Valley (ECRV) area is known to have a number of lakes and hydrological features (Jansen, et al., 2007); and along with their associated watershed areas the lakes are known to have lots of socio-economic importance. Despite its importance, increasing population pressure and economic developments put an increasing claim on the precious fresh water resources (Hengsdijk and Jansen, 2006). Large parts of the natural vegetation in the CER valley have already been converted and degraded due to pressing need for natural resources by the local population. Surface water extraction for irrigation, industrial and domestic use is continuously increasing in the CER valley. The limited available data indicate that the limits of sustainable water extraction have been reached (Hengsdijk and Jansen, 2006).

Lake Ziway is one of the central rift valley lakes that play a big soci-economic importance. The lake has a great importance by serving as a source of food and water to the local community. It is also important as sources of raw material, energy, cultivation, organic fertilizers, genetic and medicinal plants (Gebremedhin and Belliethathan, 2016). Like the other central rift valley lakes, Lake Ziway is one of the lakes that are under great threat of land-use changes mainly due to extensive and irrigation based agricultural farms surrounding the lake. Changes in land-use associated with the farms in the surrounding areas have known to have negatively affected the Lake's hydrodynamics (Aynew, 2009). Large-scale irrigation farms were established in early 1970s in the Lake Zeway's catchment by diverting water from the lake and its two main feeder rivers (Ayenew, 2001). Moreover, large-scale commercial plantation forest around the Lake has been established using water for irrigation from the lake (Muzien, 2006). These changes thought to have put the lake and its surrounding bird's habitats under great pressure. However, these natural resources have been under threat by unregulated land-use changes happening in the area (Aynew, 2009).

Different literature have noted that changes in surface water as a result of land-use changes, have made a significant impact on local biodiversity like birds, other wildlife species and subsequently erode local economies reliant on those resources (Ayenew, 2001; Sisay, 2003; Esikuri, 1998). Knowledge about the threats of an ecosystem has become important to overcome uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, and destruction of important wetlands and loss of fish and wildlife habitat (Anderson, et al., 1976). The objectives of this paper are 1) to assess the socio-economic contribution of Lake Ziway to different communities 2) to identify the major threats of Lake Ziway at current situation 3) do draw management recommendations for the sustainability of Lake Ziway.

Materials and Methods

Lake Zeway is located some 163 km south from the capital city of Ethiopia, Addis Ababa. It is situated between 07° 51′- 08° 07′N latitude and 38° 43′ – 38° 50′E longitude (Figure 1). The Lake has an open water surface area of 434 km^2, which makes it the third largest Rift Valley Lake; and has two small Islands of 6.9 km^2 area size together. The islands at the Lake are used as breeding grounds and roosting areas for water-birds, but affected by land use change impacts. The open and shallow Lake Zeway has catchments of about 6834 km^2, a maximum depth of 9 m, and a corresponding average surface and volume of 485 km^2 and 1.7 km^3, respectively. The lake is mostly used for irrigation in the central Rift Valley area. The lake is bordered by swamp, except along the south-eastern and southern margins where the shores are relatively steep.

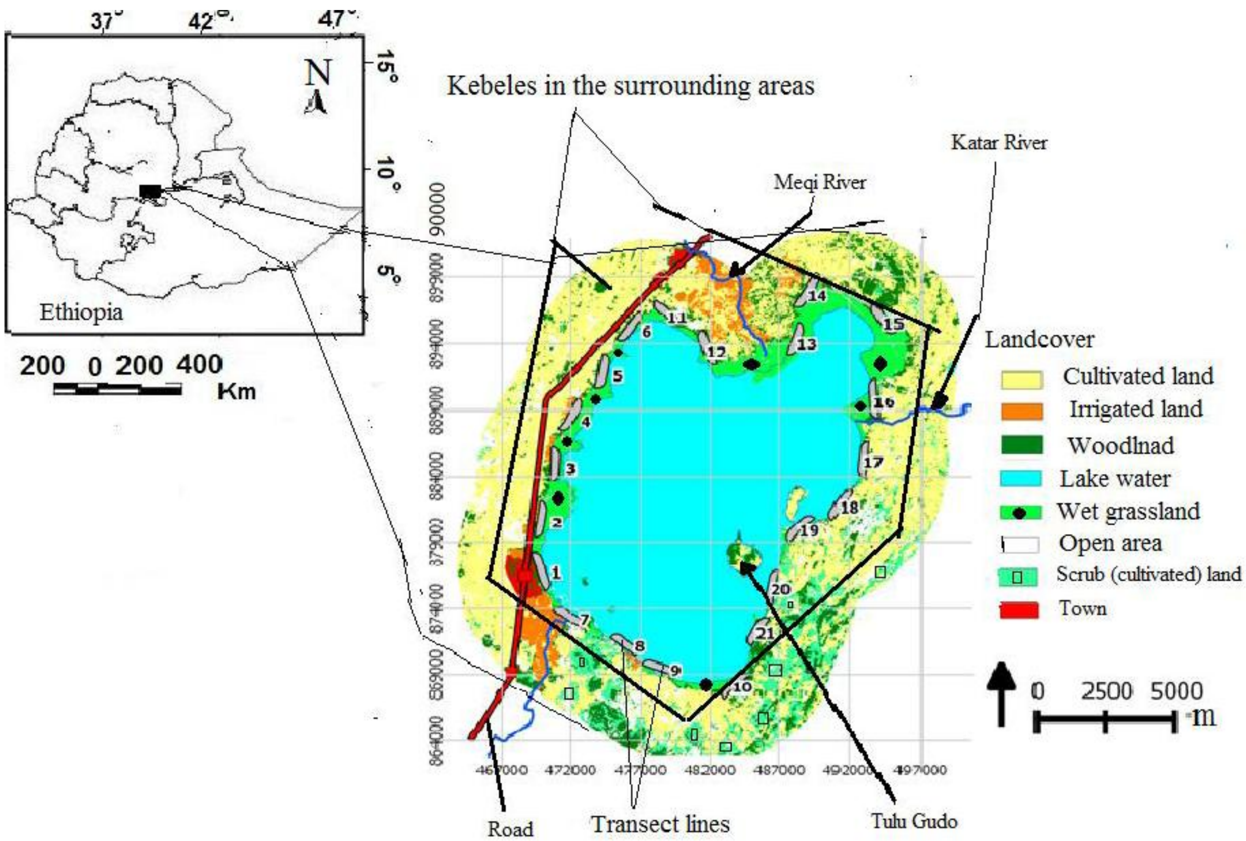

Figure 1: Study area (Source of Map; Girma et al., 2014)

Data Collection

A structured questioner were developed and used for data collection for the study. A purposive sampling was used in the selection of individual households for the study. Therefore, those households found in close proximity to the lake were selected. Besides, those household heads that lived in the area more than 30 years were selected for the questioner study with the assumpition that they have better and cumulated knowledge about the lake. A total of 297 households residing in six Kebele's (namely: Abnegermama, Bochesa, Edo-Gojela, IlkaChelemo, Negalign, Walinbula) were participated. The number of individual household heads that were interviewed for the data collection in each kebele is presented in Figure 2: Besides, twelve members of two fish cooperative (namely called kiyesitotaqurxummibatufish cooperative and Abosa genet fish cooperative) were also participated in the study. Moreover, a total of 42 key informants, who are working in different offices, have B.Sc. to Ph.D., and lived in the area for, more than 18 years, participated in the study. The key informants that were participated in the questioner survey were from irrigation, natural resource management, water resources, education, tourism and research offices.

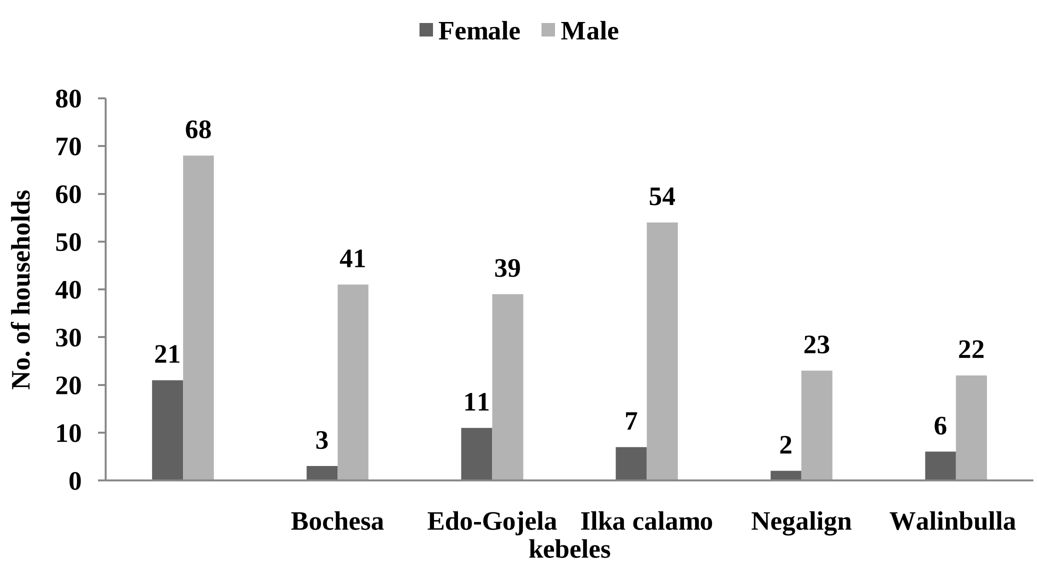

Figure 2: The number of individual household heads that were interviewee for the data collection

Method of Data Analysis

The collected data were organized in an excel sheet. Descriptive statistical methods were used for the data analysis. A percentile ranking was also used for the data analysis and the following formula was used.

$$R = P/100\ (N+1)$$

Where: R represents the rank order of the score; P represents the percentile rank; N represents the number of scores in the distribution.

Result and Discussion

Socio-economic Status of the Population

The socio-economic setting of the studied population around Lake Ziway is presented in Table 1. The results indicated that out of the total sampled population about 90.9 %, 7.1% and 2% were married, single and divorced household heads, respectively. Despite the fact that there is a difference on the average land holding size in the different studied kebeles, the average land holding size was 1.24 hectare. Out of the total household heads participated in the study, about 80.1% were literate (they can read and write) while 19.9% were illiterate (cannot read and write)

Table 1. Socio-economic setting of the household's in the study area.

Married	Single	Divorced	Average Family size	Literate	Illiterate	Average land holding size
79	9	1	6	72	17	1.4
42	1	1	6	39	5	0.8
41	6	3	5.5	42	8	1.4
56	5		6.5	51	10	1.4
24		1	5.2	20	5	1.1

28	6	14	14	1.35

The major types of crops produced in the study area, and the types of crops preferred by the studied households according to the ranking test results are presented in Table 2. The study result indicated that the major types of crops produced in the area are Maize, Barley, Wheat, Sorgum, Teff, beans and Millet. The ranking test result indicated that Maize, Wheat, and Teff were ranked as the 1st (95.4%), 2nd (60.9%), and 3rd (42.9%) crops widely cultivated in the study area.

Table 2: The major types of crops produced in the study area, and the ranking test results on the preference of the farmers to cultivate the crops

Type of crop	Percentile rank				
	1st	2nd	3rd	4th	5th
Maize	95.45	3.47	2.01	0.00	0.00
Barley	0.00	7.43	26.17	30.11	16.67
Wheat	2.89	60.89	17.45	27.96	8.33
Sorghum	0.00	2.97	2.01	5.38	25.00
Teff	1.24	20.30	42.95	20.43	16.67
Soy bean	0.41	4.95	7.38	11.83	16.67
Millet	0.00	0.00	0.00	1.08	16.67

Socio-economic Importance of the Lake

The average income of the individual household in the study area/year in Birr is presented in Figure 3. Accordingly, the results indicated that the average income/year for individual households were 44128.3 Birr ($US 1918.15). These income were generated from Rain fed farming; 17273.4 Birr/year ($US 751), Irrigation farming; 19182.6 Birr/year ($US 834), livestock; 3827.8 Birr/year ($US 166.4), fishing; 1785.8 Birr/year ($US 77.6), off-farm; 2076.2 Birr/year ($US 90.3), Charcoal production 5.2

Birr/year ($US 0.23). It means that, the lake is playing a role as a source of irrigation water and also for fishing purposes. The different types of crops produced through irrigation using the water of Lake Ziway is presented in Table 3. The study result indicated that Tomato, Onion, Cabbage, Paper, Maize, Fosolia, Lettuce, Potato, Soya bean, Wheat were the major types of crops produced through irrigation in the study area. Among, the types of crops produced by irrigation agriculture, the households were ranked Onion and cabbage, the 1st and 2nd crops preferred by the farmers to be produced through irrigation (Table 3). Such a preference of crops to be produced by irrigation might be related with marketing. This results could indicate that Ziway Lake, as a wetland plays a significant role in the livelihood of the surrounding communities.

Besides fishing from the lake, the participants of the fish cooperatives indicated that their other sources of income was ranked as rain fed farming, irrigation farming and livestock raring as the first, second and third source of income for their livelihoods, respectively. The fish cooperatives stated that on average they sell 39375 Kg fishes per year. Out of this total number of sold fishes per year, 7102 Kg and32273 Kg of them are fried fishes and live fishes, respectively. During the study the fish cooperatives sold 1Kg of fried and not fried fish by 45 Birr ($US 1.95) and 18 Birr ($US 0.78), respectively. It means that, their average yearly income from the sale of fish is $US 39152.35. Gezahegne and Satishkumer (2016) in their studies in two Kebles of Ziway indicated that fishermen in Lake Ziway cached mean amount of 2524 Kg per year with minimum and maximum amount of fish 504 Kg and 16,800Kg per year, respectively and with this fish catching they got average income of 51,398 Birr ($2,570) per year with range of 7,200 Birr ($360) and 288,000 Birr ($14,400) per year. About 18.2 % of the respondents from the fish cooperatives stated that the supply of the fish resource to the customers is more than the demand. While, about 81.8% of the respondents from the fish cooperatives stated that the supply of the fish resource by their cooperatives is less than the demand of their customers.

About 100% of the respondents from the fish cooperatives indicated that the amount and size of fish caught from the lake aredecreased. About 95.4% of the key informant participants said that the volume of fish produced from the lake is decreased while 4.6 % of them have no ideas if the fish volume is decreased or increased. Whereas, about 45.5% respondents from the fish cooperatives stated that the type of fish caught from the lake is increased while 54.5% of the respondents stated that it decreased.

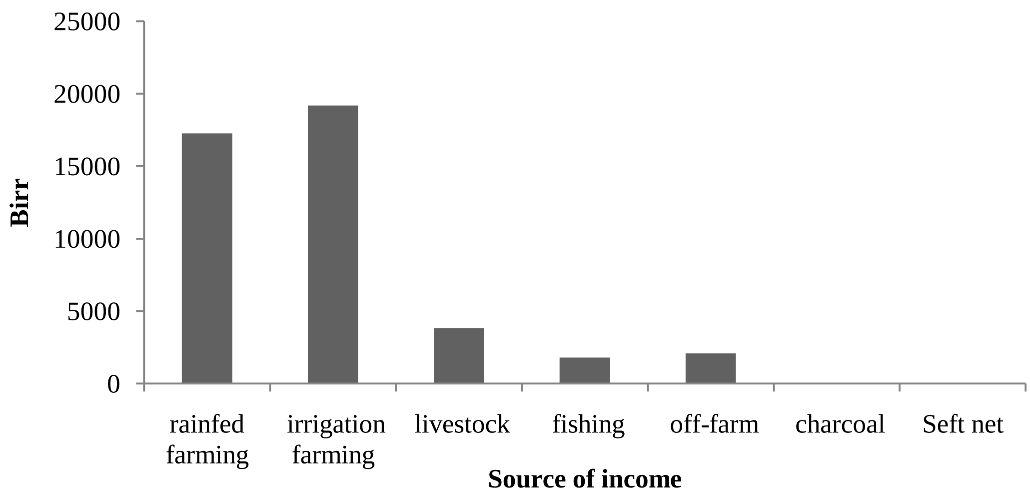

Figure 3: Average income per year of the households in the study area

Table 3: The different types of crops produced through irrigation using the lake water and the percentile ranking of the crops in their area coverage of production by the households of the study area

Crops produced by Irrigation	Ranking results in their area coverage		
	1st	**2nd**	**3rd**
Tomato	4.24	23.66	30.43
Onion	62.71	24.73	6.52
Cabbage	31.36	37.63	32.61
Paper	0	7.53	8.70
Maize	0.85	2.15	13.04

Fosolia	0	1.08	0
Lettuce	0	1.08	4.35
Tree seedling	0.00	1.08	0.00
Potato	0.00	1.08	0.00
Soya bean	0.00	0.00	2.17
Wheat	0.85	0.00	0.00

The major benefits the households get from the lake are described in Table 4. Fish, grass for thatched roofs, grass for grazing, water for cattle, irrigation and household use, wood, wild fruit are the direct values that the local communities benefited from the lake. Water for irrigation and drinking is ranked as first benefit the respondents got from lake. While, grass from the lake, ranked as the second benefit they got from the lake. Fish resource from the lake is ranked fourth by household's (Table 4).

Table 4: The direct benefits of the studied household's they got from the lake and their percenile rankings

Direct benefit of the local communities from the Lake	Percentile Ranking			
	1st	2nd	3rd	4th
Fish	26.26	27.76	24.89	29.08
Grass	26.98	38.02	29.61	7.09
Water for irrigation and drinking	34.17	19.39	20.17	7.09
Wood	11.87	14.07	24.46	51.77
Wild fruit	0	0.76	0.86	4.96
Irrigation	0.36	0.00	0.00	0.00
Over grazing	0.36	0.00	0.00	0.00

About, 33%, 40.7%, 36%, 35.7%, 32% of the respondents of households indicated that they were using the fish, grass, water, wood, wild fruit and medicine for household use and not for sale, respectively. Those household's who sale and got income by selling the resources from the lake indicted that their average yearly income per year from the sale of Fish, grass, water, wood, wild fruit and medicinal plants were 8010.3 Birr ($US 348.3) , 88.4 Birr($US 3.8) , 4151.35 Birr ($US 180.5), 2023 Birr ($US 88) , 2967.5 Birr ($US 129) , and 120 Birr ($US 5.2), respectively (Figure 4).

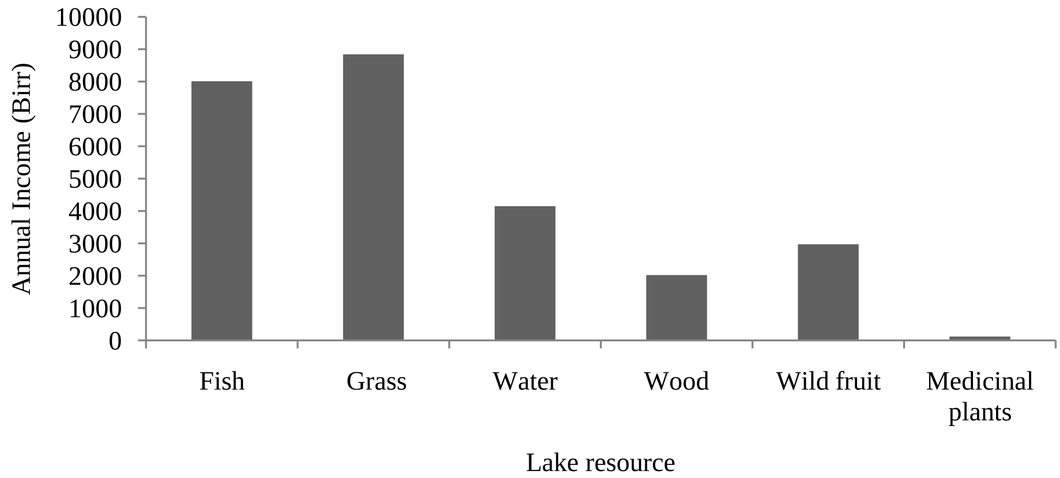

Figure 4: The average annual income generated from the sale of different resources from Lake Ziway by household's in the study area

The respondents from householdsindicated that in the study area, communal grazing land, farm land and marshy areas were used for grazing purposes (Table 5). The ranking test result indicated that during the dry periods of the year, marshy areas found around the lake, farmlands (crop residues) were the first and second sources of fodder during dry season of the year, respectively. This indicates that, Lake Ziwayplays a role for climate change resilience by providing fodder during the dry periods of the year. The source of water for the domestic animals during dry season of the year was water from the lake, borehole and river. The household's ranked the Lake as their 1st source of water for the livestock (Table 5).

Table 5. Sources of fodder during dry periods of the year and the ranking test result

Source of fodder in dry periods of the year	Percentile Rank			
	1st	2nd	3rd	4th
Communal grazing land	41.06	7.37	5.79	35.00
Cut and carry system	3.42	39.47	65.29	0.00
farm land (crop residues)	9.13	51.58	23.14	20.00
Marshy areas around the lake	46.39	1.58	5.79	45.00

Major Threats of the Lake

The ranking test result on the threats of Lake Ziway according to the perception of the surveyed households is presented in Table 6. The households indicated that sedimentation problems, farmland expansion, evapotranspiration, water pumping for irrigation, floriculture farm expansion, population and livestock increment, deforestation, pollution and iritic rainfall in the area are considered as the major threats of Lake Ziway. The ranking test result indicated that the floriculture farm expansion is ranked as the first threat to Lake Ziway by housholds. While, water pumping for irrigation and sedimentation problems are ranked as the second and third threats to Lake Ziway (Table 6). The study results of the key informants indicated that water pumping for floriculture farm, water pumping for irrigation to cultivate crops, farmland expansion around the Lake and sedimentation were ranked as the 1st, 2nd, 3rd and 4th threats of Lake Ziway, respectively (Figure 5). Whereas, the analysis of the fish cooperatives percentile rankedtest result indicated and ranked water pumping for irrigation to the floriculture farm and for cultivation of crops as the 1st and 2nd threat to the lake while they ranked sedimentation as the 3rd threat to the lake (Figure 5). Habtamu (2015) in his study showed that regardless of irrigation water abstraction in Lake Ziway only 7.74% of the initial volume of the lake was reduced, but when irrigation water abstraction was considered 17.05% of the initial volume of the lake was reduced and this showed that irrigation water abstraction merely reduced 9.31% of initial volume of the lake which indicated greater reduction due to irrigation water abstraction relative to reduction with no irrigation water use condition (7.74%). These all results revealed that irrigation water use for the whole existing and potential irrigable area brings drastic impact on the Lake Ziway.

The perception of the fish cooperatives on the major threats of the fish population in Lake Ziway is presented in Figure 6. The fish cooperatives indicated that pollution from different sources around the lake such as flower farm, fertilizer from farmlands and pesticides are the major threats for the fish of Lake Ziway. Moreover, the fish cooperatives indicated that overfishing and lack of proper management are the other causes for the fish population decline in Lake Ziway. The ranking test result further indicated that pollution, over fishing and lack of proper management of the lake are perceived and ranked as the first, second and third threats for the fish population of Lake Ziway, respectively. About all (100%) of the respondents from the fish cooperatives and key informants perceived that the Fish of Lake Ziwayare polluted since they assume that the water of the Lake is polluted. Therefore, about 61.9% of the study participants from key informant are not buying the fish of the lake and use it for household consumption since they assume that the fish of Lake Ziway is polluted. The fish cooperatives perceive and ranked water entering from the floriculture farm and also pesticides used for irrigation agriculture around the lake as the 1st, and 2nd causes of fish pollution, respectively. Similarly, the key informants indicated that the major cause of the fish pollution of lake Ziway were described as the floriculture farm around the lake and also the pesticides and herbicide used for irrigation farming are the causes of the pollution to Lake Ziway. Moreover, the key informants ranked pollutants from floriculture farm, pesticides used for vegetable production, and over fishing, as the 1st, 2nd and 3rd threats of the fish population in Lake Ziway, respectively (Figure 5).

Table 6. Percentile ranking result on the perception of the household's mentioned as the major threats of Lake Ziway

Threats of the lake	Ranking test result				
	1st rank	2nd rank	3rd rank	4th rank	5th rank
Sediment	17.47	15.17	18.28	18.52	13.76
Farmland expansion	3.42	8.97	14.55	19.44	19.05
Evapotranspiration	2.74	3.45	9.33	12.96	13.23
Water pumping for irrigation	22.26	31.38	22.01	14.35	8.47
Floriculture expansion	27.05	25.86	16.42	11.11	11.64
Population and livestock increment	2.05	5.17	9.7	5.09	16.93

Deforestation	13.36	6.21	5.22	15.28	13.23
Pollution	1.37	2.07	1.49	0.46	1.59
Invasive spp. expansion	0	0	0.37	0.46	0.53
Eucalyptus expansion	0	0.34	0	0	0
shortage of rain	10.27	1.38	2.61	2.31	1.59

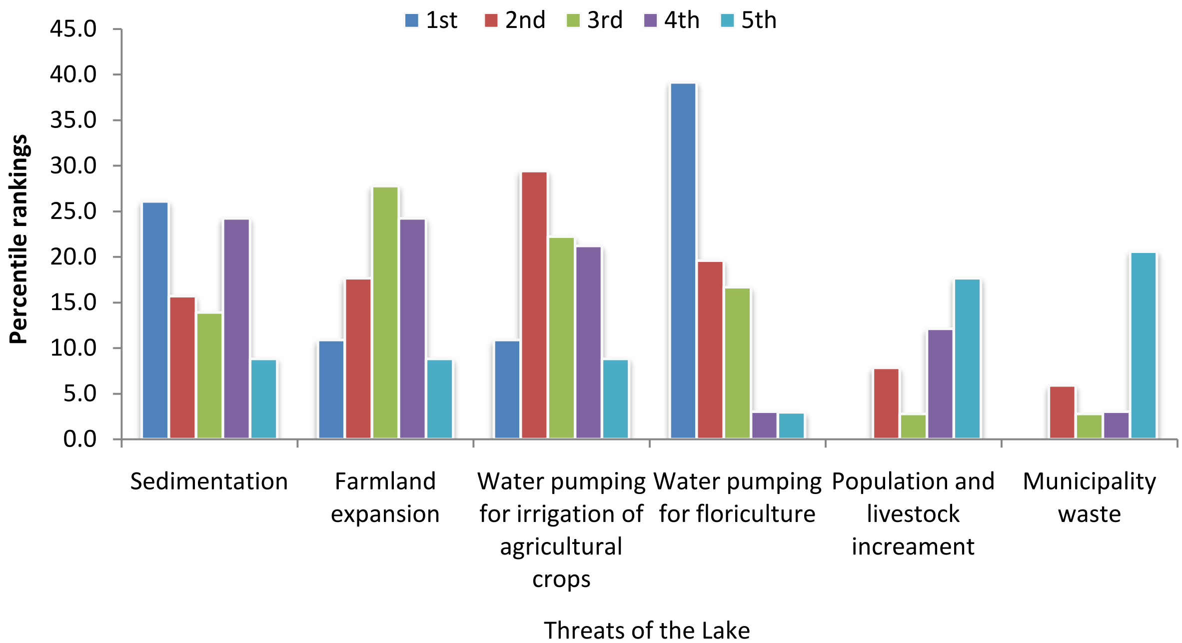

Figure 5: Ranking test result on the perceptionof key informants perceived as the major threats of Lake Ziway

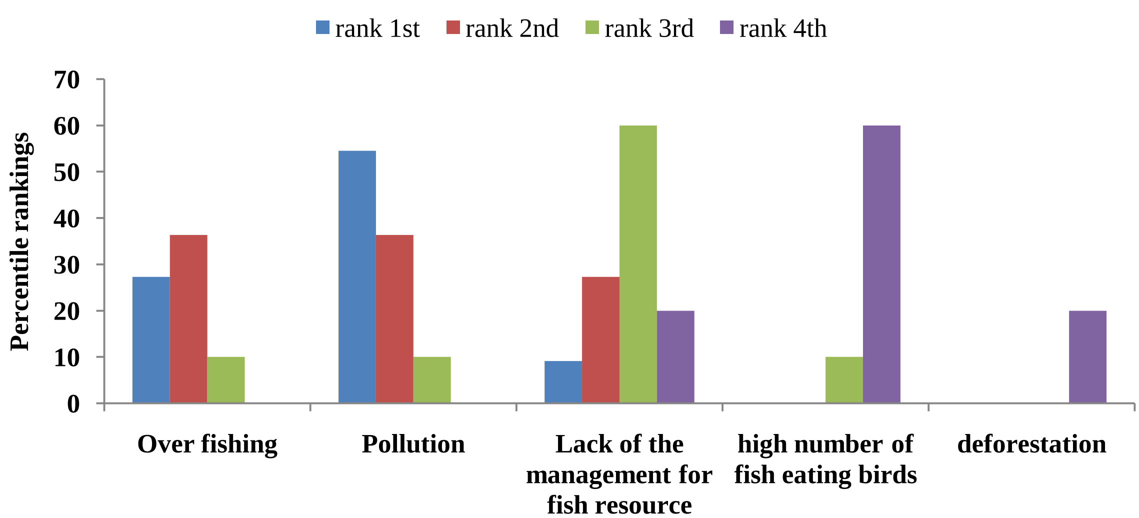

Figure 6: Ranking test result on the perception of fish cooperatives mentioned as the major threats of the fish in Lake Ziway

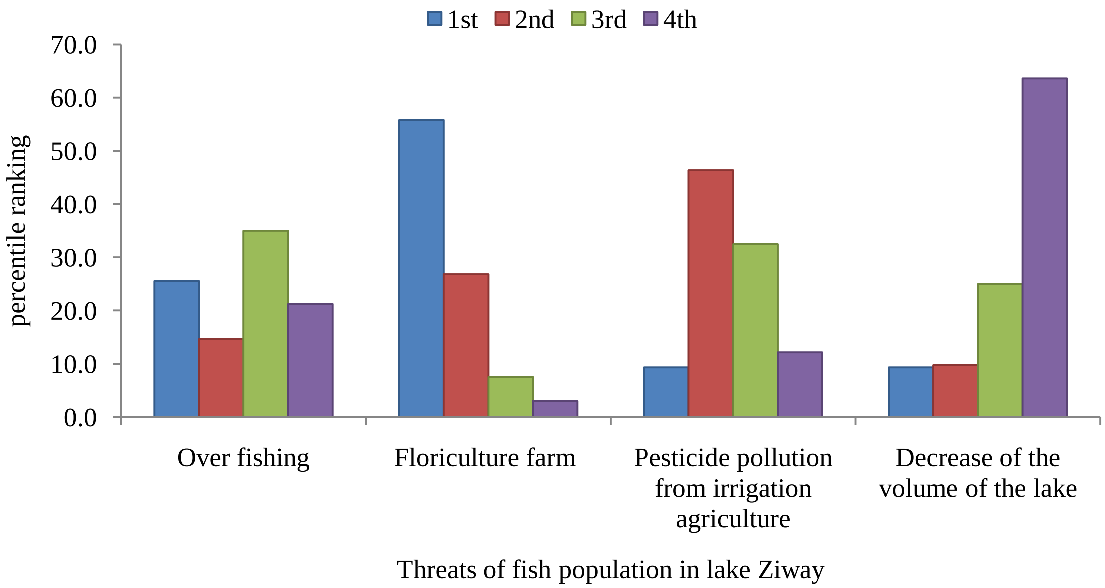

Figure 7: Ranking test result on the perception key informants that they are considering as the major threats of the fish in Lake Ziway

About, 81.8 % of the study participants from the fish cooperatives indicated that the Bird population around the lake is increasing while 18.2% of the respondents said that the bird population is decreasing. Whereas, about 93% of the key informants responded that the bird population in Lake Ziway decreased while the remaining (7%) of the respondentssaid that they do not have knowledge if the bird population in the lake is decreasing or increasing.The key informant's responded and the percentile ranking result indicated that decline of fish population in the lake, Nest disturbance, and fish population decline as the 1st, 2nd, and 3rd causes of the bird population decline in Lake Ziway (Figure 8). Similarly, the respondents of the fish cooperatives ranked decline of the fish resource of the lake, and deforestation as the 1st and 2nd threats of the bird population in Lake Ziway (Figure 6). The present result is in line with the findings of Girma et al. (2014), who indicated that between the years of 2003 to 2011, the woodland vegetation around Lake Ziway decreased by 37.5%, which was serving as a habitat for birds. Similarly, relatively low bird species diversity in Lake Ziway was recorded in blocks with less vegetation cover as compared to blocks with relatively intact vegetation cover (Girma, et. al., 2014). All (100%) of the respondents from the fish cooperatives perceived that the size and the depth of the lake is decreasing. Similarly, 100% of the key informants stated that the size and depth of the lake is decreasing. Girma et al (2014) in their the land-use and cover changes detection found that between the years of 2003 and 2011 the lake water size was reduced by 4.5% while cultivated land and irrigated land increased by 6.9% and 32.3%, respectively.

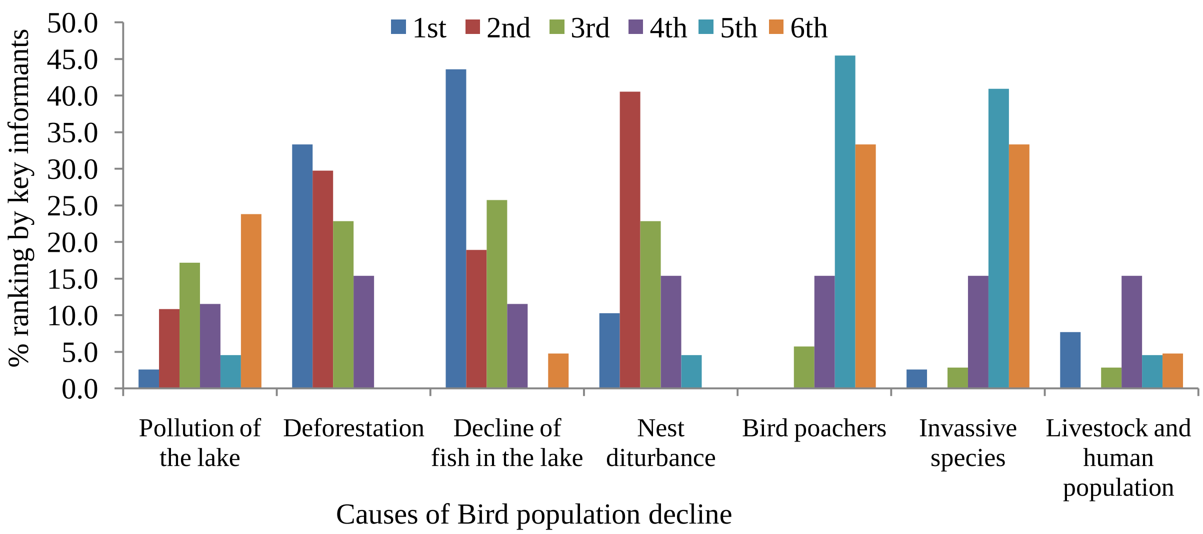

Figure 8: Ranking results of key informants that are considered as the key threats of the Bird population in Lake Ziway

Recommended Measures for the Sustainable Management of the Lake

The summarized results on the suggested and recommended measures to be taken for the sustainable management of Lake Ziway by Fish cooperatives, households and key informants are presented in Table 7, Figure 9 and Table 8, respectively. When the results from the three groups of the study participants is summarized, they recommended the following management options to be practiced for the sustainable management of the Lake; these are to reduce chemical released from floriculture; to reduce agricultural expansion around Lake; to plant trees around the lake; to protect and conserve the existing natural forest; to create buffer zone around the Lake; to practice soil and water conservation measures around the lake and in its catchment area; to reduce over irrigation; Floriculture farms should be 3km far away from the Lake; to use the Lake water wisely and efficiently; to reduce over fishing; to use modern fish catching method; to ban fishing from the lake for two years; to develop integrated management plan to the lake and its resources; to control illegal fisher man in the lake; to make awareness creation; to reduce agricultural expansion; to formulate a policy and establish a local institute that will control the use of the water from the Lake.

Table 7: Recommended measures suggested and ranked by Fish cooperatives for the sustainable management of Lake Ziway

No.	Recommended Management options by Fish cooperatives	Percentile Ranking					
		1st	2nd	3rd	4th	5th	6th
1	Reduce chemical released from floriculture	18.2	27.3	18.2	0.0	14.3	0.0
2	Reduce agricultural expansion around lake	9.1	0.0	9.1	22.2	0.0	0.0
3	Tree planting	0.0	9.1	27.3	0.0	14.3	0.0
4	Conserving the existing natural forest	0.0	0.0	9.1	0.0	14.3	33.3
5	Create buffer zone around the lake	0.0	9.1	0.0	33.3	14.3	33.3
6	Practice soil and water conservation in the sub watersheds	9.1	9.1	9.1	33.3	14.3	0.0
7	Reduce over irrigation	9.1	18.2	18.2	0.0	0.0	33.3
8	Floriculture farms should be 3km far away from the lake	0.0	9.1	0.0	0.0	0.0	0.0
9	Use the water wisely and efficiently	0.0	0.0	0.0	11.1	0.0	0.0
10	Reduce over fishing	9.1	0.0	0.0	0.0	14.3	0.0
11	Use modern fish catching method	9.1	9.1	0.0	0.0	0.0	0.0
12	Complete ban of fishing from the lake for two years	9.1	9.1	0.0	0.0	0.0	0.0
13	Develop integrated management plan to the lake and its resources	18.2	0.0	0.0	0.0	0.0	0.0
14	Control illegal fisher man in the lake	0.0	0.0	9.1	0.0	14.3	0.0
15	Practice area closure in the upper catchment of the Lake	9.1	0.0	0.0	0.0	0.0	0.0

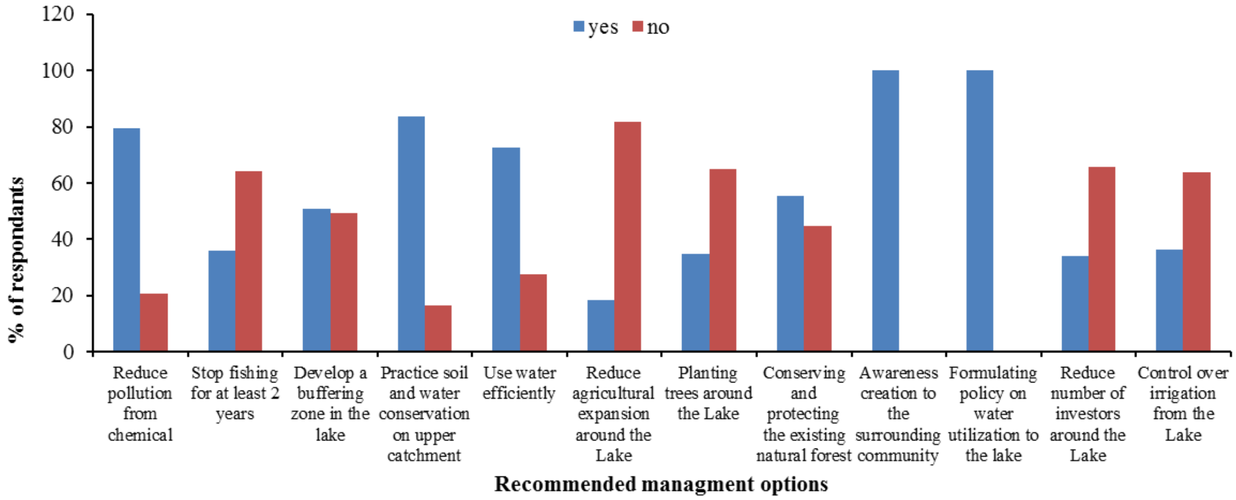

Figure 9: Recommendations of households on the management options to Lake Ziway in percent

Table 8: Recommended measures suggested and ranked by key informants for the sustainable management of Lake Ziway

Key Informant Study Recommendations

№	Management Recommendation by the Key Informants	Percentile Ranking					
		1st	2nd	3rd	4th	5th	6th
1	Avoid chemical pollution	47.4	17.7	29.0	0.0	0.0	0.0
2	Stop fishing for at least 2 years in the Lake	2.6	0.0	3.2	5.9	0.0	25.0
3	Create a buffer Zone to the Lake	5.3	8.8	9.7	17.7	16.7	0.0
4	Establish soil and water conservation in upper catchment	13.2	20.6	6.5	11.8	33.3	75.0
5	Utilization of water efficiently by the users	2.6	29.4	9.7	23.5	50.0	0.0
6	Develop a water shade plan and create a forest	7.9	14.7	25.8	17.7	0.0	0.0
7	Awarness creation to the local community	5.3	2.9	9.7	17.7	0.0	0.0
8	Policy formulation on the use of the water of the Lake	13.2	2.9	6.5	5.9	0.0	0.0
9	Reduce agricultural expansion	2.6	2.9	0.0	0.0	0.0	0.0

Conclusion and Recommendation

The study results indicated that Lake Ziway is playing a significant in the socio-economy of the surrounding community directly and to the country indirectly. Its role in the diversification of livelihood of the different stakeholders is immense. Despite these facts, the study result shows, pollution, over irrigation, sedimentation resulted from deforestation, etc. are the major threats of the lake. The respondents of the study have recommended different management options for the sustainability of the Lake. Therefore, the Authors recommended to apply the recommended measures by the respondents in order to save the lake from being polluted, lose its biodiversity, etc.

Acknowledgment

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Chapter Four: Forest Protection Research

New Records of Red Gum Lerp Psyllid, *Glycaspis brimblecombei* Moore (Hemiptera: Psyllidae) Invasion on *Eucalyptus* sap Sucking Insect Pest in Southern Ethiopia

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Abstract

Eucalyptus species were introduced to Ethiopia since the last hundred years and known to be free of insect pests in any corner of the country. However, recently a number of insect pests that attack eucalypts were reported by different experts in various part of Ethiopia which may require management action in a roadside and farm woodlots as well as plantation situation. This paper provides new information about the first record of Red Gum Lerp Psyllid, Glycaspis brimblecombei in Southern Ethiopia and new information about its biology and reason for its expansion. The assessment was conducted in Gedeo and Sidama zone of Southern Nation Nationalities Peoples Region (SNNPR) from November 5 – 9, 2017. Sample was collected from infested Eucalyptus camldulensis trees and field observation, semi-structured interviews and discussions were conducted with members of zonal and district experts and local community. More than 11experts and 15 farmers in the surveyed area were participated in the interview and discussions. Information on the socioeconomic perceptions, ecological implications and preference of the community towards Eucalyptus production and other related information were collected and the data was transcribed and content analyzed. At the end of assessment, the team discussed with the region experts. Finally, we tried to conduct laboratory investigation on different samples collected from the field and reviewed related literature to confirm identification made by region experts and developed possible interventions. Accordingly, the pest identity, biology, history, distribution, damage symptoms and impacts and possible management options were summarized.

Key Words: *Eucalyptus camldulensis, infestation, damage symptomsand management options*

Introduction

Eucalyptus is a large genus in the family *Myrtaceae* which includes evergreen trees and shrubs, mostly native to Australia (Brennan, et.al., 2001). The rapid growth of *Eucalyptus* species and their adaptability to different environmental conditions has favored their widespread cultivation, particularly in the tropics, providing one of the most important global sources for structural timber, pulp and fuel-wood.It is one of the important tree species in various socioeconomic dimensions of many Ethiopians. For many years, Ethiopians have been attached to it as it served by being the prime source of construction material for houses. This fast growing tree has provided goods and services that enabled livelihoods development in one way or another to different localities by providing income generation opportunities and wood products for household consumption (Mekonnen, 2010).

Though there are magnificent developments in increasing agricultural production and productivity, the forestry and the green energy sector is still lingering to bridge the energy and construction demand of the growing population. Hence, placing proper management practices for the production of fast growing trees like Eucalyptus could help to intensify the sustainable development of the nation (Madalcho and Tefera, 2016).

Since *Eucalyptus species*are introduced to Ethiopia,it was found to be free of insect pests in any corner of the country for well over 100 years. However, now a day, a number of insect pests that attack *Eucalypts Species* were reported by different experts in different regions which may require management action in a roadside and farm land as well as plantation situation. Recently, AmharaRegion Forest Enterprise and and Southern Nation, Nationalities People Region (SNNPR) reported that *E. camaldulensis* has been infested severely by Blue Gum Chalcide,*Leptocybe invasa* Fisher and La Salle and RedGum Lerp Psyllid*, G. brimblecombei*, respectively.

The red gum lerp psyllid and the eucalyptus psyllid have become problems outside of their native Australia and have followed the eucalyptus that has been exported out of the country. They are more prevalent during seasons when the soil stays consistently moist and is not allowed to dry out. In warmer climates, the Red Gum Lerp Psyllid growth and development become fasten, these makes the insect become most troublesome during the fall and winter when they will feed on the leaves of the trees. These insects will excrete a white substance on the leaves as they feed on them, and these small white dots are one of the easiest ways to distinguish a psyllid infestation (Debra, 2017). The experts working in SNNPR, Gedeo administrative zone, understood this insect invasion but need more confirmation with researchers' confirmation. Therefore, the objective of this assessment was to assess the insect pest occurrence and damage extent of the administrative zone and draw possible research and extension interventions.

The objectives of this study were to investigate newly outbreak insect pests, identity; review brief history and impacts and status of invasion level in the study area, to understand the perception of community and experts working in the study area; to investigate the interventions undertaken by the community and organizations operating in the area, and to draw possible interventions of pest management research and extension

Materials and Methods

Description of the Study Area

Gedeo and Sidama administrative zones are located in the Southern Nations, Nationalities and People's Regional State of Ethiopia. The altitude of Gedeo administrative Zone ranges from 1268 meters above sea level in the vicinity of Lake Abaya to an elevation of 2993 meters at HaroWolabu Pond. Gedeoadministrative zone has 215 kilometers of all-weather roads and 54 kilometers of dry-weather roads, for an average road density of 199 kilometers per 1000 square kilometers.

Sidama Administrative zone is found within 5′ 45″ and 6′ 45″N and 38′ and 39′E. It has a total area of 10,000 km^2, of which 97.71% is land and 2.29% is covered by water. Of the land, 48.70% is cultivated, 2.29% is forested, 5.04% is shrub and bush land, 17.47% is grazing land, 18.02% is uncultivated, 6.38% is unproductive and 2.10% has other uses. Some of the cultivated lands are in undulating escarpment and create difficulties for the farmers in the area. It has a variety of climatic conditions. Warm conditions cover 54% of the area. Locally known as Gamoojje or Woinadega, this is a temperate zone ranging from an elevation of 1500 m to 2500 m above sea level. The mean annual rainfall of the area varies between 1200 mm and 1599 mm, with 15 -19.9 °c average annual temperature.

Data Collection and Analysis

The assessment was conducted in Gedeo and Sidama administrative zones from November 5–9, 2017. Sample was collected from infested *E. camldulensis* trees. Similarly, sample collection and photographing through field observation, semi-structured interviews and discussions were conducted with members of zonal and district experts and local community. The research also deployed ground truthing so as to substantiate the information with the ground realities. Eleven experts and 15 farmers in the surveyed area were participated in the interview and discussions. Concerned government staffs werealso approached to solicit primary and secondary information both atadministrative zones and regional levels. Information on the socioeconomic perceptions, ecological implications and the preference of thecommunity towards Eucalyptus production and other related information were collected and the data was transcribed and content analyzed. At the end of assessment, the assessment team discussed with the region experts. While writing the report, we tried to conduct laboratory investigation on various samples collected from the field and reviewed related literature to confirm identification of region experts and develop possible interventions.

Results and Discussions

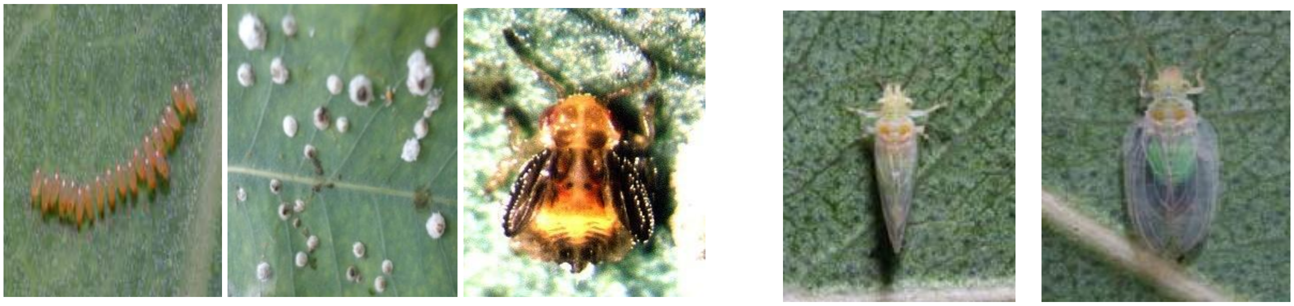
Biology and Taxonomy of Identified Insect Pests

During the field visit conducted at Gedeo and Sidama administrative zones, it has been observed that *E. camaldulensis* planted in the farm land, roadsides and woodlots of both administrative zones. In all niches of *E. camaldulensis* the occurrence of psyllids outbreak was recorded. We identified the insect pests recorded at species level as psyllid. Confirm with comparison of ourphotograph with different literature reported about this particular insect pests. Therefore, identified Psyllidspecies belongs to the insect Order *Hemiptera*, Suborder *Homoptera* and Family *Psyllidae*, recorded in Australia and represented by some 330 variably structured species which cover a wide range of habitats. Psyllids are small insects that suck sap from plants. Under the above family, Red Gum Lerp Psyllid, *Glycaspis brimblecombei* is recorded for the first time in the southern region of Ethiopia in October 2017.

Female psyllids lay clusters of eggs on leaves from which hatch the nymphs, the immature stage of the Psyllid. Females of the Red Gum Lerp Psyllid lay randomly on the leaves or in clusters of 50-75 eggs, usually at an angle or perpendicular to the plant surface. They are spindle-shaped, yellow or cream colored, and are slightly less than 1 mm in length. The eggs hatch in 10 to 20 days and the nymphs will pierce the plant tissue with their stylet (mouth parts), feeding on the xylem (Figure 1a and b).

Nymphs construct individual white waxy covers (called lerp) of conical shape (Figure 1b). Nymph size varies depending on the instar; last instar is approximately 1.5-2.0 mm in length. The body color is yellowish orange, with dark-brown coloration on the wing pads, legs, antennae, last abdominal segments, and in blotches on the dorsal areas of the head and thorax. The nymphs do not produce white flocculent wax secretions as in some other eucalyptus feeding species, but instead use the lerp covering as a source of shelter and protection from the elements. Lerps are 1-4 mm in diameter depending on the stage of the nymph, and are usually whitish in appearance, but may take on a grey or black coloration with age or if sooty mould begins to grow on the lerp. Lerps still occupied by nymphs often have curled tendrils of wax protruding from the upper surface (Figure 1 c).

Adults are approximately 4-5 mm in length from the head to the wing tips. They are yellow or light green in colour with contrasting dark eyes, and occasional dark-brown markings. The genal cones, a common morphological feature of most psyllids, consist of a pair of cone-shaped extensions of the frons and may extend anteriorly or downward depending on the head orientation of a given species. In *G. brimblecombei*, the genal cones are extremely long and well developed, being as long as or longer than the head itself (Figure 1d and e).



a) eggs b) nymph with lerp c) nymph out of lerp d) adult male e) adult female

Figure 1: Different stages of Red Gum Lerp (photographs adapted from the field assessment)

In Ethiopia, this insect is recorded in *Gedeo* and *Sidama* administrative zones at low and mid altitude. The farming community living around *Kocherie* and *Wenago* districts reported that the insect infestation starts in the beginning of September 2017. Moreover, the farming community also communicate with the neighboring farmers of Oromia in eastern *Guji* (*Abaya* and *Tore* district) the insect infestation were occured in May/June 2017 then expands to *Gedeo* administrative zone (*Kocherie, Wenago, Yirgachefie* and *Dilla* Zuria districts) in September 2017 then expand to *Sidama* administrative zone

Infestation Signs and Symptoms

In our visit to the pest out break area, when we look up the *E. camaldulensis* tree, we quickly notice the white spots all over the leaves (Figure 2a). When we pick of the white spots using our fingernail we immediately notice a tiny wingless insect underneath (Figure 2c). These are the "lerps" that forming a protective cover the nymph of the psyllid. These protective cover falls from the tree to the ground when the nymph reaches the adult stage or a heavy wind blows and during heavy rain shower. When we observe the ground under the tree, we observed the coated substance with tiny, sticky, white spots (Figure 2b). Honeydew on leaves also observed. This honeydew allows growth of a black layer of mold called sooty mold and this may cover the leaves as well (Figure 2c). Infestation of red gum lerp occurs in all stages of trees, more dense on matured tree.

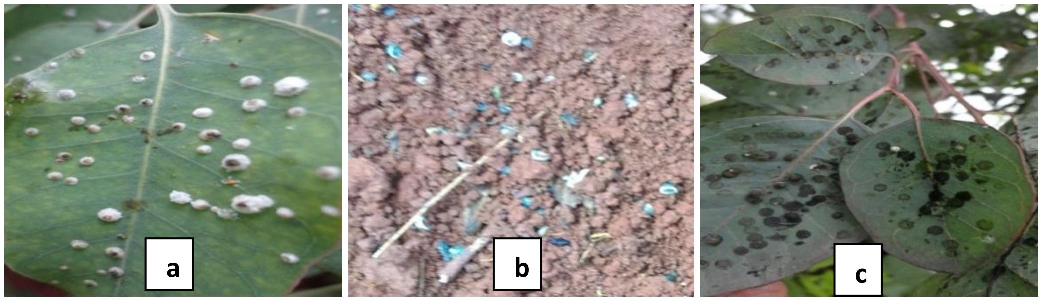


Figure 2: Infestation signs and symptoms ofred gum lerp
a) Infestation over the leaf b) Drop of white waxy covers c) Blacken sooty mold over the leaf

The infestation level is very much high in Gedeo administrative zone of 4 districts such as Kocherie, yirgachefie, Wenago and Dillazuria but when we go Sidama and West Arsi the infestation is present but intensity was very low. *E. camaledulensis* trees infested by Red Gum Lerp Psyllid have leaves covered in "lerps," blackened by sooty mold and drop leaves. Honeydew from eucalyptus trees may also be an indication of Red Gum Lerp Psyllid (RGLP) heavy infestation. It looks as an aggressive insect that spreads rapidly. Similarly, Nick (2001) reported that RGLP become aggressive during dry warm condition. This severe outbreak by RGLP causes extensive foliage discoloration on tree crown become brown/rusty red spots, leading ultimately to leaf necrosis and defoliation. Symptoms of its feeding include dropping of leaves and drying of leading shoots. Infested leaves are covered with waxy secretions and honeydew, on which sooty mould grows.Heavy infestations can totally defoliate and kill trees. *Eucalyptus* species differ in their susceptibility to attack by the red gum lerp psyllid, with *E.camaldulensis*lookshighly susceptible and *E. globules* being more tolerant.

Distribution of Red Gum Lerp, *G. brimblecombei*

According to FAO (2012) Red Gum Lerp, *G. brimblecombei is n*ative to Australia, it has been accidentally introduced into various countries in Africa: Madagascar (2004), Mauritius (2001) and South Africa (2012); Europe: France (2011), Italy (2010), Portugal (2007) and Spain (2007); Latin America and the Caribbean: Argentina (2005), Brazil (2003), Chile (2002), Ecuador (2006), Peru (2008), Uruguay (2008) and Venezuela (2007) and North America: Mexico (2000), USA (California (1998) and Florida, Hawaii (2001).

Considering the current update, the psyllid is distributed in oromia region (East Guji administrative zone including Abaya and Tore districts and western Arsi administrative zone (around Shashemnae town) and southern region (Gedio and Sidama administrative zones) as indicated in Table 1 below.

Table 1: Observations made in understanding the distribution of Red Gum Lerp in the Gedeo and Sidama administrative zones

Administrative zone	Woreda	Number of Keble reported infestation/total	Kebele observed	Status of infestation
Gedio	*Kocherie*	23/23	*Chelelektu*surrounding	High
	Yirgachefie	28/31	*Adamae*	High
	Wenago	17	*Kara sodite*	High
	Dillazuria	8/17	*Nechisho*	Medium to high
Sidama	*Hawassa city*	Not reported but observed		
	Shebedino	Not reported but observed		
	Yirgalem	Not reported but observed		
	Aletachiko	26		
	Aletawendo	Not reported but observed		
	Dara	11		
	Dale	Not reported but observed	*Bicha* *Wara*	Low to medium Low
	Lock Abaya	4		

Source: Field observation and various level expert discussions

In Ethiopia, this insect is recorded in Gedeo and Sidama administrative zones lowland and mid altitude. The farmer living around Kocherie and Wenago reported that the insect infestation starts in the beginning of September. However, the farmers who communicated with the neighboring Oromia districts found in eastern Guji (Abaya and Tore district) reported that the insect infestation occurs in May/June 2017 and expands to Gedeo administrative zone (Kocherie, Wenago and Dilla Zuria districts) and Sidama administrative zone in September 2017. Though the field assessment is limited in Gedeo and Sidama, this result showed that the insect pest might occur in other districts of the region and other regions districts.

Infestation and Damage Impact of insect pests Outbreaks

Psyllid nymphs and adults infest and feed by sucking plant phloem sap from the leaves and shoots through their straw like mouthparts.Its continual sucking and the excretion of 'honey dew' can severely stress the trees from loss of starch. High populations of feeding psyllids secrete copious amounts of honeydew making leaves and sidewalks sticky. Leaves can turn black as a result of sooty molds growing on honeydew Figure 3a and b). Feeding damage can be severe enough to cause premature leaf drop and sticky fallen leaves can adhere to shoes, vehicles, clog swimming pool filters, and may rapidly increase amounts of flammable material beneath trees. In addition to that, Red Gum Lerp, *G. brimblecombei* injury includes leaf discoloration and in heavy infestations, severe leaf drop and twig dieback (Figure 3c).

(a) Wilting (b) White spots and sooty mold (c) discoloration

Figure 3: Feeding damage symptoms of red gum lerp on eucalyptus leaves

Farmers and Experts Perception on the Insect Pest Histories and Impacts

According to farmers and experts perception working in Gedeo administrative zone, since the insect outbreak occurs, a number of animals (sheep, cow, donkey, ox, goats, horse and chicken die) died in Kocherie, Yirgachefie and Wenago districts as indicated in Table 2. They also perceive that the drop of lerp from the tree to the ground causes allergic to human. They understand that *E. camaldulensis* at various stages become the host of this insect without any damage impact of the insect on the tree. However, when we review the history of identified insect pests' outbreak, there is no reason to cause animal diseases but when the lerp dropped from the tree to the ground if the lerp dropped on human being body it may cause allergic and nuisance effects.

Table 2: Number of animals died as reported by community and districts after the insect outbreak occurrence

Districts	Number of animals died	Number Keble reported animal death	Type of animal species died as per the report						
			Sheep	Goats	Cow	Oxen	Horse	Donkey	Chicken
Kocherie	141	23	128		12			1	
Yirgachefie	205	28	176	8	10	2	6	7	
Wenago Dillazuria	65	17	53			2	2		8

Source: District reports to the Gedeo zone and discussion result

Conclusion and Recommendations

Our results have revealed that Red Gum Lerp; *G. brimblecombei* is the main insect pest which infests *E. camaldulensis* trees in the roadsides, farmlands and plantations of *Gedeo*and *Sidama*a dministration zones. As per discussion with local community in *Kocherie* and Yirgachefie, the insect outbreak occurrence starts in Oromia region *East Guji* administrative zones Abaya and Tore districts and recently expands to west *Arsi* administrative regions, *Shashemenae* area.

The high frequency of trees at different life stages with red gum lerp*, G. brimblecombei* infestson their leaves both at the bottom, middle and top part of the plant. Abiotic factors that may facilitate the outbreak of *red gum lerp, G. brimblecombei* infestation remain unknown, as well as potential synergistic interactions with plant stress caused by rainfall shortage become considerable. Therefore, if there is a repeated psyllid attack in the area, *E. camaldulensis* plantation at various stages can get chronic damage to foliage on trees then death happens.

In Gedeo administrative zone, the incidence ofred gum lerp*, G. brimblecombei* coincides with the number of animal death. Due to this coincides both the farming community and experts working in the area perceived that the reason for animal death is this insect out break rather the insect does not have impact on the tree. However, the anti-mortem and post mortem symptoms of different dead animals in different districts did not yet investigated to confirm whether the death of animal is due to the insect poisoning effects or other reasons.

Recommendations

Short Term

A) Monitoring

- Inspect eucalyptus plantations regularly to detect problems with tree growing environment and care as well as psyllids and their natural enemies. Do not wait until infestations are severe to monitor trees because cultural practices such as changes in irrigation or nitrogen application are primarily preventive and must be applied early.
- For effective seasonal monitoring action, use of yellow sticky traps to capture adult psyllids and parasitic wasps. Monitoring traps for adults is more efficient than inspecting foliage for immature.Yellow sticky traps provide a strong indication of seasonal changes in psyllid and parasite activity.
- By selecting infested eucalyptus trees in different location can inspect and determine the impact of red gum lerp, G. brimblecombeiat different location and season.

B) Community and Experts' Awareness Training

- In the region red gum lerp, G. brimblecombeiand blue gum chalcide, become a serious insect pest of eucalyptus which affects its growth speed and wood product quality. Awareness creation training on red gum lerp, G. brimblecombeiand blue gum chalcide,Leptocybeinvasa Fisher & La Salle biology, ecology and management practice for experts at various level and tree growers at community level is quite important. Through these training, participants will learn how management efforts may affect the other introduced eucalyptus pests before taking any management interventions and during management action.

- The awareness creation training also make clear the perception of experts and community on impact of red gum lerp, G. brimblecombeion animal and human health.

C) Cultural Control

- Cultural practices and overall tree health also influence populations and the extent to which trees are damaged. Careful management of RLP infested trees may be important in reducing stress from defoliation.
- Experiences with other sucking insects has shown that excessive watering and fertilizing can exacerbate feeding damage and promote higher numbers of pests because of improved food supply. Providing adequate irrigation and limiting nitrogen can reduce susceptibility to damage of eucalyptus due to RGL.
- Avoid pruning practice to remove infested leaves, as RLP will rapidly colonize and kill young leaves that result from flushing following pruning. Pruning over summer may provide additional stress to trees making them more attractive to eucalyptus longhorn borers.

D) Introduction of Some Eucalyptus Species

- Instead of *E. camaldulensis*, some Eucalyptus species and hybrids can be introduced to evaluate the adaptability in various the locality and resistance capacity to the RGL can be done. Then the adapted and resistance species and hybrids can be disseminating to the community.

E) **Chemical Control**

- Systemic insecticides (toxins that can move within the plant) may provide control if applied at appropriate time of application and plant growth stage such as application of systemic insecticides at seedling and sapling stages below four meter height and time of planting on soil or soil drench at any stage but usually require specialized equipment to inject material into tree trunks.

- Systemic insecticides such as Dimethoate 40% E.C., imidaclopiride 80% WP are registered insecticides for crop pests in Ethiopia which can be readily absorbed by the tree tissues and are more effective against sap-sucking insects such as psyllids and scale insects, which protect themselves with lerps and scales, or are protected by plant tissues as is the case with leaf miners, gall-forming insects and the later stages of autumn gum moth.
- Application of oil and soap will kill some of the psyllid adults, eggs, and nymphs that are not covered by the lerps, and help to wash off honeydew. Oil and soap sprays are not highly effective against lerp psyllids and foliar spraying provides only temporary population reduction control.

Long Term

A) Cultural Control

- Diversifying plantings of trees using several species of eucalyptus and other species of shade trees adapted to local environmental conditions will help mitigate future problems with outbreaks of red gum lerp.

B) Host Plant Resistance

- Choose eucalyptus species that are well adapted to the location, including tolerance to the prevailing moisture conditions.The objective of this activity will be to evaluate adaptation of various species in the area and evaluation of resistance/tolerant reaction of Eucalyptus genotypes affected by *G. brimblecombei* egg (female preference) and nymph densities, particularly, compared to E. camaldulensis, other eucalyptus speciesand hybrids.
- In order to compare *E. camldulensis*, other eucalyptus speciesand hybrids, interspecific and phenotypic differences related to leaf traits (e.g. texture,

roughness, and trichome density) occurrence may play a role in psyllid preference and performance, especially affecting the first instar nymph adhesion to the leaf surface. The level of epicuticular wax varies among Eucalyptus genotypes and is important for the adhesion of psyllid nymphs and stylet probing on waxy resistant eucalypt leaves.

Biological Methods

Biological Control with Local Natural Enemies

- Redgum lerp psyllid is attacked by many predators including birds, the convergent lady beetle (*Hippodamia convergens*) and multicolored Asian lady beetle (*Harmonia axyridis*), larvae of green lacewings (*Chrysoperla* spp.) and syrphid flies, pirate bugs (Anthocoris spp.), and spiders. Dragonflies (Order Odonata) will hover near infested trees and catch adult psyllids in mid-air. Although predators do not provide complete biological control, they can reduce psyllid abundance. Whenever possible, select management efforts those have less adverse effects on these beneficial species.

Classical Biological Control

- Specialist RGLP biological control agents (e.g., small stingless parasitic wasps) imported from Australia may offer the best chance for long-term control of RGLP by natural enemies. UC entomologists are currently searching for RLP parasites in Australia with the cooperation of Australian colleagues. Once located, parasites need to be checked for safety in quarantine before being released. Searching for, screening, safety testing, mass rearing, and releasing natural enemies for RGLP control is expected to take a minimum of 12-18 months.
- Natural enemies of the red gum lerp psyllid can be imported from Australia, native to *E. camaldulensis*. One of these, the parasitic wasp *Psyllaephagus bliteus* (Hymenoptera: Encyrtidae) has become established in the USA as a biological control agent for the red gum lerp psyllid.

- The biological control program with P. bliteus against the red gum lerp psyllid has been very successful in California's mild coastal regions, but has provided, only sporadic control in the hot dry interior regions of California. This result suggests that other strains of *P. bliteusmore* tolerant to hot arid conditions need to be imported from Australia for potential release in California, or alternatively, a different species of parasitoid may be needed for areas where P. bliteus has provided inadequate control.

C) Chemical Methods

- New generation of Systemic insecticides (toxins that can move within the plant) should be introduced and evaluated in Ethiopian context. Details of insecticides should register or covered by Pesticide Orders for the control of psyllids with pamphlet.

E) Integrated Pest Management Options.

- Various suggested Red gum lerp management options will be evaluated by integrating selective management practice for sustainable means of pest management

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Observation on Parasitic Plants in Southwestern and Central Part of Ethiopia

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Abstract

A survey on the occurrence of parasitic plans was conducted around Dembi, Yayu, Tepi and Menagesha forest of southwest and central Ethiopia. The aim of the study was identifying the type of parasitic plants present in the forests; list the host species that were infected with the parasite and look into the distribution of the parasitic plants. The result showed the presence of different aerial and strangler types of parasitic plant. In the study Phragmanthera regularis, Viscum tuberculatum and Viscum triflorum that belong to Family Loranthance and Viscaceae were recorded in the study area. These parasitic plants were infecting both indigenous and exotics tree species including Prunus africana, Trichilia dregeana, Cordia africana, Milicia excelsa,a Croton macrostachys, Albizia gummifera, Coffea arabica, Olea europea subsp. cuspidate, Acacia melanoxylon, Eucalyptus globulus, Grevellea tobusta and Sapium ellipticum. In Menagesha, gradual death of Acacia melanoxylon trees was observed following heavy infection of Phragmanthera regularis. On the other hand, infestation of Diaphananthe schimperiana, Microsorum punctatum, Tridactyle bicaudata that belong to Orchids were also found associated with Trichilia dregeana and Albizia grandibracteata. In most cases, the infection of parasitic plants seems to be common on trees around the edge of the natural forest, in open secondary forest and trees on-farm. The impact of parasitic plant on the growth performance of trees needs further studies.

Keywords: *parasitic plants, Loranthaceae, Viscaceae, Orchidaceae, strangler, Ethiopia,*

Introduction

Parasitic plants species makeup about 1% of all angiosperms (Kuijt, 1969; Atsatt, 1973). To date there are approximately 4500 species of parasitic plants in about 280 genera that belongs to 20 families. They are found in all regions except in Antarctica and the aquatic environment (Kartoolinejad, et al., 2007; Lim, et al., 2016). They are partially or completely rely on translocation of host's carbon, dissolved minerals, nutrients and water through the penetration of haustoria (Press and Phoenix, 2005; Watson, 2009). Parasitic plants are responsible to decrease host tree growth, survival and fruit production that enhance tree mortality (Puustinen and Mutikainen, 2001; Way, 2010). In

Switzerland, for example, damage from *Viscus album* spp. *austriacum* infection has been estimated to cause the cutting or death of 10% of *Pinus sylvestris* (Way, 2010). On the other hand, these plants have been used as traditional medicinal herbs and are documented for their anticancer, antimicrobial, antioxidant and antihypertensive activities (Lim, et al., 2016).

In Ethiopia, there are about 28 species that belong to 10 genera (Hedber and Edwards, 1980). Despite the fact that, the FLORA of Ethiopia had done work on the identification and distribution of several plants, including parasitic plants (Hedber and Edwards, 1980), most of the description of these plants were limited at broader administrative regions than on forest areas and district levels. In addition, this work had shortcoming in providing comprehensive list of host plants and parasitic plants association across the country. Hence, study on the distribution of parasitic plants at forests level has significant value in broadening our knowledge and designing management options. Therefore, the aim of this study was to assess and describe list of parasitic plants on trees grown in southwestern and central parts of Ethiopia.

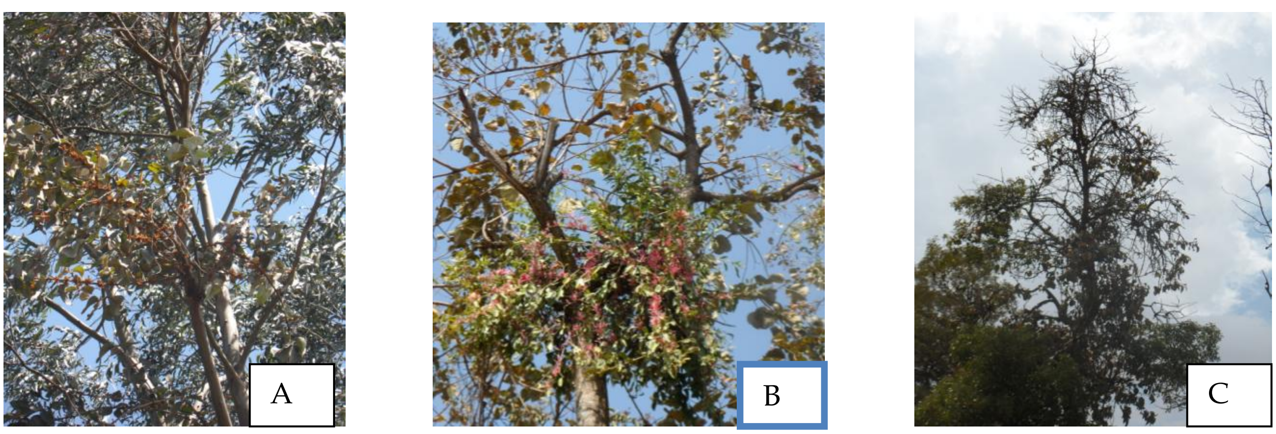
Materials and Method

Study Area and Sample Collection Method

A survey on the presence of aerial parasitic plants was conducted between 2016 and 2017 in closed natural forests, trees on farm and farm-boundary trees, homesteads' and secondary forests of southwest of Ethiopia particularly in Gera (formerly in Keffa Administrative Region but now in Jimma Zone), Dembi (nearby Bedele Zone), Yayu, Tepi (in the compound of Tepi Agricultural Research Center (TARC) in the Green Coffee Development Farm in formerly Illubabor Administrative Region, and in the Central Ethiopia at Menagesha localities in formerly in Shewa Administrative Region. Sample of specimens were collected from accessible trees that were reachable to local climbers. Each of these samples were recorded with respective its host plants, and sent to National Herbarium of Addis Ababa University, Addis Ababa, Ethiopia for identification.

Results

Two types of parasitism were widely observed among the study areas: aerial parasitism (Figure 2) and strangler type of infection (Figure 3), where the aerial parasitic plants belong to Family Loranthance and Viscaceae (Table 1). Among these species, *Phragmanthera regularis* was found dominantly infesting both indigenous and exotic tree species. In addition, the infestation of *Viscum tuberculatum* A. Rich, was also observed in the Core Zone of Yayu Biosphere Forest *Phragmanthera macrosolen* and *Englerina woodfordoides* were uniquely found in Gera forest, where they infested native trees. Some of the aerial parasitic plants such as *Phragmanthera regularis* and *Viscum tuberculatum* did not show host preference infestation and limited geographical distribution. On the other hand, patches of *Eucalyptus globulus* trees grown in the periphery of farmland and adjacent to road side were seen infested by aerial parasitism around Menagesha Town.



A) *Eucalyptus* globulus, B) *Cordia africana* C) *Acacia melanoxylon*

Figure 2: Aerial parasitic plants

The parasitic plants develop haustoria at the point of attachment with its host(s) (Figure 3d). This attachment develops and forms bulk of aerial biomasses that can reach more than 2 m in length. In addition, the parasites produce masses of flowering in the off-season of their respective host plants.

Figure 3: Different species of parasitic plants and haustaria formation

Strangler type of parasitism was frequently observed on *Ficus thonningii* and *Celtis africana* trees in Gera, Yayu and Tepi localities, where relatively aged trees found. We assume that the strangler tree use the root systems of the host plant to absorb water and minerals gradually establish its own root system and it gradually kill the host tree through excessive competition for space, water and minerals.

Figure 2: Strangler tree infection in different tree species at Gera, TARC and Yayu forests

In addition to the aerial and strangler type of parasitism, two species belonging to Orchidaceae and one species belonging to Polypodiaceae were also recorded in different trees.

Table 1: List of parasitic plants found at different localities

Locality	Parasitic plants	Family Name	Host plant
Gera	*Phragmanthera macrosolen* (A.Rich.) M.Gilbert	Loranthaceae	*Albizia gummifera Millettia ferruginea, Acacia abyssinica*
	Englerina woodfordoides (Schweinf) M Gilbert	Loranthaceae	*Vernonia amygdalina, Galiniera saxifrage* (Hochst.) Bridson, *Coffea arabica* L., *Maesa lanceolata* Forssk.
	Viscum triflorum DC	Viscaceae	*Millettia ferruginea* (Hochst.) Bak, *Prunus africana* (Hook. f.) Kalkm
	Phragmanthera regularis (Sprague) MGilbert	Loranthaceae	*Ficus vasta, Podocarpus falcatus* (Thunb.), *Prunus africana* (Hook. f.) Kalkm
Dembi	*Phragmanthera regularis* (Sprague) M Gilbert	Loranthaceae	*Prunus africana*
	Viscum tuberculatum A. Rich	Viscaceae	*Erytherina abyssinica*
Yayu	*Diaphananthe schimperiana* (A. Rich.) Summerh.	Orchidaceae	*Albizia grandibracteata*
	Viscum tuberculatum A. Rich	Viscaceae	*Sapium ellipticum*
Tepi	*Phragmanthera regularis* (Sprague) M Gilbert	Loranthaceae	*Grevellea robusta, Trichilia dregeana, Cordia africana, Milicia excelsa*
	Viscum triflorum DC.	Viscaceae	*C. africana, Croton macrostachys*
	Microsorum punctatum (L.) Copel.	Polypodiaceae	*C.africana, Coffea arabica*
	Tridactyle bicaudata (Lindl.) Schltr.	Orchidaceae	*C. africana, Trichilia dregeana, Albizia gummifera*
Menagesha	*Phragmanthera regularis* (Sprague) M Gilbert	Loranthaceae	*Olea europea subsp. cuspidate, Acacia melanoxylon, Eucalyptus globulus*

Discussion

This study found three aerial parasitic plants, two orchids, and one Polypodiaceae species. These parasitic plants were commonly found on intact forest margins, disturbed forests, edge of farmlands, and on scattered trees.

Phragmanthera regularis were found in Dembi, Tepi, and Menagesha localities. This parasitic plant infected several tree species including *Prunus africana, Grevellea robusta, Trichilia dregeana, Cordia africana, Milicia excelsa, Olea europea subsp. cuspidate, Acacia melanoxylon* and *Eucalyptus globulus* trees. The gradual death of *Acacia melanoxylon* following heavy infestation of *P. regularis* in Menagesha could be associated with extraction of water (where parasitic plants have high transpiration rates and conductance than their host plants) and diverting important resources of nutrient from the host plant (Aukema, 2003; Joel, 2013; Way, 2011). Previous studies showed that this parasitic plant was widely distributed throughout Yemen, Southern Saudi Arabia and some African countries, e.g., Ethiopia, Kenya, N-Tanzania (http://www.catalogueoflife.org/annual-checklist/2014/details/species/id/16866428).

The parasitic plant has also reported on a wide variety of evergreen and deciduous trees including *Zizyphus spina-christi*, *Ficus* and *Acacaia* sp. (reviewed in Mothana, et al., 2012). In Ethiopia, *P. regularis* was distributed in montane forest or woodland, usually near margins, growing on *Croton macrostachyus*, *Ficus*, *Rhus* and less frequently on a variety of other hosts in different administrative regions such as Tigray, Gonder, Gojam, Shewa, Arsi, Wolega, Ilubabor, Kefa; Kenya (Hedberg and Edwards, 1989). The present study added more hosts (such as *Prunus africana, Grevellea robusta, Trichilia dregeana, Cordia africana* and *Milicia excelsa*) to the previous list describe along with *P. regularis* in Hedberg and Edwards (1989). The broader host ranges of *P. regularis* might be associated to non-host specificity of the parasitic plant. It is the first time for *Eucalyptus globulus* infested by any parasitic plants including *P. regularis* in Ethiopia. In addition, *P. regularis* was reported to treat hypertension, diabetes, inflammation, gastro-intestinal complaints, kidney stones, and cancer treatment (Mothana, et al., 2011; reviewed in Mothana, et al., 2012).

Phragmnthera macrosolen (367) occurs in open forest or woodland in higher rainfall areas, nearly always growing on *Acacia* or *Albizia* sp. (Hedberg and Edwards, 1989). In addition, this study found infestation of *Millettia ferruginea* by *P. macrosolen*. In the Flora of Ethiopia, this parasitic plant is distributed in Tigray, Gondar, Gojjam, Shewa, Wellega, Illubabor, Keffa and Sidamo (Hedberg and Edwards, 1989).

Two species namely *Viscum tuberculatum* and *V. triflorum* belong to Family Viscaceae were hosted by *Erytherina abyssinica, Sapium ellipticum, C. africana,* and *Croton macrostachys* in Dembi, Yayu, and Tepi localities. No infection of this parasitic plant was observed in trees grown in Menagesha forest. Previous studies showed that *V. tuberculatum* was widely distributed in Eastern half of Africa from Ethiopia to South Africa and from Rwanda to Angola (Hedberg and Edwards, 1989). In Ethiopia, this parasitic plant was common both in relatively dry woodland and evergreen bushland on a variety of hosts. Infections were recorded on *Croton macrostachyus*, *Rhus*, *Maytenus*, *Nuxia congesta*, *Olea europaea* ssp. *africana* in Tigray, Gojam, Welo, Shewa, Arsi, Welega, Kefa, Gamo Gofa, Sidamo, Bale, and Harerge (Hedberg and Edwards, 1989). *Viscum tuberculatum* is used as a poultice on the chest of a person with pneumonia and for a person with liver troubles (Idris, 2004). On the other hand, *V. triflorum* DC. was reported in eastern Africa south to Transkei and west to Zaire. It was hosted by *C. macrostachyus, Buxus*, *Tamarix*, *Euphorbia abyssinica, Coffea* and *Cordia africana*. This parasitic plant reported in montane forest margins through to relatively dry riverine forest. In Ethiopia, *V. triflorum* was distributed in Tigray, Gojam, Welo, Shewa, Arsi, Kefa, Sidamo, Bale and Harerge (Hedberg and Edwards, 1989).

According to Flora of Ethiopia, *Englerina woodfordoides* were found of wetter montane forests, particularly common in thickets resulting from forest clearance (Hedberg and Edwards, 1989). In addition to the common availability of *E. woodfordoides* on *Maesa* *lanceolata,* this study found the infestation on *Vernonia amygdalina*, *Galiniera saxifrage* and *Coffea arabica.* Infestation of *E. woodfordoides* was reported in Gojjam, Shewa, Arsi, Wellega, Illubabor, Keffa, Sidamo, as well as found in other African countries including Kenya, Uganda, Tanzania, Rwanda, Zaire (Hedberg and Edwards, 1989).

Ficus thonningii is widely known as strangler tree, where it lives together with other host in such a manner that one benefits while the other is harmed to death. In agreement with previous studies, *F. thonningii* has been recognized in our study as to eventually kill the host and resulted in full-grown tree (Orwa, et al., 2009). On the other hand, two different Orchids were found around Yayu and Tepi localities on *Cordia africana*, *Trichilia dregeana, Albizia gummifera,* and *Albizia grandibracteata* trees. In agreement with previous works, none of these epiphytic plants found hurting the host trees (Roberts and Dixon, 2008). This might be reproductive and dissemination strategy of the parasitic plants to attract vectors (i.e. birds) that help the dispersion of fruit berries. This might add extra cost to the host plant through expenditure of nutrient and water. Infection of branches occurs in the tip of the host tree branches, in any direction of the tree (north, south, east and west) and kill the branches during severe infestation.

Conclusion and recommendation

Parasitic plants in Ethiopia have been poorly studied, and need to get adequate attention. In the future, the expected climate change might help to extend the altitudinal range of these species to new areas along with host plants (Way, 2010) and may put pressure in the survival of economically important tree species including *Eucalyptus globulus* that is widely planted across the country. Hence, future studies need to address the impact of climate change on the distribution and abundance of parasitic plants, and observe the cause of limited distribution of these plants in closed canopy forests. Also it is important to investigate the medicinal value of these parasitic plants with respect to growing on different host plants, magnitude of damage they exert on host plants and devise appropriate management options in case of sever incidence of infection. Furthermore, emphasis needs to be given to the sky-high tall trees of the southwest forest of the country where it is difficult to climb using local climber and collect specimens of parasitic plants.

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Chapter Five: Soci-eonomics, Policy, Extension and Gender Research

Improvement Measures on Bylaws for Successful Scaling up of Exclosures in Northern Ethiopia

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Abstract

In Ethiopia, deforestation and over exploitation of forests compromised the efforts of local and external bodies to reduce rural poverty and improve livelihoods of the poor. To address this problem, communities in the country established exclosures on formerly degraded grazing lands for promoting natural regeneration of plants, and getting economic benefits. The communities devised bylaws to prevent human and livestock interference and to enhance the sustainable use and management of exclosures. Establishing a national framework bylaw governance system as an institutional structure and process is necessary to sustain and scaling up of exclosures as well as communities participation in decision-making regarding exclosure use, management and governance. This piece of information analyses the contribution of bylaws for sustainable management of exclosures through clearly defined boundaries, and benefit sharing mechanism, monitoring system, distribution of benefits, participation of the community, user right, sanctions of offense, conflict resolutions and meeting the economic needs of users. We used qualitative and quantitative methods including in depth interviews and focus group discussions and individual interview for data collection in two regions (Tigray and Amhara) of the country from 18 exclosures that differ in agro-ecologies. Results revealed that the bylaws mitigated the forest degradation by mobilizing users towards common goals in the management of exclosures and resolved the conflicts among users, defining resource and use boundaries, and monitoring system. In the exclosure the enforcement of bylaws was different from exclosure to exclosure as well as in the region. The participants from the community confirmed that the village bylaws resolved conflicts among users by punishing free riders, defining users who have the right to access the exclosures, empowering the villagers to manage the exclosures in their villages and reducing the problems related to demarcation of exclosures. The management activities include guarding, constructing different soil and water conservation practices and enrichment planting. The communities have locally written and unwritten formulated rules and regulations on area exclosures to assist the administration and utilization of resources found inside the exclosures, but more focused on conservation than economic objectives. Bylaws prevent over exploitation of *forest resources by mobilizing users towards common goals in the management of exclosures and defining users who have access to the exclosures in defining the physical boundaries of the exclosures and the protection of the exclosures by guarding. Bylaws have contribution to sustainable exclosure management by creating a suitable environment for joint decision making of communities and government, enabling exclusion at low cost for common exclosure users and using locally agreed sanctions. Therefore, overcoming the poor rule enforcement of bylaw, improvements measures undertaken with regarding to participation and empowerment, institutional and organizational set up, equitability of benefit sharing, livelihood diversification, effectiveness of bylaw on exclosure management and conflict resolution mechanism.*

KeyWords: *bylaws, exclosure, common property resources, governance,*

Introduction

Ethiopia endowed with vast natural resources which contribute to the economic development of the country. But, these resources are highly threatened by chronic degradation, recurrent drought and shortage of skilled manpower and improved technologies. On the other hand, natural resources are scarce and increasingly affected by the competition of mutually exclusive uses. Farmers mainly use this basic resource in traditional ways without any logical organization of different types of land according to their physical configuration. As a result, inappropriate land use decision leads to inefficient exploitation of natural resources, destruction of land resources and the country remains among the poorest countries in Africa and the world as well (Reusing, 2000; Fitsum, 2003).

Various evidences revealed that a century ago more than 65% of the total land mass of Ethiopia was covered by dense forests, but now only 3% remain (Badeg, 2001; Demil, 2001; EPA, 1998; Million, 2011). Mulugeta and Habtemariam (2014) also stated that deforestation in Ethiopia has a long history especially in the central and northern highlands of Ethiopia. Consequently, land degradation which is triggered by population expansion and over-exploitation of natural resources becomes the major environmental problem causing adverse social, economic and ecological impacts in the country (Badeg, 2001; Hurni, et al., 2005).

In response to the problem of land degradation and other environmental problems, various natural resource conservation practices and rehabilitation interventions have taken place. Among the various rehabilitation techniques used, the predominant is area exclosure (Mulugeta, 2004; Betru, et al., 2005) and establishment of fast growing plantations of exotic species and physical conservation measures such as terracing. Area exclosures can be defined as degraded lands that have been excluded from human and livestock interference for rehabilitation (Betru, et al., 2005; Wolde, et al., 2007, Tesfaye, 2002). Degraded lands that almost lost their production potentials are set aside for nature based rehabilitation. These areas, if properly managed and rehabilitated through exclosure system, allow native vegetation to regenerate (Emiru and Tefera, 2002).

Recently, area exclosure is the most widespread practice in Ethiopia, which involves protecting mainly through social fencing from any form of cultivation, cutting trees and shrubs or grazing by livestock to allow regeneration and forest natural ecological succession for the rehabilitation of deforested areas or degraded forests (Mulugeta and Habtemariam, 2014). However, large commitments and efforts have been devoted to rehabilitate degraded lands in Ethiopia; the efforts could not have brought all-encompassing solution for the forest degradation due to various reasons. First, the establishment of exclosures has been focused on physical aspects and on the protection of natural resources over the social aspects. Second, lack of strong instructional arrangements (local bylaws) which govern and define clearly the use of rights among local communities or user groups and the government are also vital problem (Birhane, 2002).

Enforceable bylaws are seen as crucial for the success of conservation efforts in Ethiopia. However, most of the present bylaws do not match with the demands of changing realities as a result of the establishment of area exclosures (Wisborg, et al., 2000). In most cases bylaws are not efficient and only seen as penalizing tool against offenders (Birhane, 2002). In addition to efficient bylaws, conservation and development initiatives need an institutional/bylaw framework that promotes co-ordination (Yifter and Haile, 2002). This institutional/bylaw framework must be able to sort out the roles and responsibilities of all the stakeholders involved in area exclosures defining in particular relationship the relationship between the community and the government. Absence of an appropriate institutional framework gives rise to (inter-institutional) rivalries thus making implementation and integration at local level is difficult. As the result, developing of national framework of bylaw through improvement measures is important to sustain exclosures. Therefore, the aim of the study was to assess and evaluate the existing bylaw in northern Ethiopia and develop national framework on bylaws of exclosures.

Materials and Methods

Description of the Study Area

This study was conducted in two regional states of Ethiopia (Tigray and Amhara regional states) at 18 exclosure sites representing different agro-climatic and socioeconomic conditions based on their best experiences on area exclosures (see Appendix1). Tigray covers a total area of 5170225 ha and most of the region is arid and semi-arid. The climatic condition of the region is characterized as 39% Kola, 49% Woina Dega and 12% Dega. The total annual rainfall ranges from 450mm to 980mm.The region also covered by 37% agricultural land, 27% shrub land, 24% forest, 1.8% grassland and 10% bare land (DADPTC 2014). Amhara regional state is located in northwestern part of Ethiopia located between 9^{o} 45`-13$^{o}$45`N latitude and 36^{o} 15`-40$^{o}$ 30`E longitude with a total area of 170,152km^{2}. Of the total area, cultivation and grazing land make up 30% each. Forest, shrub, bush and woodland, water bodies and waste land make up 17%, 4%, and 16% of the total area, respectively; and the remaining 3% take up by settlement (Ludi, 2004).

Data Source and Data Collection Methods

In this study, data was collected from primary and secondary data sources. Primary data were collected through key informant interview (KII), focus group discussion (FGD) and semi-structured questionnaire with the user groups based on design principles of Ostrom (1990). Interview was conducted based on Elinor Ostrom's management principles was conducted in order to understand the local management systems and traditions, the importance of the exclosures, the boundaries of resources and users, monitoring system, ways of benefit sharing and the user- and access rights of area exclosures. On the other hand, the main source of secondary data was the guidelines of their local bylaw of each peasant association (PA). Moreover, various literatures, reports of regional states bureau of agriculture and natural resources and district's office of agriculture and natural resources were other sources of information.

Multi-stage sampling procedures were taken place for sampling. In first stage, two regional states that have best experience on area exclosure namely, Tigray and Amhara were selected. Secondly, in each region, three zonal admirations and from each zone three woredas were selected. Finally, in each woreda three peasant associations with their user groups of exclosures were selected based on their successfulness.

For this study, a total of 18 area exclosure over the two regional states were selected. From these 18 area exclosures sample household respondents were selected for interview, group discussion and key informant interview based on the population ratio sampling procedure. Accordingly, a total of 54 focus group discussion consists of 10-15 persons with segregation of age and sex, 272 household interviews who are user groups of exclosures, and 90 key informant interviews who are knowledgeable about the sites were held that have assumed to be sufficiently large for drawing valid statistical inferences and also manageable to be surveyed with the available resource of finance and time.

Method of Data Analysis

Quantitative data were analyzed using the Statistical Package for Social Science (SPSS) programme (Version 20). The result was presented using descriptive stastics such as graphs, tables. In order to determine levels of association and significance between performance of institutional indicators and regions a Chi-square Test of Independence (Pearson) was adopted. The study hypothesized that performance of eight design principles differed between the regions. Qualitative data were analyzed using content analysis.

Results and Discussion

Assessment and Evaluation of Existing Practices of Bylaw on Exclosures

Socio-Economic Characteristics of the Respondent

A total number of 272 respondents were interviewed of which 84% were male and 16% were female respondents. The majority of the respondents were between 36 to 50 years and constituted 48% followed by persons between 20 and 35, constituting 25%. Persons younger than 20 years constitute 74.3% while respondent between 51 and 65 years and above 65 years constitute 22.8% and 2.9% respectively. About 34.6% of the respondents were illiterate, 15.4% had informal education, 39.7% had attended primary school (1-8) and the rest 10.3% of the respondent attended secondary school (9-12). Thus show most of the respondent attend primary school. The respondents' average family size was 6. The average landholding of the respondent was 0.7ha per household, which is less than the national average that was 1ha per household (Kassa, 2004).About 50% of dependents were involved in both crop and animal production as their main livelihood activity. Others were involved in crop production (41%), animal production (4%), petty trade (3%), and handicraft (1%). Therefore, about 91% of the respondents were involved in agricultural activities for their livelihoods.

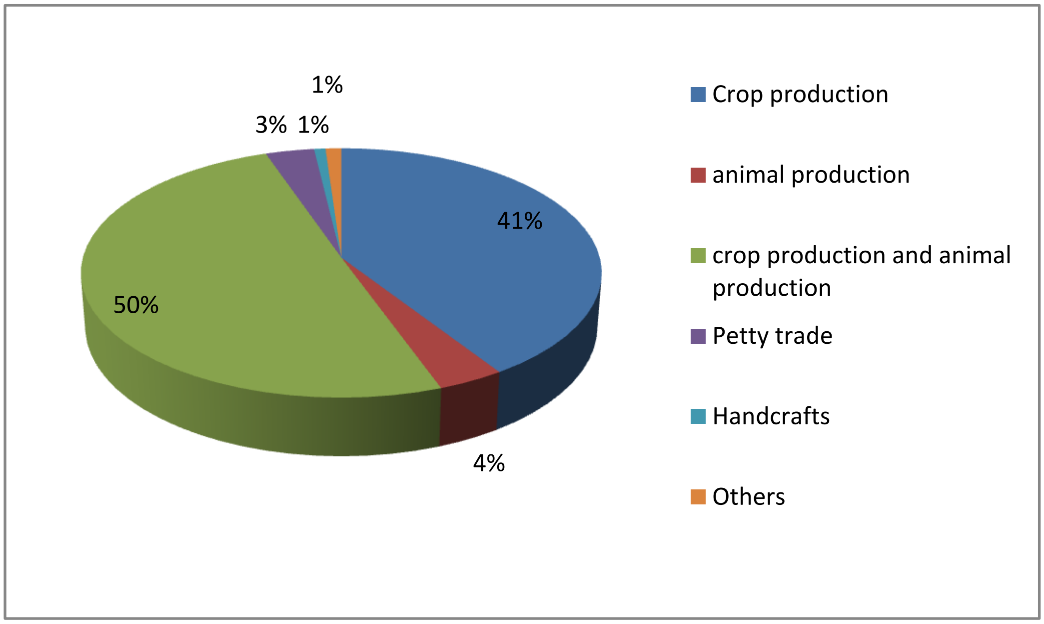


Figure 1: The respondents' livelihood activities

Community Participation in Site Selection, Planning and Implementation

About 12.5% of the respondent not participated any of site selection, planning and implementation. Other respondents participate 7.4% on site selection, 3.7% on planning, and 31.6% on implementation stages. The results also show respondents of 2.9% both site selection and implementation, 3.7% on site selection and planning and 36.0% of the respondent participated on site selection, planning and implementation. The result indicates that, majority (36%) of the community participate at implementation stage and also there were communities not engaged any of exclosures establishment activities.Genarally, the result revealed most of the community participation was not smoothed at each activity stages. From this result, the absence of full participation of the community will be difficult for sustainable management of exclosures in the future.

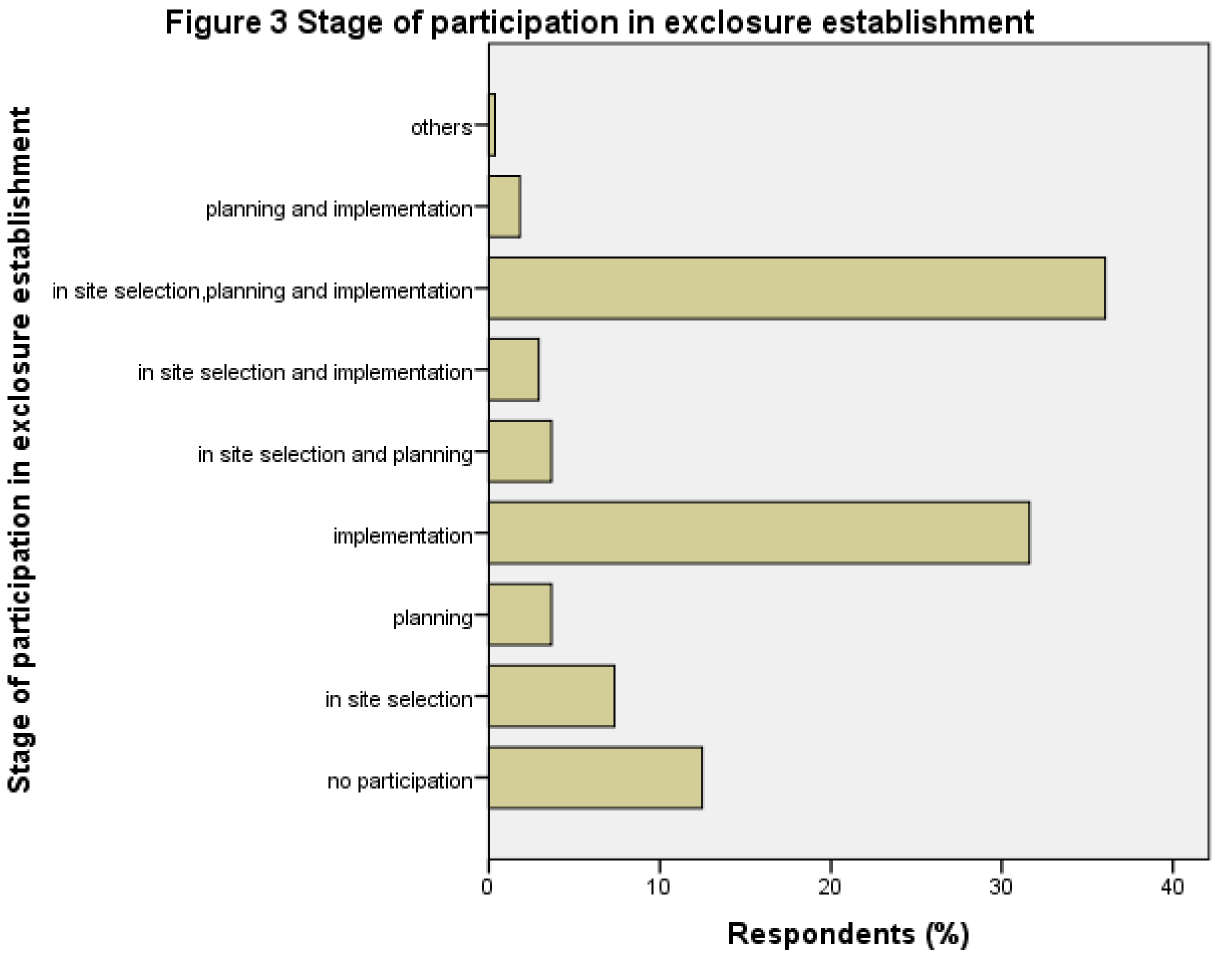


Figure 3: Stages of participation in exclosure establishment

Community Perception on Bylaws of Exclosures Management

Respondents who involved in focus group discussion and key informant interview said that exclosure provide various direct and indirect economic benefits. However, there is unbalance between ecological and economical benefits and not generate benefit that expected by the local communities. About 52.9% of the interviewees agreed that exclosures were established and managed for the purpose of ecological benefits and 45.6% of the respondent agreed on the ecological and economic purpose. The other few

(1.5%) respondents said management of exclosures achieves economic purpose (Figure 2). Thus, most respondents focus group and key informant participants expressed that, bylaw of exclosures was developed more emphasis on the conservation than economic utilization. This result is sported by (Yami et al. 2012), who studied that; village bylaws were not effective to meet high expectation of communities to generate economic benefits.

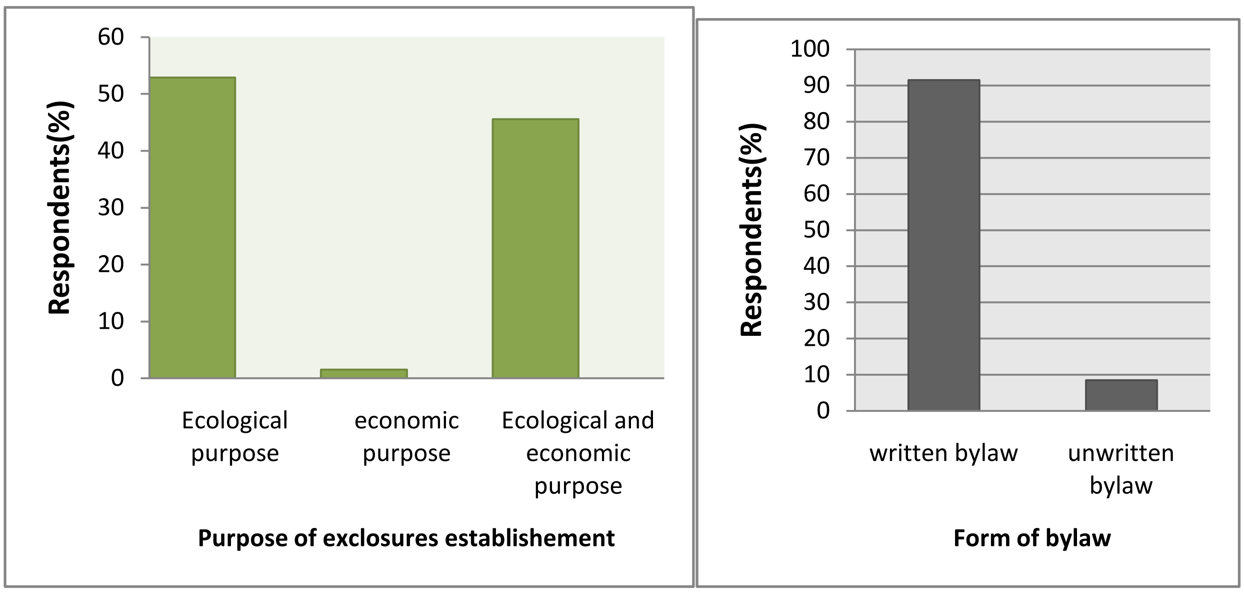


Figure 3: Community responds on purpose of exclosure establishment and bylaw format

From the total respondents, 91% of the community had a written form of bylaw rules while 9% of respondent had unwritten form of bylaw rules that govern and manage the exclosures. This implies that, Most of the intervention did have written long-term management plan, the communities had recognized that the potential benefits of establishing of exclosures and were able to respect the bylaws by documented guidelines but few intervention did not have written management plan for establishment of exclosure and able to respect the bylaws set orally.

Performance Evaluation of Bylaw Rules

Table 1: Respondents' replies for effectiveness of bylaw penalize opportunism

			Tigray	Amhara	Total
Do bylaw rules effectively penalize opportunism?	I don't know	Obs.	3	0	3
		%	1.1%	0.0%	1.1%
	yes	Obs.	118	134	252
		%	43.4%	49.3%	92.6%
	no	Obs.	16	1	17
		%	5.9%	0.4%	6.2%
	Total	Obs.	137	135	272
		%	50.4%	49.6%	100.0%

Source: Field survey data. Test for significance between regions: Pearson chi2=17.24,P<0.0001

About 92.6% of the interviewees around the exclosure have bylaws that effectively penalize opportunism while other 6.2% of the communities have no bylaws that effectively penalize opportunism. The result indicated that the majority of the communities perceived bylaws of exclosures effectively penalize opportunism and there is significance variation between the two regions (x2=17.24, P=0.0001).

Table 2: Users response on graduated sanctions of bylaw who violate the rule within the regions

			Tigray	Amhara	Total
Users who violate the rule receive graduated sanctions	I don't know	Obs.	3	0	3
		%	1.1%	0.0%	1.1%
	yes	Obs.	103	124	227
		%	37.9%	45.6%	83.5%
	no	Obs.	31	11	42
		%	11.4%	4.0%	15.4%
	Total	Obs.	137	135	272
		%	50.4%	49.6%	100.0%

Source: Survey result 2016-2017. Test for significance difference between regions: Pearson $\chi 2$ *=14.45,P<0.001*

Results on whether graduated sanctions are devised and applied consistently, there was significant association with the two regions (χ_2 =14.45; P=0.001).Sanctions are mechanisms imposed to punish rule violators or non-compliance with the collective rules. The findings revealed that majority of (83.5%)/39.9% Tigray and 45.6% Amhara region of respondents trusted that sanctions were applied. While 15.4% of respondents were respond that sanctions were not applied. Focus group discussion and key informant interview point out that, Monetary and non-monetary sanctions were commonly used by communities that have bylaws related to participation such as late arrival in meeting and violating the bylaw rules. The monetary sanctions/penalties were in most cases increasing with the number of violations but in fewer cases the same amount regardless whether the violation was the first, second or third time. There was also a lot of variation in monetary amounts that had to be paid across the exclosures and regions and the variation from first to second and third violation by the same person and also vary based on the seriousness of violations. Monetary sanctions in a form of paying fines were devised for punishing users that broke the bylaw rules depending on the level of guilt. The amount of fines decisions were made based on a level that majority of the community can afford if found guilty of breaking the rules. The discussion with focus group and key informant interview the role of bylaw revealed that communities link with penalties that violate the rule than economic incentives/rewards. Similar studies believed that allow communities use exclosure would simply destroy them, and rehabilitating the environment needs to be seen as separate from individuals (Gebremichael, 2007).

Table 3: Are members of the exclosure well defined

			Tigray	Amhara	Total
Members of the exclosure well defined	I don't know	Obs.	4	-	4
		%	1.5%	-	1.5%
	yes	Obs.	127	135	262
		%	46.7%	49.6%	96.3%
	no	Obs.	6	-	6
		%	2.2%	-	2.2%
	Total	Obs.	137	135	272
		%	50.4%	49.6%	100.0%

Source: Survey result 2016-2017. Test significance of difference between regions. Pearsons $\chi 2$ *=10.23,P<0.006*

Interviewees revealed that, about 46.7% in Tigray and 49.6% in Amhara regional states members/users of area exclosures were well defined. And also 2.2% respondents in Tigray said that, members of area exclosures were not defined and the other 1.5% had no information. As shown the significances level of the result, there was significance association between two regions ($\chi 2$=10.23, p=0.006).Thus, in both regions most respondents express members of exclosures were well defined.

Table 4: Respondents replies on defined boundary and resources utilization rights

			Tigray	Amhara	Total
Exclosure has well defined boundary to utilize resources	I don't know	Obs.	6	-	6
		%	2.2%	-	2.2%
	yes	Obs.	128	135	263
		%	47.1%	49.6%	96.7%
	no	Obs.	3	-	3
		%	1.1%	-	1.1%
	Total	Obs.	137	135	272
		%	50.4%	49.6%	100.0%

Source: Survey result 2016-2017 .Test for significant difference between regions. Pearson $\chi 2$ *=9.17,P<0.010*

Results show that performance of clearly defined boundaries of resource extraction and users had a significant association within regions. ($\chi 2$ =9.17; P<0.010 (Table 6).The finding revealed that47.1% of the community in Tigray and 49.6% in Amhara regions said that there was clear delineation of the resource boundary. This result shows that from the total respondent 96.7% of the community in Tigray and Amhara Regions have clearly defined boundaries of their exclosures. Indicated in the focus group discussion, community access resources from their delineated exclosures able to exclude outsiders or free riders for accessing of the resources. According to the focus group, key informant and individual respondents, the local communities clearly knew the boundary of the user group and resources that has the right to use the resources from specific exclosures. Thus implies, there was no knowledge problem among the majority community members about the boundary of the resources and sharing benefits. Similarly, knowledge of the physical boundaries of resources is one of important factor in sustainable management of common property resources (Ostrom, 1990). On the other hand, elder participate in discussion session said access of resources from exclosures were limited and restricted to fulfill economic benefits. This implies that bylaw mainly focused on managing of degraded lands. However, there is need to amend the existing bylaw to attain balanced ecological and benefits based on local context resource potential in the exclosure.

Table 5: Equitability of benefit sharing among member

			Tigray	Amhara	Total
Equitable benefit sharing among members	I don't know	Obs.	1	0	1
		%	0.4%	0.0%	0.4%
	yes	Obs	67	135	202
		%	24.6%	49.6%	74.3%
	no	Obs.	69	-	69
		%	25.4%	-	25.4%
	Total	Obs.	137	135	272
		%	50.4%	49.6%	100.0%

Source: Survey result 2016-2017. Test for significant difference between regions. Pearson Chi2=92.88, P<0.000

The result in table showed there was significant association for equitable benefit sharing between the two regions (χ^2 =92.88; p=0.0001). The result indicated that, 24.6% and 49.6% respondents in Tigray and Amhara regions enjoy their rights for applying equitable benefit sharing from exclosures respectively. On the other hand 25.4% of respondents in Tigray region had no equitable benefit sharing but in the case of Amhara it was secured. Generally, majority of (74.3%) respondents had equitable benefit sharing while other 25.4% had no equitability of benefits from the total respondent. Focus group and key informant participants believed that, bylaw had not incorporate clear equitable benefit sharing mechanisms.Thus unfair benefit sharing mechanisms reduce sense of ownership among communities on exclosures.

Table 6: Monitoring system of exclosures

			Tigray	Amhara	Total
Monitoring system to	yes	Obs.	123	127	250

	%	45.2%	46.7%	91.9%
no	Obs.	14	8	22
	%	5.1%	2.9%	8.1%
Total	Obs.	137	135	272
	%	50.4%	49.6%	100.0%

Source: Survey result 2016-17. Test for significance difference between regions. Pearson χ^2 =1.686,P<0.194

The monitoring principle concerns actors who actively audit/check exclosure and appropriators' behavior. The result showed no significant association (χ^2 =1.686; P=0.194) between the communities of the two regions on the effectiveness of monitoring system for their exclosures. 50.4% of respondents in Tigray and 49.6% in Amhara respond on the performance of monitoring system. Generally, 91.9% of the community in both regions there is a system that monitors the exclosures and the resources within the exclosures by guards and monitoring and evaluation committee. The chi-square test showed there is no association difference between the two regions for monitoring of exclosures. The findings were supported by focus group discussion and key informant interview, but the local communities had had no frequent monitoring system for proper use and management of exclosures and resources and focused on penalties of rule violators.

Table 7: Existing of conflict resolution mechanisms regarding to bylaw rules

			Tigray	Amhara	Total
Conflicts resolving measures are based on bylaw rules	no conflict	Obs.	129	89	218
		%	47.4%	32.7%	80.1%
	yes	Obs.	2	41	43
		%	0.7%	15.1%	15.8%
	no	Obs.	6	5	11
		%	2.2%	1.8%	4.0%
	Total	Obs.	137	135	272

	%	50.4%	49.6%	100.0%

Source: Survey result 2016/17. Test for significant difference between regions. Pearson χ^2 =42.79,P<0.0001.

About 80% of the respondent said there is no conflict around the exclosure while only 15.8% of the communities have conflict and conflict resolution mechanisms. The other 4% of the respondent revealed that have conflict but they have no conflict resolution mechanisms. Findings show that there was a significant association between two regions on the use of conflict resolving mechanisms (χ^2 =42.79; P=0.0001). This result also indicates there is no serious conflict on exclosures.

Developing of National Framework and Improvement Measures of Bylaw

Strength and Weakness of Existing Management Practices and Bylaws of Exclosures from the Finding

Indicators	Strength	Weakness
Livelihood diversification	-	- Allow limited products and services from exclosures
Benefit sharing mechanism and resource access	-Resources use right from exclosure	-restricted resource from exclosure -Unclear and inequitable benefit sharing
Management of exclosures	-Covered degraded lands	-More emphasis on conservation than utilization
Graduated sanction	-Penalize bylaw violators according based on level of penalty	-Focused mainly on wrong doers than economic rewards
Objective setting of exclosures establishment	-Enhance rehabilitation	-Not meet expected economic benefit of the community
Participation	-Mass mobilization	-Not full participation at all stage
Monitoring and evaluation	-Strong monitoring bylaw violators/defaulters	-Not effective for monitoring and enforcing the rules for economic aspects

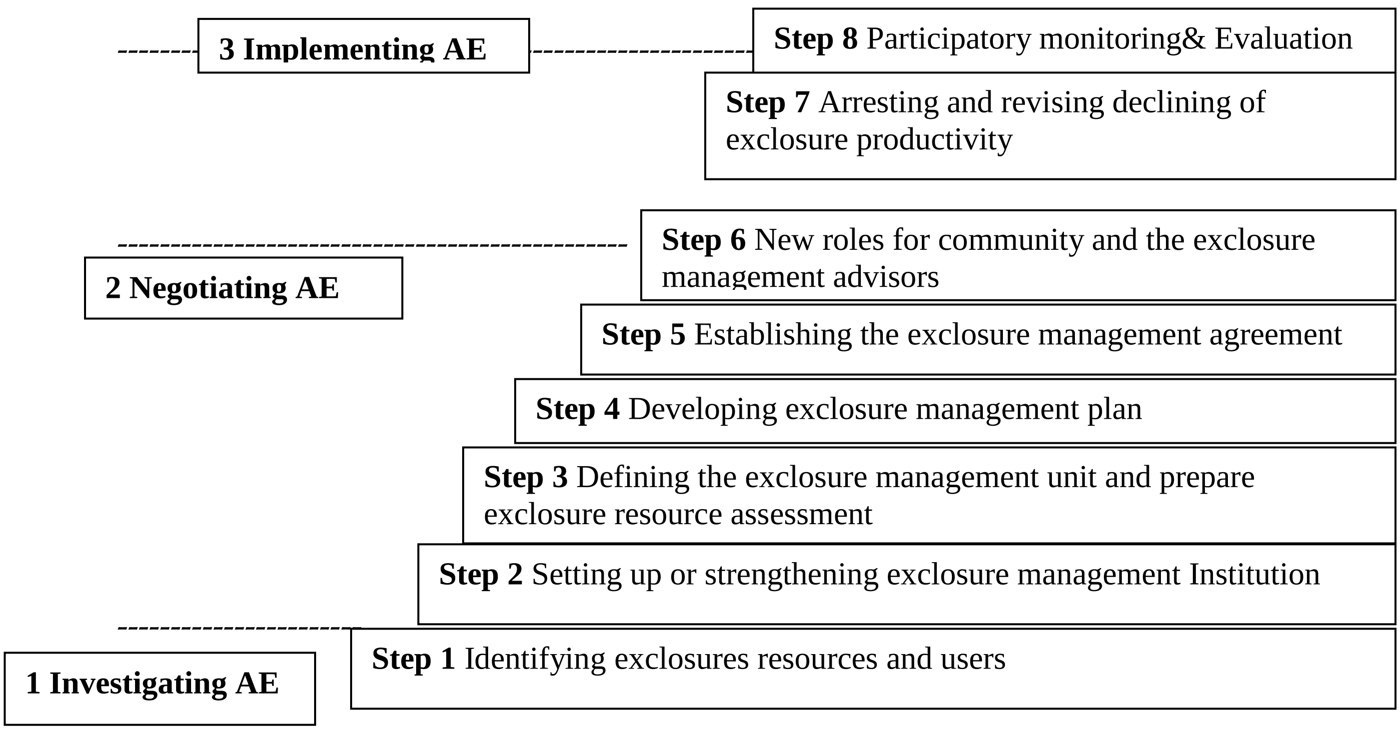


Figure 3: Stages and steps of area exclosure management

Summary of the Process

a. Investigating Exclosure Management

This is the first process that gathering information about different resources found inside the exlosures, their uses, users and stakeholders who have role on the management of exclosures. This is achieved through using of different tools like stakeholder analysis and resource mapping.

b. Negotiation

This is the second stages that focus on appropriate community led bylaws. The bylaw play significant role for the managements of exclosure resources, their access and utilization of resource from exclosure for different stakeholders. Establishing of bylaw based on type of resources, resource access and local context. The local community and government develop bylaw accordingly the local context and society. The bylaw covers that benefit sharing mechanism, penalty for offenders, reward for achievement, and assure equitability of benefit sharing and economic benefits and exclosure management activities .Drawing and signing up of exclosure management agreement through extensive meeting, discussion, and negotiating with government officials, responsible institutions and communities particularly on rights and responsibilities. The management goal of exclosures should be defined at their establishment and these objectives should be negotiated and agreed upon by major stakeholders.

c. Implementation

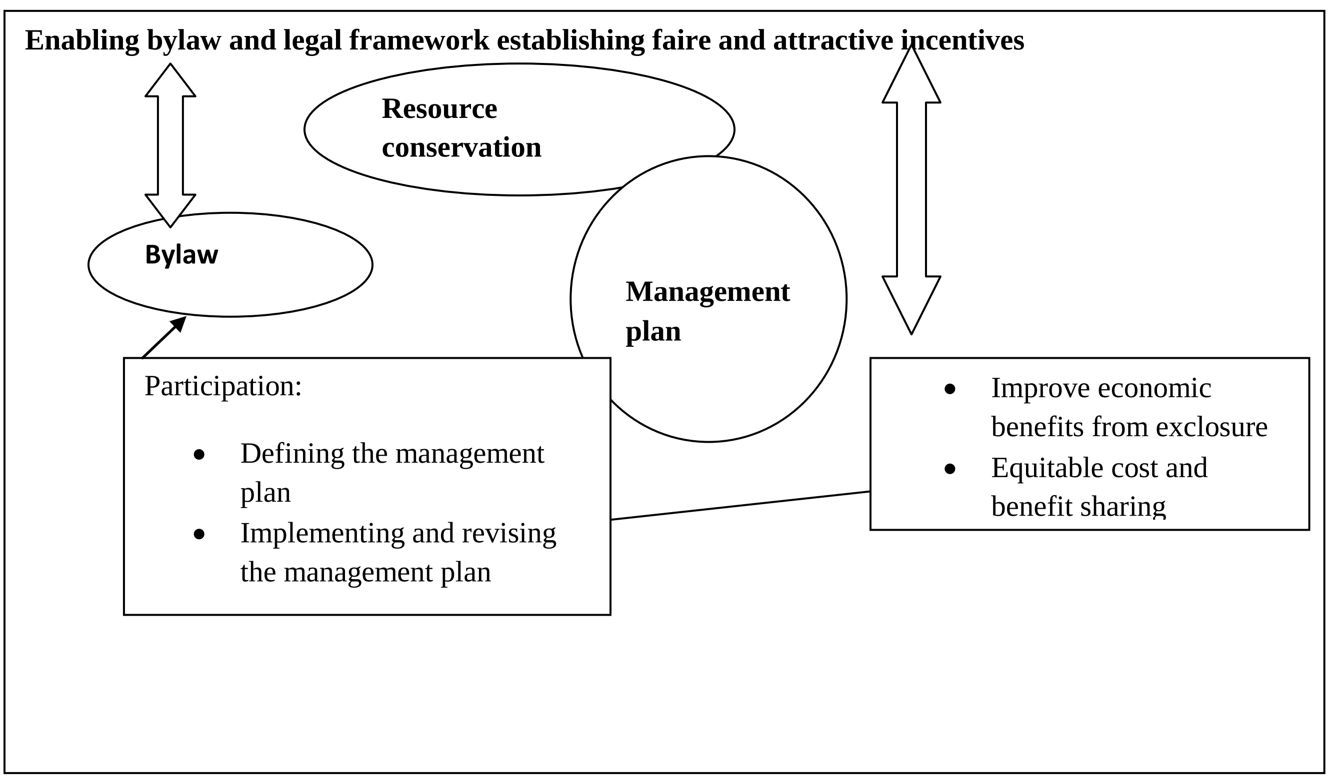
Criteria	Proposed improvement measures of bylaw on exclosures from findings
Participation and empowerment	✓ All inclusive participation (youth, minorities, women, elders, disables etc.) in all aspects of area exclosure management for doing objective setting, ecological and economical evaluation, benefit and responsibility sharing etc. ✓ Balance both conservation and economic objectives of exclosure management when setting objectives and developing management plans. ✓ Put short-term and long-term benefits from exclosures during setting of conservation and product focused objectives based on community demand. ✓ Enhance access to information such as marketing, technology… and capacity building (technical, material, etc.) ✓ Enhance community empowerment on decision making ✓ Creating enabling environment to allow active participation of ordinary members. ✓ Communities actively engage and negotiate to clarify ownership rights.
Institutional and	✓ Facilitate the implementation of community bylaws appropriate

organizational setup	to exclosure management and legal recognition of bylaw ✓ Establish, legalize and empower of community base organizations, both in exclosure management and resource marketing from exclosures, and dissolve more decision making power to community base organizations for effective exclosure protection and management ✓ Provide legal provisions ✓ Setting provisions and taking progressive actions to support the evolution of exclosures to community ownership. ✓ Create awareness of exclosure among law enforcement bodies and other related offices. ✓ Include payment for ecosystem service in to community base organization bylaws ✓ Organize all user groups as cooperatives, unions etc. around exclosures
Equity/equitability of benefit sharing mechanisms	✓ Benefit sharing and management responsibility should take into account economic heterogeneity of community members(participation, livelihood strategies, forest dependence inside the exclosure, level of poverty, and other criteria) ✓ Recognize different types of exclosure management membership, combined corresponding responsibilities in collective management arrangements, as appropriate to the social and cultural practices of the community.
Economic benefit/Livelihood enhancement	✓ Ensure forest access rights from exclosure to meet the local needs: grasses, fuel wood, construction wood, bee keeping, etc and other environmental benefits based on exclosure potential. ✓ Strength support for forest-base livelihood diversification inside the exclosure based on the resource potential. ✓ Enhancing value addition and marketing such as honey processing, ecotourism, etc. ✓ Ensure community benefits from payment for ecosystem services such as carbon. ✓ Integration of exclosure base benefits with other livelihood activities like fattening through stall feeding, beekeeping, fruit and vegetable production if irrigation is available around the exclosure, etc. ✓ Crop and animal damage by wild animal become minimal/low. ✓ Establish time line for collection of products from exclosures
Exclosure management	✓ Strength periodic resource assessment inside the exclosure through community involvement to support informed decision making for adaptive management ✓ Enhance community capacity to act as exclosure managers, and ensure that resources extraction from exclosure is based on management plan to ensure sustainable exclosure management.

	✓ Encourage non-invasive enrichment planting, and provide technical support to establish forest plantation around the exclosures site were appropriate based on consultancy. ✓ Quantifying the periodic impact of exclosures through periodic monitoring and evaluation of participatory approach and generate reliable data periodically.
Enhance effectiveness of bylaws for sustainable management of exclosures	✓ Exclosure boundaries are clearly defined and agreed upon by communities ✓ Establish well defined property right(security of tenure is clear and documented) ✓ Communities participate at various levels of exclosure management and decision making mechanisms. ✓ Clearly defined rule access to products from exclosure and benefit sharing mechanism ✓ Clearly defined management, monitoring and controlling rules accordingly the demand of local community. ✓ Bylaw establishment should be participatory decision and attempt to balance conservation and economic objectives of exclosures based on the site, resource type and community needs.
Adequate knowledge and awareness of local community	✓ Community has clear knowledge about socio-economic and environmental service provided by exclosure ✓ People recognize the need to balance the number of people with natural resource use. ✓ People invest in their surroundings (time, effort and money) ✓ Local community is able to compare future long-term benefits to short-term benefits from exclosure ✓ Local community meet with satisfactory frequency to discuss issues with related to management of exclosures.
Conflict resolution mechanism	✓ Legally grant communities the power to address all exclosure related issues, including conflict over resources between members. ✓ Ensure the participation of all community groups (youths, women, elites, marginalized groups) and other all relevant stakeholders during CBOs development. ✓ Consider the needs and aspiration of non-members and alleviate negative impacts of exclosures that affect them by means of employment opportunities, income diversification, etc… ✓ Emerging and periodically update bylaws, taking emerging needs into account

It moves from preparation, official recognition and approval to action. It requires effective integration of local government, community and other advisory institutions like NGOs to success the exclosure implementation. Communities have a leading role in this stage for identifying the resources that require proper rehabilitation or improvement measures to sustain the exclosures. Participatory monitoring and evaluation also important by the integration of different stakeholders to evaluate the achievement of established objectives regarding to conservation and economic aspects.

Figure 4: Institutional set up and national context of bylaws on area exclosures from the result EE



Bylaw on management of exclosures to enhance different objectives

Conclusion and Recommendation

The Findings of the study indicated that, most exclosures are established and identified by joint initiative of local communities, local Government and Non-Governmental Organizations who are financial funders and also managed communally by the local communities. In the previous time, exclosures were establishing mainly for the objective of ecological purpose and with limited economic benefit. Participants of focus group discussions around the exclosure highlighted that the bylaws prevent overexploitation of forest resources by mobilizing users towards common goals in the management of exclosures and defining users who have access to the exclosures. Most exclosure have management, utilization and penalty bylaw rules but not satisfy the current demand of the community. Bylaw for area exclosure was more focused on environmental conservation than economic benefits. Benefit sharing was equally among the user communities but not equitable. exclosure bylaws were focused on sanction of rule violators and limited on economic rewards. Exclosures in the current time, not effective for generating socio-economic benefits with increasing demand. Most products were limited from exclosures.

For the recommendation, scaling up of area exclosures should improve and diversify the products and services obtained from area exclosure, establish and strengthen continuous monitoring and evaluation systems, boost sense of land and resource tenure rights, and strengthen law enforcement at all levels. Bylaw on area exclosures management should achieve both conservation and economic objectives for sustainable conservation and utilization of exclosures, clearly defined equitable benefit sharing mechanisms based on local criteria, clearly devising timing of short term and long term benefits from exclosures, focused on developing awareness, sense of ownership and economic rewards among users other than focusing on penalties.

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Constructing Comprehensive Forest Resource Accounting System in Ethiopia (EFRAS)

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Abstract

Forests in Ethiopia provide a variety of benefits to people such as food, medicine, energy, shelter, clean water, land stabilization, erosion control, preserving biodiversity, and regulation of climate change. However, many of these benefits from forests do not involve market transactions and therefore are not included in the conventional System of National Accounts (SNA). SNA is used for calculating Gross Domestic Product (GDP), which is the standard indicator for evaluating macroeconomic performances. Some marketed forest goods and services are accounted into other sectors, e.g. industry, agriculture, energy. There is inconsistent treatment of man-made and natural assets. SNA allow depreciation allowance for man-made assets. However, the contributions of environmental assets to economy are not valued and thus, no depreciation allowance is made for these assets.Therefore, this study attempts to develop comprehensive forest resources accounting system, Ethiopian Forest Resource Accounting System (EFRAS) that enable us to measure the direct and indirect economic contribution of forest resources to national economy. This study draws on assessment methods based on the SNA/SEEA framework. The outputs of this study provide policy-makers useful information about the important link between economic growth and the environment. Such information is useful to design more coordinated and effective national development policies that also integrate forest environmental resources. It also uncovers the extent of other sectors' dependence on forests, which helps to build strategic alliances with other sectors, such as agriculture, tourism, hydroelectricity, water and fishery.

Key words: *System of National Accounts (SNA), Gross Domestic Product (GDP); Ethiopian Forest Resource Accounting System (EFRAS), Ethiopia*

Introduction

Forests in Ethiopia provide a variety of benefits to people such as food, medicine, energy, shelter, clean water, land stabilization, erosion control, preserving biodiversity, and regulation of climate change by serving as a carbon sink. However, many of these benefits from forests do not involve market transactions and therefore are not included in the conventional System of National Accounts (SNA). SNA is used for calculating Gross Domestic Product (GDP), which is the standard indicator for evaluating macroeconomic performances. SNA also does not fully take into account the changes in the national forest stock, especially those due to forest degradation. This insufficient inclusion of forest values into the national accounting reflects the fundamental problems with the conventional SNA. As a result, there is a growing interest in finding economic indicators that better capture people's well-being than the conventional national accounting. The focus and intentions of this study is to properly account forest-based economic activities in the national economy drawing on assessment methods based on the SNA/SEEA framework.

The conventional System of National Accounts (SNA) incorporated forest goods that their secondary products are transacted in the market. However, the information included in the ESNA is not sufficient to accurately understand the economic significance of forests for the following three reasons:

1. It misses or underestimatesthe economic value of forest goods or services that are not transacted in the market, mainly because of the domestic or informal nature of their production. A considerable portion of forest income benefits are in-kind benefits associated with the subsistence use of forest goods and services. The value added of wood fuel production, for example, provides very large in-kind income benefits because many households collect wood fuel themselves rather than purchasing it in the market. The current ENSA estimate of the value added of wood fuel in 2013-13 is 25.5 billion ETB ($US3.82 billion), but this figure excluded the in-kind income from subsistence use of fuel wood (Smith, 2016). The current forest related GDP figures also understate forest income because they are unable to include estimates for production that takes place outside of the observed economy (for example, illegal harvesting of wood and in-kind household income benefits from round-wood production).

2. In some cases, the income flows associated with forests goods and services are not captured at all in GDP under the current accounting system.These wild meat production, forest-derived wild edible plant production, civet musk production, forest carbon sequestration, and medicinal plant. The current ESNA requires significantimprovement and incorporate these goods and services by providing comprehensive data and valuation methods.
3. Registers some forest-derivedbenefits not in the forestry sector but in non-forest industries such as the agricultural sector. These, for example, the production of forest coffee, fodder that livestock farmers obtain freely by allowing their animals to graze on forest land, the value added of forest soil erosion control, the value added of forest pollination services, and protected area tourism. The latter benefit is attributed to hotels and restaurants, travel and communications and public administration.

Therefore, the study was conducted with the general objective to incorporate the missing forest goods and services to the ESNA. Specifically, the study is conducted to incorporate forest goods and services that are accounted to other sectors of the economy or totally missed from the ESNA in the system and estimate forestry's share of the missing forest goods and services to the national income.

Materials and Methods

The study was conducted through reviewing the recent practice of accounting Ethiopian Economy, examining its structure and contents about economic values of forest products and service. Review relevant literature, forest sector statistics, economic reports at micro and macro-levels about forest products and service flow in the economy. We reviewed different published and unpublished documents regarding forest goods and services and synthesize them to estimate forestry's share. The data obtained from different sources using primary and secondary data is analyzed using framework of physical and monetary accounts by drawing on assessment methods based on System of Environmental Economics Accounting (SEEA, 2012).

Results and Discussion

The missing Forest Goods and Services

A comprehensive accounting that could estimate the annual value-added originating from Ethiopian forests is vital to accurately assess the total economic contribution of this sector. Inferences from other similar cases (benefit transfer) will be made for those forest goods and services where hard data are not available. The benefits derived from forests can be assessed based on the concept of ecosystem services, which are classified into provisioning, regulating, Cultural and recreational services, and supporting services (MEA 2003).

A. Provisioning Services

The provisional services of forests constitute timber, fuel-wood and various non-timber forest products (NTFPs). Some of those goods are formally sold and purchased as market products, and their market values are to be estimated from those records. A significant part of those goods, however, are either domestically used or only informally exchanged in Ethiopia, and their values cannot be drawn directly from market data. It is therefore necessary to make inferences on missing values based on the information of dispersed data sources. Previous studies on the subject conduct estimations of the quantities and values of forest products in Ethiopia, relying on a combination of market data, generalizations of representative values, and expert judgments.

Livestock Fodder

Fodder was considered important because Ethiopia has one of the largest inventories of livestock in Africa, with livestock ownership currently supporting and sustaining the livelihoods of an estimated 80% of the rural poor. Forest grazing is a major source of livestock fodder in Ethiopia (Nune, et al., 2010;Teketay, et al., 2011; Yimer, 2016). Yimer (2016) found that 33% of farmers' needs for livestock feed are met by forest grazing.

About 5% of forestland, plantation and bamboo; and 24% of woodland, bush land and shrub land are subject to livestock grazing (WBISPP, 2005b).Yimer's estimate of the value added of forest-derived fodder production is consistent with other statistics describing rural households and livestock rearing. Over 50% of the total fodder supply comes from forest resources with forest trees supplying 20%. Fodder trees also provide significant amounts (15–29%) of crude protein. Fodder is usually fed as a supplement to crop by-products or grass, because although its production is limited, it is regarded as a high milk producing forage with high palatability (www.fao.org/). Forests are major source of the feed and fodder for livestock of forest dependent communities (Planning Commission, 2006).

The value of fodder grass from forest resources, which is embedded in the output of the livestock sector. The provision of forest-derived products (livestock fodder) made the greatest contribution to national income. Economic valuation of fodder through scientific method may act as an instrument for incorporation of livestock forest feed contribution into relevant (Forestry) sector of SNA, which is till recently accounted in Livestock. However, the concept of conversion of green to dry weight basis was considered keeping in view of fibrous nature of the forest feed particularly herbs and foliages. The ratio of 33% was considered for dry to green weight of herb and grasses and accordingly price of dry grasses was estimated by multiplying the weight with the green grass price. The WTP for forest fodder which include grasses and tree fodder was estimated through contingent valuation. This was with the premises that the households obtained grasses as well as tree foliages from forests. The forestry sector contribution ranges from 32 to 51% and non-forestry contribution ranges from 30 to 48% in hilly region i.e. forest dominant region.

Forest Coffee

Ethiopian forests are depositories and gene pools for several domesticated and/or important wild plants and wild relatives of domesticated plants. For example, coffee (*Coffee arabica*) is found in the wild in the moist evergreen montane forests of the south and southwest of the country (IBC, 2005). There are four types of coffee production systems: *forest (wild) coffee, semi-forest coffee, garden coffee and plantation coffee*. Forest coffee is self-sown and grown under the full coverage of natural forest trees. Forest coffee accounts for about 10% of Ethiopia's total coffee production (Paulosand, 2000; Workaffess and Kassu, 2000).

Under the semi-forest production system, farmers acquire forestland for coffee farms. However, there is no much farming activity practiced inside the semi-forest coffee areas. They slash weeds once a year to facilitate the coffee bean harvest. In some instance, naturally regenerated or raised seedlings are planted under naturally growing trees. It accounts for about 35% of Ethiopia's total coffee production (Workaffess and Kassu, 2000). About 70% of the semi-forest coffee production is attributed to forest.Modern type plantations only constitute 6 % of the total coffee production area in Ethiopia, while the majority of the production area consists of montane rainforest with wild coffee (Demel, 1999).

Wild Food (edible) Plant

The phrase "wild foods" refers to all plant and animal resources that are not domesticated but gathered and hunted from forests and bush-lands for the purpose of human consumption (Bell, 1995). Wild edible plants refer to species that are neither cultivated nor domesticated, but are available from their wild natural habitat and used as source of food. Forests are sources of livelihoods for people. Gathering and hunting wild foods are one among the many livelihood activities provided by forests.

Food insecurity and malnutrition affect much of the world's population. Wild edible plants are known to make important contributions to the livelihoods of local communities of sub-Saharan Africa countries including Ethiopia. The populations in Ethiopia have a rich knowledge of consumption of wild edible plants and wild edible plants are still an integral part of the society in the country. A total of 22 wild edible plants belonging to 17 families were documented. Most of the wild edible plants were trees (81.82%), Fruits were the dominant edible parts (68%) followed by seed (18%) consumed by the people (Kebede, et.al, 2017). A total of 30 wild edible trees and shrubs were identified and documented, of which 15 species (50%) have a supplementary role in household food security, three species (10%) are used to fill the seasonal food shortage, and 12 species (40%) have an emergency role. In addition to food, four species are used to generate income for households in the southern Ethiopia. The harvestable edible materials also varied from site to site, with average quantities of 85 and 382 kg ha-1 for the lowlands and mid-altitudinal zones, respectively (Assegid and Tesfaye, 2011).Wild edible plants are valuable resources for improving food and nutritional security and income of households living in dry land areas

Medicinal Plants

Most people in Ethiopia have relied heavily on plants; almost 80% of the total population has been using medicinal plants for health care. It is also observed that urban people also use medicinal plants. In most urban backyards, conserving 3 to 4 medicinal plants is a normal practice. However, the extent of species diversity and variability is not discriminated and documented based on scientific grounds. According to traditional healers, the concentration of the chemical composition of Ethiopian medicinal plants varies across altitude, temperature, and moisture regimes. From the corner of modern research, Ethiopian medicinal plants were not properly studied and utilized (Institute of Biodiversity Conservation (IBC, 2012).

Medicinal plants still play important roles in daily life in developing countries. Medicinal plants not only serve as complements or substitutes for modern medical treatments, which are often inadequately available, but also enhance the health and security of local people. Thus, these plants play indispensable roles in daily life and are deeply connected to diverse social, cultural, and economic events associated with life, aging, illness, and death.Similar to the situation in many developing countries, including those in sub-Saharan Africa, 70% of human and 90% of livestock populations in Ethiopia depend on traditional medicines derived from medicinal plants for their primary health care (JAICAF, 2008).

Medicinal usage of NTFPs tends to overlap with that of forest foods; indeed, particular items added to foods serve bothto improve palatability and act as a health tonic or prophylactic. There are also often strong links between medicinal use and cultural values.Traditional pharmaceutical products and wild foods are primarily for domestic consumption and made from plants growing in the forest (JICA, 2017).According to Ethiopia data portal total health expenditure of Ethiopia at 2012 was about 2,042.33 million US dollar (Ethiopia Data Portal, 2014).Based on this figure, we can estimate the value of medicinal plants in Ethiopia.

Spices

The production and use of spice crops in Ethiopia has a long history. They are used in the Preparation of daily dishes, and as traditional medicines. The popular indigenous spices of Ethiopia include: black cumin (*Nigella sativa* L.), coriander (*Coriandrum sativum* L.), sweet basil (*Ocimumum bassilicum* L.), garden cress (*Lepidium sativum* L.), Ethiopian cardamom (*Aframomum corrorima* (Braun) Jansen), wild pepper (*Piper capense*L.), Ethiopian caraway (*Trachyspermum ammi* (L.) Sprague ex Turrill),and *Koseret* (*Lippia adoensis* Hochst.Ex Walpvar *koseret* Sebsebe). They are cultivated in small plots of land in home gardens often as secondary crops. They grow all over the country, and have huge diversity with regard to agro morphological characters (EIAR, 2008).

Korarima and long pepper exist both under cultivation and in the wild states. However, the bulk of the product comes from the natural forests in the south and south western parts of the country where coffee grows. Farmers collect these spices from these forests and sale at the local market. These days, however, the destruction of the natural forests for various uses has significantly reduced the diversity of these shade obligate spices.

Honey and Beeswax

Ethiopia is one of the top 10 producers of honey in the world, and it is the largest one in Africa (USAID, AGP-AMD, 2012).The total volume of honey production in 2011 was estimated to be 39.89 million kg (CSA, 2012).Ethiopia is known for its tremendous variation of agro climatic conditions and biodiversity which favored the existence of diversified honeybee flora and huge number of honeybee colonies It has the largest bee population in Africa with over 10 million bee colonies, out of which about 5 to 7.5 million are estimated to be hived while the remaining exist in the wild. This makes Ethiopia a leading in Africa and ninth in the world in honey production, respectively. Similarly, it stands first in Africa and third in the world in beeswax production.Traditional beehives make up 95.57 percent of the total quantity of beehives in Ethiopia, while the percentage of transitional (Kenya top bar) and modern beehives are 1.63 percent (81,596) and 2.8 percent (139,682), respectively (CSA, 2012).

The country's potential for honey production, the variety of natural honey flavors associated with the country's diverse sources of bee forage, and Ethiopian honey's desirable qualities, such as low moisture content, have been widely recognized(Honey Production in Ethiopia, 2017). Most of the forest trees produce abundant nectar and pollen, which supports a huge number of bee colonies. Beekeepers do not use antibiotics or other medicines and so the beeswax is free from chemical residues. (Tropical Forest Products, http://www.tropicalforest.com/). The average household in Ethiopia is composed of six people, and annual honey consumption is estimated to be 10 kg per household. Honey in Ethiopia is generally produced as a cash crop, with yearly sales amounting to 90 to 95 percent of total production. Currently, the majority of honey produced (about 70 percent of the 90 to 95 percent designated for sale) is sold to *Tej*houses. The remaining portion is marketed as table honey for general consumption (Tadesse and Phillips, 2007).

According to the study conducted in Hammer district, about 61 and 68% of sample households at the Agro pastoral and pastoral site indicated the production of honey as one of their forest-based livelihood activities. According to the household survey, honey production in the study areas was mainly carried out by placing hives hanged in a forest. Honey from the forest is produced /harvested three to five times annually; and three to five Kilograms of honey can be produced in one bee hive in one harvest. As reported during the survey, households delivered the raw honey to the nearby market, without product processing or any other value adding activity. The raw honey was reported to be sold at an average price of ETB 40 per kg. Income from honey contributed a significant proportion of the annual forest income of households at both study sites: of the total forest income of 2390 ETB at AGPAS and 2827 ETB at PAS, honey accounted for 47 and 51 % (D. Fikir, W.Tadesseand A. Gure, 2016).Ministry of Finance and Economic Development (MoFED)makes no estimate of forest-derived honey value added. Rather, it estimates the value added of honey in general (forest-derived plus non-forest) and reports this as part of the value added of the livestock agriculture industry.

B. Regulating Services

A large number of studies have found that the forests offer a variety of regulating services such absorption and retention of carbon dioxide, water flow control and soil erosion control, reservoir sedimentation control, and pollination. All of the services, other than carbon sequestration, are already implicitly included in MOFED's estimate of GDP but they are not attributed to the forestry industry. Rather, they form part of the value added attributed to the crop agriculture and electricity and water industries, the vast majority to the former. Carbon sequestration is currently a gap in the Ethiopian system of National Accounts (ESNA).

i. Carbon Sequestration Service

The carbon sequestration service is the absorption and retention of carbon dioxide as a greenhouse gas and it is one type of regulating service provided by forests. This service has been widely discussed worldwide both by academics and practitioners. The emitted CO_2 affects the global climate and has negative consequences on human activities, such as a declining crop yields and intensifying natural disasters from extreme weather. Thus, the unit cost of deforestation in Ethiopia, or the unit benefit of Reducing Emissions from Deforestation and Forest Degradation (REDD) measures in Ethiopia, should in principle be identical with the Social Cost of Carbon (i.e., an estimate of the global economic damages associated with a unit increase in CO_2 emissions in a given year) that is estimated globally.

The capacity for carbon retention by forests and woodlands varies depending on prevailing tree species, tree density, and age structure, and the estimation of carbon contents should in principle take into account the heterogeneity of such features across all the forest areas of the country. The annual carbon stock balance or change was calculated by converting the volume-based balance into a carbon equivalent and then carbon dioxide equivalent (CO2e) quantity. That means the volume at the beginning of the year, the volume of timber, construction wood, and fuelwood harvested during the year were all converted to carbon stock equivalent using a Biomass Conversion and Expansion Factor (BCEF) for the various forest types, and using a carbon fraction of

50%, i.e. assuming half of the biomass being carbon based on the IPCC good practice guide (IPCC, 2006). The average Root to Shoot (R/S) ratio of 25% was applied to calculate the below ground carbon stock. The range of R/S ratio applied varies from 20 to 30, based on forest types. The carbon stock is converted to CO2e by multiplying the carbon stock with the factor 44/12. See Table 2 for details of our parameter choices.

The value of forest carbon is calculated by multiplying the amount of carbon mass in the forests of Ethiopia and the price of a unit of carbon (tCO2e), which reflects the climate policy. Benchmark carbon price value (US$12/tCO2e at a 5% discount rate, adjusted to a 2013 dollar unit) can be used for this study following the Social Cost of Carbon presented by the US government (Interagency Working Group on Social Cost of Carbon 2013, updated in 2015).

ii. Soil Erosion and Water Flow Control

Academicians and policymakers recognize that much of the Ethiopian land has been experiencing a serious problem of soil erosion, and that vegetation can mitigate the problem (e.g., Hurni, et al., 2015). Previous economic valuation studies of Ethiopia also consider this issue, using various estimation approaches to assess the value of vegetation for soil erosion mitigation. Nune et al. (2013) calculate the value of soil erosion mitigation by forests from estimates of two parameters: the crop productivity loss per unit of soil loss and the soil conservation efficiency of forest land. Meanwhile, Reichhuber and Requate (2012) estimate the value of watershed services by forests including erosion control by referring to figures from a case study in the Mount Kenya Forest Reserve. Another set of relevant studies use cost-benefit assessments of exclosures to provide estimates of the benefits of exclosures on soil erosion affecting agricultural productivity. Balana et al. (2012) calculate the benefits of vegetation on soil as the increased productivity of plant biomass. Mekuria and Aynekulu (2011) and Mekuria (2013) estimate the value of soil nutrition retention by forests by both investigating physical properties and conducting a socioeconomic survey. Therefore, it is possible to consider the benefits of soil erosion mitigation not for forests in general but only for exclosures, whose benefits on farming are clearer than those for other types of tree-covered areas, and we estimate monetary-equivalent benefits using the case study by Mekuria et al. (2009).

Soil erosion not only reduces nutrients in farmlands but also causes sedimentation of dams and reservoirs. Keeping natural forests helps reduce the problem of sedimentation, as natural forests are largely able to retain soil on the land (Ahmed and Ismail, 2008). This benefit of Removal of sediments from dams and reservoirs is widely performed across Ethiopia, involving costs borne by public expenses. In his valuation study of deforestation in south-west Ethiopia (the Baro-Akobo Basin), Sutcliffe (2009) estimates the cost of deforestation from increased sedimentation by assuming it to be equivalent to the increase of removal costs of sediments. The monetary values can be calculated by taking an average of recent data from observational studies of Haregeweyn et al. (2012) and Mekonnen et al. (2015). It is estimated that the unit removal cost by machinery to be about 33.35ETB/m3.

iii. Reservoir sedimentation control

The presence of vegetation generally affects the hydrology of river basins and also water quality (Brauman, et al., 2007). The nature of forests' effects on hydrology is however influenced by various factors such as topology, rainfall patterns, the size of watersheds, and soil conditions.Forests potentially reduce the flood frequency and damages. A global study by Bradshaw et al. (2007) finds that flood frequency is negatively correlated with the amount of remaining natural forest and positively correlated with the loss of natural forest area. However, a later study by Ferreira and Ghimire (2012) concludes that the relationship is not clear when a similar method but a larger dataset are used. As of yet, there is no country-level assessment on the relationship between forest cover and flood frequencies in Ethiopia.

iv. Pollination

Other important regulating services of forests include pollination, i.e., forests as a habitat for pollinators. The currently SNA makes no direct estimate of value added from pollination service. However, this income is captured implicitly in ESNA's measure of the value added of the crop agriculture industry. Pollinators play an important role in plant reproduction. While many plants are capable of self-pollination, the majority depend to some extent on animal pollinators. A loss in the diversity and abundance of pollinators can lead to a parallel loss of plant diversity and abundance. Animal pollination is an important ecosystem service for agricultural production. Pollinators can improve the quality and quantity of many crops – even those that are capable of self-pollination – increasing yields and farmer incomes as a result. A wide variety of agricultural crops would decline in productivity in the absence of animal pollination, including some 70% of the 1330 crops grown in tropical regions. Crops that depend on animal pollination include fruits, vegetables, nuts, and oil seeds (Aizen, et al., 2009). Many of the crops that rely on animal pollination, including coffee, have relatively high market prices and are important to regional economies. The production of crops reliant on pollinators is also increasing faster than the production of crops that are not reliant on pollination (Aizen, et al., 2009). This creates a worrying scenario for future agricultural production should pollinator abundance and diversity continue to decline (Smith, 2016). Retaining the services of wild pollinators requires that natural habitat is maintained within agricultural landscapes. Pollinators have limited a foraging range and depend on natural habitat to nest and feed. Declines in wild bees in agricultural landscapes have been linked to loss of natural habitats that provide feeding and nesting ground (Klein,et al., 2007).

C. Cultural and Recreational Services

a. Protected area tourism

Forests provide many cultural services, such as tourism, amenities, spiritual and existence values, cultural heritage, and identity. Although most of these services cannot be fully captured by the utilitarian framework, a part of those cultural services could be assigned monetary-equivalent values through methods of economic valuation. The values of forests on tourism are the simplest to be evaluated among all their cultural services. Forests often characterize the landscape and also support the wildlife, and consequently the presence of forests may determine how attractive certain natural areas are to tourists. The number of visitors and the amount of revenues in entry fees to the protected areas (wildlife reserves) in Ethiopia are recorded by the Ethiopian Wildlife Conservation Authority (EWCA).In Ethiopia, all the protected areas could be regarded as natural forests or woodlands. Thus, the economic benefits of protected areas including secondary benefits such as revenues earned from visitors should be counted as revenueearned from forests in the form of tourism benefits.

Estimation ofthe MissingForest Goods and Services

The data on forest coverage and composition are essential for a forest accounting and such data should be obtained from MEFCC recent forest inventory. Forest areas include not only the narrowly defined natural forest but also four other types of tree-covered areas: the plantation, the woodland, the shrub land, and the trees outside forests, which is consistent with those in the WBISPP classification and definition. All of the forest goods and services listed above are accounted directly and indirectly to other sectors of the economy. So appropriate share of these products should be accounted to the forestry sector and here we tried to estimate forestry's share by reviewing different literatures.

Provisioning Services

Honey and Beeswax

Other than areas with extreme climatic conditions, beekeeping is common in most villages and in virtually all smallholder farms in Ethiopia. The sector is characterized by a large number of smallholder farmers with low average yield per hive (MoA and ILRI, 2013). Generally, honey production of the country is categorized into three which are traditional, intermediate and modern (CSA, 2015). Of these, production using traditional beehives is the dominant one. Forests are the major sources of forage for bees in the country.

Beeswax is a valuable hive product obtained from honeybees as a by-product of honey production. Beeswax is largely collected from traditional hives. Wax yield from traditional hives is 8-10% of the honey yield, compared to 0.5-2 % from modern hives (Mulugeta, 2011). In the current Ethiopian system of national accounts (ESNA) honey and beeswax are fully accounted for the livestock agriculture sector (Smith, et al, 2016). Forest being the major contributor for beekeeping the appropriate share of these products should be accounted to the forestry sector. Nune et al. (2010) assumed that 70% of the total honey and beeswax production is derived from forest resources. Another study by Smith et al. (2016) estimates that 70% of the traditional, 50% of the intermediate (transitional) and 20% of the modern honey production and 70% of beeswax production should be accounted for the forest sector. By using these estimates and CSA (2015) data on honey production of the country about 66% of the total honey production is derived from forest resources. By considering the above two literatures the share of forestry sector from the total honey production ranges from 65 to 70% and we take 65% appropriate cause we believe that the share of intermediate and modern production will increase. We can take similar figure with the previous studies for beeswax. Therefore, forestry's share of honey and beeswax production is estimated to be 65% and 70% of the total annual production respectively.

Forestry's share of honey = total production of honey in Kgs/tones in a given year * 0.65

Forestry's share of beeswax = total production of beeswax in Kgs/tones in a given year * 0.70

Coffee

There are four different ways of producing coffee in Ethiopia i.e. forest coffee, semi - forest coffee, garden coffee, and plantation coffee. *Forest coffee* is a wild coffee grown under the shade of natural forest trees, with no defined owner. *Semi-forest coffee* farming is a system where a farmer living near by a forest coffee does some thinning and pruning on the forest coffee to finally claim ownership of the forest coffee. The thinning will allow adequate light to reach the coffee plant without exposing the plant to too much sunlight. The farmer who prunes and weeds the forest area claims to be the owner of the semi-forest coffee and collect the annual yield of the plant. *Garden coffee* is normally found in the vicinity of a farmer's residence. Farmers use organic fertilizers to produce *Garden coffee* and inter-crop it with other crops. *Plantation coffee* is commercial farms planted by the government or private investors for export purposes. Fertilizers and herbicides are usually used in this coffee plantation farming system (Abu and Teddy, 2014).

Forest coffee accounts for 10%, semi-forest coffee for about 35%, garden coffee for about 35% and plantation for about 15% (5% government, 10% private) of total coffee production in Ethiopia. 95% of coffee produced under these systems is organic. (CSA, 2008) as cited in Chauhan*et al* 2015. Differently according to Gole forest coffee, garden coffee and plantation coffee account for 55%, 35% and 10% of total coffee production respectively (Smith, et al., 2016). The forest-based traditional coffee production systems mainly include: forest coffee (FC), semi-forest coffee (SFC) and forest garden coffee (FGC). The level of management intensities varies from a little (none) to significant influences in these different coffee production systems. These forest -based coffee production systems with different management intensities accounts for about 50 -60% of the total production in Ethiopia (MoA, 2013).

Nune et al. (2010) take 100% of forest coffee and 70% of semi forest coffee while UNREDD take 100% of forest coffee (includes semi forest coffee), 100% of plantation coffee and 50% of garden coffee based on a suggestion by Tadesse Gole, Director of the Ethiopian Environment and Coffee Forest Forum. So, based on the above literatures at least 60% of the total annual coffee production should be accounted to the forestry sector.

Medicinal Plants

The various literature available show the significant role of medicinal plant in primary health care delivery in Ethiopia where 70% of human and 90% of livestock population depend on traditional medicine similar to many developing countries particularly that of Sub-Saharan African countries (Endashaw, 2007). Smith et al. (2016) assumed 80% of the medicinal plants are derived from forests (assuming that all wild plants come from forested areas). Nune et al. (2010) assume that forestland, plantation and other forest types (woodland, bush land, and shrub land), respectively, will supply 100, 5 and 60 percent of medicinal plants and derive the pharmaceutical value of a specific forest by multiplying the respective forest area by per hectare value (US$ 1.80 per ha per annum which is based on a study by Reichhuber and Requate (2007) in Yayu and Sheko districts of south-west Ethiopia) and its percentage contribution of medicinal plants. By considering the work of Smith and his partners and assuming that some of the wild plants can be obtained from areas other than forests we suggest that 70% of the medicinal plants are derived from forests and should be accounted to the forestry sector.

Spices

Ethiopia is one of the ten countries in the world where spices are used the most, in particular in meat-based recipes. Most Ethiopian foods are spiced. Jansen (1981) lists 12 major spice plant species, and provides a detailed account of the taxonomy, husbandry, distribution, culinary and medicinal uses, and chemistry of these spices. Most of these spice species are grown in home gardens or cultivated as field crops, and a few are collected from the wild. Korarima and Timiz are two most popular spices that are produced as non -timber forest products in Ethiopia. Both occur in humid montane forests of south western Ethiopia, in a similar habitat with wild coffee. In Ethiopia, Korarima and Timiz are mainly produced from wild population in the forest, though there are some efforts of domestication. Hence, they represent key NTFPs of humid forest in the southwestern part of the country along with coffee and honey (MoA, 2013).

Over forty spices, herbs, medicinal and essential oil plants are still grown in Ethiopia, but the four most important are ginger, turmeric, cumin and korerima, with market shares of 65%, 15%, 8% and 3% respectively (Meaton, et al., 2013). According to Smith et al, 2016 the spices mostly derived from forest are korerima and long pepper and 90% of both korerima and long pepper are assumed to be derived from forests taking in mind that korerima's and long pepper's share 3% and 1% from the total spice share.Keeping in mind that most of these two spices are collected from the forest, at least 90% of these spices should be accounted to the forestry sector.

Livestock Fodder

As cited in Smith et al. (2016), Yimer (2016) found that 33% of farmers' needs for livestock feed are met by forest grazing. He further found that:

- 92% of rural households keep livestock
- The average rural household keeps about 12.3 head of livestock of various sorts with an annual animal feed (dry material) requirement of 3.35 tones
- The average market cost of dry animal feed is 1,619 ETB/ton, and
- The average rural household has 6.2 members.

Then take the rural population and divide it by 6.2. Multiply the result by 0.92 to get the total no of households who keeps livestock. Then multiply it by 12.3(average no of livestock per hh), 3.35 (annual feed requirement in tones per head), 1619 (average cost of feed in birr/ton) to find the total value of livestock fodder derived from the forest.Nune et al, 2010 estimated the value of forests in supplying fodder using the opportunity cost of agricultural land needed to grow the amount of fodder supplied from forests. Here we found Yimer's work more convincing and take that 33% as an appropriate share of forestry for livestock fodder and should be accounted to the sector.

Wild Edible Plants/Fruits/Foods

The estimated wild meat value is 475 million Birr (Robert, et al., 2015). Accordingto Hugo van Zyl (2015), EWCA is administrating an area of 3.9 million ha which bounded 1.8 million ha of forest and woodlands (Vreugdenhil. et al., 2012). Based on area relation (1.8 million ha) computing with the total area, the share of the forest for meat is 219.23million Birr per year from the protected areas.

The estimated value wild edible plants are 206 million Birr per year (Hugo van Zyl, 2015). By computing the areas relations, protected areas forest contributes 95.1 million Birr per year. Wild meat and edible plants, they altogether contribute 314.33 million Birr per year. In one period of time (2015), the overall contribution of forest for protected area was 355 million Birr per year.

Regulating Services

Carbon Sequestration to Mitigate Climate Change

The Government of Ethiopia launched a Climate Resilient and Green Economy Strategy (CRGE Strategy) in 2011 with the goal of achieving middle-income status for the country by 2025 while following a carbon-neutral growth path. The existence of forest resources is necessary in achieving this goal through the capability of forest resources in carbon sequestration (limiting the build-up of CO_2 in the atmosphere) and thereby mitigating climate change. The carbon sequestration impact of Ethiopian forest resource is the potential for the country to gain foreign income in return for increasing the rate at which carbon is sequestered in its forests or decreasing the rate at which it is emitted due to deforestation (Smith, et al., 2016).

As cited by Nasi et al. (2002), Brown and Pearce (1994), Dixon et al. (1994) and IPCC (2000) suggest benchmark figures for carbon content and loss rates for tropical forests. A closed primary forest stocks in vegetation and soils around 250 tons of carbon per ha and if converted to agriculture would release about 200 tons, and a little more if converted to pasture or permanent agriculture. Open forests would begin with around 115 tons of carbon and would lose between a quarter and third of this on conversion. To the extent that this carbon stored in forests is at risk of being released into the atmosphere, it has a high economic value. A review of the literature by Clarkson (2000) suggests a consensus value of $34 per ton and Tol et al. (2000) suggest that it is difficult to produce estimates of marginal damage above $50 per ton (Robert, et al., 2002). In practical terms, a better guide to the value of carbon is what it is likely to be traded at in a "carbon market" because the market determines the value of carbon, which may be less than the price suggested by different scholars.

Markets for carbon dioxide (CO_2) and carbon monoxide (CO) are however not that well established, although there has been some experimental trading of CO_2 recently, usually in the $1 to $20 per ton range (see examples in Egenhofer and Mullins, 2000; Williams, et al., 2000). Costa Rica developed its system of Certified Tradeable Offsets (CTO). These CTO's are credits of carbon fixation based on the amount of carbon dioxide fixed in forests. The first batch were sold of 200,000 tons of carbon for US$10 per ton of C for US$2,000,000 to Norway (Nasi, et al., 2002). The recent carbon price value (US$12/t$CO_2$e at a 5% discount rate, adjusted to a 2013-dollar unit) can be used for this study following the Social Cost of Carbon presented by the US government (Interagency Working Group on Social Cost of Carbon 2013, updated in 2015).

Such payments represent a potentially large source of forest-derived income for Ethiopia. Studies show that Carbon sequestration is currently a gap in the Ethiopian System of national Accounts (ESNA). This gap will require filling if payments for emissions reductions through REDD+ and other mechanisms become important in the future. Ethiopian GDP also need to be adjusted for the benefits from carbon sequestration by forest plantations since it is realized within climate sensitive industries as a result of reduced climate change impact even though source sectors are not charged with the social costs of their carbon dioxide emission externality. Accordingly, the value of these benefits needs to be established and reallocated (reduced) from value added of source sectors and accounted to value added in forestry (Nune, et al., 2010)**.** This will adjust for the proper accounting of the contribution of the forest resources to GDP of Ethiopia.

At the moment, payments for emissions reductions are negligible in the Ethiopian national context because it is not currently considered in the contemporary Ethiopian SNA. The Humbo and Soddo Community-Based Natural Regeneration Project, initiated in 2004, was the first carbon sequestration project in Ethiopia and the first forestry CDM project in Africa. It involves the rehabilitation of degraded forestland to sequester carbon and provide a variety of other community benefits (greater availability of non-timber forest products, for example). About 888,000 tons of CO_2 is expected to be sequestered at the site over 30 years, generating certified emission reduction credits. Only this project is currently operational in the country and it had generated just 2.8 million ETB as of 2013, all of which flowed to local communities in SNNPR state (for which the project undoubtedly has significant benefits) (Smith et al, 2016). Further revenue will be available to the community from the sale of the remaining carbon credits not purchased by the World Bank on the secondary carbon market, as well as from the sale of timber products from designated woodlots in the project area.

Some studies conclude that the largest store of carbon in the country is found in the woodlands consisting 45.7% and the shrub lands 34.4%, using WBISPP data as relevant source of information for Ethiopian forest carbon accounting (Nune, 2010). The same study proves that the national carbon stocks in Ethiopian forest resources is about 2.7637 billion tones and it largely agree with 2.5 billion tons in 2005 reported by Nune et al.(2010), Brown (1997) reported a carbon density of 101 tons ha^{-1} for high forests in Ethiopia, and agrees well with the estimate presented here. However, some case studies show even higher carbon density values of close 200 tons ha^{-1} than the estimates based on WBISPP for high forests in Bale Mountains (Nune, et al., 2010).

The accounting of carbon sequestration of Ethiopian forest resources is significant to the Ethiopian national income if well accounted to the ESNA. Even using the estimates of the carbon stock above if we calculate the monetary value of carbon stocks it will be about 33 billion USD. This amount money from carbon trade will boost the contribution of forestry sector to Ethiopian economy in general and export sector in particular. Therefore, using the current forest inventory by MEFCC on the carbon stock sequestered by Ethiopian forest resources the study will construct the monetary contribution of forest resources to the Ethiopian national income through increase in GDP.

Watershed and Associated Soil Protection and Regulation

Ethiopia is indicated as the highest levels of soil erosion and soil nutrient depletion. It is estimated that more than 50% of the land is affected by soil erosion, 25% being seriously eroded and 4% of it has no longer productive (Chimdesa, 2016). It is estimated that a 13% yield loss is as a result of severe degradation on 40% of agricultural land and moderate degradation on a further 9% of agricultural land, is equivalent to a decline in water use efficiency of at least 13%. The severity of soil degradation in the Ethiopian highlands is the result of the past and present agricultural activities, mountainous and hilly topography, torrential rainfall, low degree of vegetative cover and unsustainable land resource management in general. The average annual rate of soil loss in the country is also estimated to be 12 tons/hectare/year and it can be even higher (300 tons/hectare/year) on steep slopes and on places where the vegetation cover is low (Fisseha, 2016).

Many scholars witnessed that forest provides water shade and soil nutrient protection services to different sectors such as agriculture and electricity sectors. Watershed protection benefits were essential because there are clear direct impacts of change in forest cover on watershed functions which encompasses soil erosion, altered downstream water flows, flooding and sedimentation, and consequent damage to agriculture, fisheries, dam storage, and power generation. It is proved by some researchers that the soil conservation efficiency of forestland and other forest types (woodland, bush land, and shrub land) is assumed to be 99 and 93 percent, respectively, compared to bare land. Data on soil conservation efficiency for bamboo and plantation forests are not available. For bamboo, however we assume soil conservation efficiency of 99 per cent compared to bare land. This is because bamboo forests are characterized by a complex network of rhizome-root systems, which makes the bamboo forest better than other forest types in effectively holding soil particles together, thereby preventing soil erosion and promoting water percolation (Embaye, 2003).

Indirect environmental benefits and ecological services provided by forest resource is already accounted for in Ethiopian GDP through the manifestation of its impacts on the affected sector and activities. For instance, the benefits of watershed protection services of forest are already realized as higher output within the agriculture sector as potential damage leading to reduced output is avoided. Ministry of Finance and Economic Cooperation of the Federal Democratic Republic of Ethiopia does not estimate the value of these services directly in GDP, though their values are implicitly included in the value added of the agriculture industry that uses them (UN-REDD, 2016). The value of these services, however, needs to be estimated and reallocated to value added of the respective sectors without altering existing GDP. An estimate of the value of the contribution of forestry through watershed protection needs to be established and reallocated to forestry, i.e. subtracted from agriculture value added and attributed to forestry value added to show the proper contribution of forestry sector to the national economy (Nune, 2010**).** According to the recent report of Smith et al. (2016), the value of forest water flow control services could not be estimated based on available data and the value of sedimentation control in reservoirs was found to be negligibly small (Smith, et al., 2016).

But the services provided by forests in watershed protection can be valued using replacement cost approach and its benefit in preventing soil erosion can be accounted through the change in productivity method. For instance, the value of water shade services of forest resource can be measured in terms of loss in crop yields due to soil erosion, sedimentation, or flooding. Using the change in productivity approach, it is possible to value soil erosion prevention benefits of forest resources. The value of the watershed protection benefits of forestland, bamboo and other forest types (woodland, shrub land and bush land) are ETB 27.25, 22.12 and 25.68 per hectare, respectively. The value of watershed benefits of each forest resource is derived by multiplying the respective area account by per hectare watershed value and its soil conservation efficiency value. Based on this, the total watershed value of Ethiopian forest resources is estimated to be worth ETB 230.32 million in 1995 and ETB161.29 million in 2005 (Embaye, 2003). As cited by Nune et.al, according to a recent estimate by World Food Programme Ethiopia (WFPE), the value of crop productivity loss of 1 ton of soil loss on cultivated land varies from ETB 0.35 to ETB 0.73, with an average value of ETB 0.395. In this accounting, the average value of ETB 0.395 per ton of soil loss is used. Average annual soil loss from forestland, other forest types (wood, bush land and shrub land) and bare land is estimated at 5, 1, and 70 tons/ha/year, respectively (Nune, et al., 2010).

Other countries like Brazil have in several federal states implemented an Ecological VAT, where heavily forested municipalities are tax-rewarded for their water and recreation services. As a result, they have received a more than proportional share of VAT tax revenues, based on regular monitoring of their forest size and quality, so that forest rehabilitation is also being rewarded (Nasi, et al., 2002). If we apply the accounting for services provided by the forest resources in Ethiopia using the above methodologies, there will be dual advantage for the country's economy. On one hand, there will be increase in gross domestic product of the country as a result of proper accounting of the missing services from forestry sector. On the other hand, the increase in contribution of forestry sector to the national income will enable the policy makers to give more emphasis to this sector, which in turn results in forest conservation and creating the multiplier effect on Ethiopian GDP.

Pollination and Pest Control Services of Forest

There is growing evidence that forest ecosystem services, such as biological pest control and crop pollination, benefit world food production. Forests resources are used as a habitat for pollinators in agriculture sector contribution to the increase in world crop production. At least 1,035 species of vertebrates, including birds, mammals, and reptiles, also pollinate many plant species. In turn, the continued availability of these pollinators depends on the existence of a wide variety of habitat types needed for their feeding, successful breeding, and completion of their life cycles. Studies indicated that most important pollinator for agricultural purposes is the honeybee (a European species) but natural 'wild' pollinators' services are worth between $4 and $7 billion a year to United States agriculture. These wild pollinators are often forest species and are sustained by natural forest habitats adjacent to farmlands(Nasi, et al., 2002).

Nevertheless, the currently SNA makes no direct estimate of value added from pollination service. However, this income is captured implicitly in ESNA's measure of the value added of the crop agriculture industry. It is an ecosystem service in that wild pollinators, in particular wild bees, contribute significantly to the pollination of a large array of crops. As cited by Ghazoul (2005), most crops do not totally depend on pollinators, i.e., only 13 globally important crops would be entirely unable to set fruit if pollinators were absent. However, the majority of crops 75 percent – showed a reduction of fruit quality or quantity, or both, when pollinators were excluded experimentally (Klein, et al., 2007).

In addition, more than a decade of active pollination research has led to a greatly improved general understanding on animal pollination benefits to crop yields worldwide. Production of 39 of the leading 57 single crops increases with pollinating animals. In aggregate, these crops account for 35% of global food production, but because most of these crops are not entirely dependent on animal pollination, the amount of production directly attributable to animals is lower than this value. In addition, production of 48 of the 67 crops of the five leading global commodities increases with pollinating animals. Only insects are demonstrated pollinators of the single crops, while vertebrates pollinate very few commodity crops (Bartomeus, et al., 2014). Other findings stated that twenty percent of the overall crop production comes from crops that increase fruit and vegetable production with animal pollination, and 15% comes from crops that increase seed production with animal pollination (Klein, et al., 2007). The total economic value of pollination worldwide amounted to €153 billion, which represented 9.5% of the value of the world agricultural production used for human food in 2005 (Gallai, et al., 2008).

Forest resources are also very useful in crop pest’s control. Different studies in the world show that an estimated 99 percent of potential crop pests are controlled by natural enemies, including many birds, spiders, parasitic wasps and flies, lady bugs, fungi, bacteria, viral diseases, and numerous other types of organisms. As cited by Nasi et al. (2010), the natural biological control agents save farmers billions of dollars annually by protecting crops and reducing the need for chemical control. Moskowitz and Talberth (1998) report that the cost to U.S. agriculture of replacing natural pest control services with chemical pesticides would be about $54 billion annually. In Costa Rica, a citrus plantation pays an adjacent forested conservation area $1 per hectare every year to provide natural pest control services(Nasi, et al., 2002). However, in Ethiopian no emphasis is given to accounting of forest sector regarding pollination and biological pest control services provided by forest resources, which in turn makes forest sector to be the least contributor to the national income. Therefore, using different approaches explained above in accounting of pollination and biological pest control services of forestry sector is advantageous as it increases the contribution of forest sector to the national income and increment in GDP.

3. Cultural and Recreational Services

Forest Contribution for Protected Area Tourism

Ethiopia protected areas comprise national parks, wildlife reserves and sanctuaries. Protected areas forests in the country are footing of different services. Such as harvesting forests often illegally by both surrounding communities and, in some cases, by households living inside boundaries. According Zyl (2015), the overall services provided by the protected areas are:

A. grazing
B. medicinal plant collection
C. watershed protection and water delivery
D. carbon sequestration
E. pollination and pest control
F. tourism and recreation
G. existence and cultural values

Ethiopia Wildlife Conservation Authority (EWCA) is administrating 14 protected areas which have an area of 3.9 million hectares at federal level. Out of 3.9 ha, 1.8 million ha is forest and woodlands (Vreugdenhil. et al., 2012). This is 46.15 percent of the protected areas are forests and woodlands.In 2012/2013, EWCA collected 30 million Birr (Zyl, 2015). Using the relation forest and total area, the share of contribution of the forest and woodland is 13.85 billon Birr per year. Here, the contribution of carbon sequestration is not counted. Within EWCA protected areas, carbon stock estimated to a value of 90 billion (Zyl, 2015). Based on area relation (1.8 million ha) computing with the total area, the share of the forest contribution in carbon sequestration is 41.54 billon Birr per year.

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Comparative Economic Analysis of Three Competing Land Use Types in Southern Ethiopia: Tools for Informed Decision-Making on Land Use Choices

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Abstract

Land is a scarce natural resource and increasingly being constrained by competition among mutually exclusive uses. Ethiopia has experienced serious challenges to allocate this limited resource to socio-economically efficient uses. By using economic performance indicators such as Net Present Value (NPV) and Benefit Cost Ratio (BCR), this paper compares the socio-economic value of three major competing land use types in southern Ethiopia over three investment time horizons (5, 10 and 15 years). The study aims to provide empirical evidences for rational decision-making in allocating scarce land resources. We applied descriptive statistics, ANOVA, and econometric model to analyze and present the results of these three land uses. Wood Based Mono-Cropping (WBMC), Tree Cereal Mixed Cropping (TCMC), and Cereal Based Mono-Cropping (CBMC). Our results reveal that the economic value of WBMC is significantly higher than CBMC and TCMC as shown by the two performance indicators (NPV and BCR). Our study also finds labor, product price, land, tenure security, and rainfall variability significant to explain factors that determine farmers' land use choice in the study area. The study concludes that WBMC is economically feasible compared to the two-competing land uses and is a lucrative enterprise in the study area. The outputs of this study can give useful insights for smallholder farmers and investors who like to engage in forestry enterprise; and assist decision-makers and practitioners to improve the current practices in land use planning.

Key words: Net Present Value, Benefit Cost Ratio, WBMC, TCMC, CBMC, Southern Ethiopia.

Introduction

Over the past decades, land use pattern in developing countries has shown an unprecedented dynamic change, mainly because of demographic pressure and the growing demand for crop and livestock products. Similarly, in Ethiopia, the scale and pace of the ongoing land use changes are historically unprecedented primarily due to the expansion of arable land by smallholders and large commercial farms. For instance, cultivated area in Ethiopia has increased from 9.44 to 15.4 million ha between 2001 and 2009 (Alemayehu, 2014). Franks et al. (2017) also reported that crop production area has increased by 88 per cent between 1994 and 2014. It is projected that total cultivated area will reach 27 million hectares by 2030 with an annual growth rate of 3.9%, following the conventional agricultural development path (Melaku, et al., 2015). The demand for spatial expansion of land to increase agricultural production often creates the conflict of interest between agriculture and other land use options, which put the different economic sectors in a state of competition rather than complementing one another. In addition to improving agricultural intensification and biotechnological innovation to meet the growing demand for food, natural resource management deserves significant focus in the face of growing competition for cultivable land.

In Ethiopia, lack of comprehensive information on socially, environmentally and economically feasible land use options is often mentioned as a key problem for the inefficient allocation of scarce land resources. As the demand for land grows, efficient allocation of this scarce resource becomes more crucial than ever. Comparative economic analysis of the competing land uses can be a useful tool to understand the evolving patterns of land allocation in the country and eventually improve the current practices in land use planning. This study aimed to analyze the economic performances of three competing land use types and identify factors affecting land use choices in Southern Ethiopia. The outputs of this study provide concrete evidence for making rational decisions in allocating scarce land resources. The three competing land use types studied were Wood Based Mono-Cropping (WBMC), Tree Cereal Mixed Cropping (TCMC), and Cereal-Based Mono-Cropping (CBMC). The economic performances of the three land use types were compared across three-time horizons (5, 10 and 15 years) using economic performance indicators such as Net Present Value (NPV) and Benefit Cost Ratio (BCR). Data were collected from one hundred and twenty sample units through structured questionnaire and direct measurements of the farm plots in Gedeo zone of Southern Nations, Nationalities and Peoples Regional State.

Methodology

This study was conducted in the Gedeo zone of the Southern Nations, Nationalities and Peoples' Regional (SNNPR) State of Ethiopia (Figure 1). The total area of Gedeo zone is 134,700 ha, with a total population of 1,028,063 (513,113 men and 514,950 women) (CSA, 2013). Gedeo zone is one of the most densely populated areas in Ethiopia, averaging 627 persons per km^2 (Mesele, 2013). The topography of the zone is generally comprising hills and rolling plateaus, with elevation ranging from 1300 – 3064 m.a.s.l with the mean annual temperature (which) varies from 12-28^oC. The mean annual rainfall of the zone ranges from 800mm to 1800mm per year. The dominant soils mainly developed from volcanic rock and classified as Nitosols. Gedeo zone has three agro-climatic zones namely: Lowland (areas below 1500 m), Midland (areas between 1500 and 2300 m), and Highland (areas between 2300 and 3100 m) (Mesele, 2013). The major annual crops grown in the area are: maize (*Zea mays*), teff (*Eragrostis tef*), wheat (*Triticumae stivum*), barely (*Horgeum vulgare*), bean (*Phaseolus vulgaris*), sweet potato (*Ipomoea batatas*), ginger (*Zingiber officinale*), Ethiopian cabbage (*Brassica oleracea*), beetroot (*Beta vulgaris*), tomato (*Solanum lycopersicum*), garlic (*Allium sativum*) and chili (*Capiscum annuum*). The main perennial crops grown are Eucalyptus species, enset (*Ensete ventricosum*), Coffee Arabica, Khat (*Catha edulis*) and a variety of fruit crops such as avocado, Annona, banana, kazmir (*Mexican apple*), Lemon, Mango, and Papaya. The enset-coffee mixed farming system is a dominant; and cereal farming is one of co-dominant land use types in the study area.

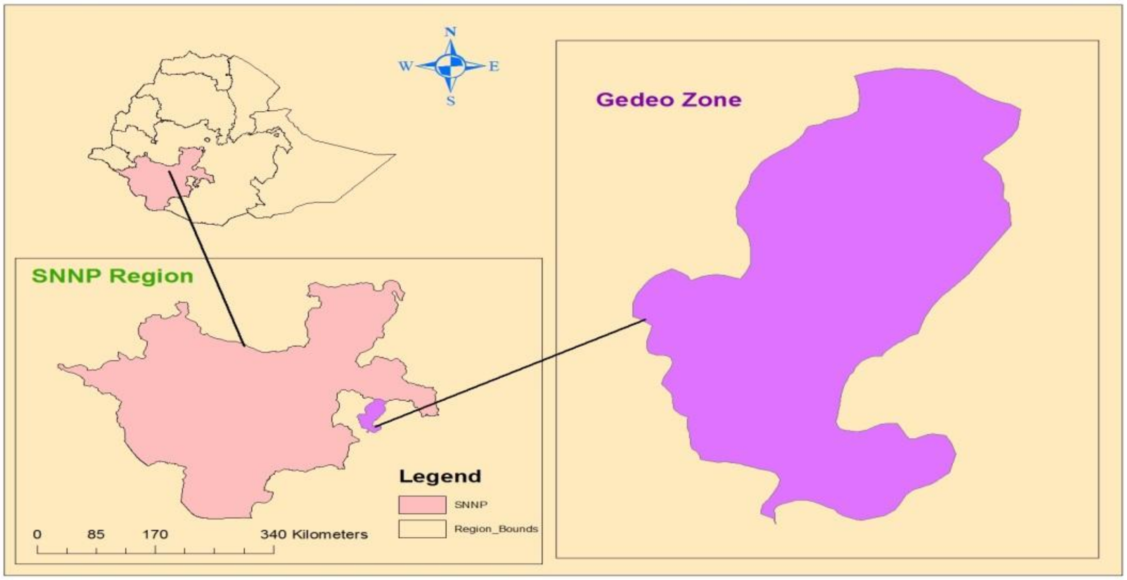

Figure 1: Map of the study area

Methods of Data Collection and Analysis

Three *Woredas* namely Wenago, Yirga Cheffe, and Gedeb were purposively selected based on their location in three agro-climatic zones. One hundred twenty sample units were selected based on multi-stage stratified random sampling techniques. Detailed interview using close-ended questionnaire was conducted with the owner of each farm plot to generate information on the socio-economic attributes, the major inputs, and products from the plot understudy for fifteen years. Direct measurements and field observations were also made to estimate the size of the plot, stock density, major crops and tree species grown, and the different assortment of products from the plot, and then to corroborate with the interview data.

Respondents were asked for the prevailing market prices of goods traded in the common marketplaces such as the current market price of grains, straw, forage, vegetables, fruits, fuel wood, construction wood, house utensils, farm implements etc. and triangulated with the nearby marketing price through the market survey. Similarly, quantity and the market prices of different input associated with the specific plot were also obtained from the owner. Current market price method was used to calculate direct economic benefit for the given land use type.

Economic performance indicators such as Net Present Value (NPV) and Benefit Cost Ratio (BCR) of the three land use types were calculated and compared. The NPV determines the net returns by discounting the streams of benefits and costs back to the beginning of the base year using appropriate discount rate over the lifetime (analysis period) of the production system. NPV is calculated using the following formula:

$$NPV = \sum_{t=0}^{n} (Bt - Ct) / (1+r)^{t} > 0$$

Where Bt are benefits flow at time t, C_t is costs of production at time t, t is a year, and r is the discount rate.

The BCR compares the discounted benefits to discounted costs. Among the three alternatives compared, the land use with higher BCR is taken as a better economic option and it is computed using the following formula.

$$BCR = \frac{\sum_{t=0}^{n} Bt / (1+r)^{t}}{\sum_{t=0}^{n} Ct / (1+r)^{t}} > 1$$

To facilitate comparison between the three land use types, all direct benefits and costs were quantified across the study years. After collecting, compiling and classifying of costs and benefits flows from each land use, the net present value of each option for the selected time period was calculated by adopting the current discount rate.

To address the objectives of the study, descriptive statistics, ANOVA, and econometric analysis were employed. We interpreted the data using mean, percentage, frequency, and standard deviation; LSD-test and Multinomial Logistic Regression. The data was analyzed using Statistical Package for Social Sciences (SPSS) version 20 and Microsoft Office Excel 2007.

Model Specification

A Multinomial Logistic Regression model was used to answer the question of the possible constraints in farming activities. The model used to describe the relationship between dependent variable and a set of independent variables. The dependent variables have three groups: the choice of an individual farmer to practice cereal based mono-cropping and/or wood-based mono-cropping and/or tree-cereal mixed cropping, whereas, the explanatory variables could be continuous, categorical or dummy. The probability of a land user to be constrained in their farming activities is:

$$P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^{Z_i}}{1+e^{Zi}} \quad \text{……………………………………………} \quad \textbf{(1)}$$

Where, in the notation ***P***

$$Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_m X_{mi} \quad \text{……………………………………………} \quad \textbf{(2)}$$

If $\boldsymbol{P_i}$, is the probability of the i^{th} farmer to be constrained by choosing the specific land use type by various factors, as given by (equa. 1), then ($\boldsymbol{1 - P_i}$), is the probability of the i^{th} farmer to not be constrained by practicing the specific land use types.

$$\boldsymbol{1 - P_i = \frac{1}{1+e^{Z_i}}} \quad \text{……………………………………………} \quad \textbf{(3)}$$

Dividing (1) by (3), we get

$$\frac{P_i}{1-P_i}=\frac{1+e^{Z_i}}{1+e^{-Z_i}}=e^{Z_i} \quad \text{...} \textbf{(4)}$$

$\frac{P_i}{1-P_i}$ is simply the odds ratio in favor of the *i*th farmer to be constrained to the probability to not be constrained by practicing the specific land use types.

Taking the natural logarithm of the odds ratio in both sides of (4) will result in what is known as the Multinomial Logistic Regression model as indicated below:

$$\ln\left(\frac{P_i}{1-P_i}\right)=\ln\left(\frac{1+e^{Z_i}}{1+e^{-Z_i}}\right)=\ln\left(e^{Z_i}\right) \text{...} \textbf{(5)}$$

$$\ln\left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1X_{1i}+\beta_2X_{2i}+\ldots+\beta_mX_{mi} \text{..} \textbf{(6)}$$

$$\ln\left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1 LandShortage+\beta_2 LandTenure+\beta 3 Poorsoilfertility+\beta 4 Rainfall\ variablity+\beta 5 WeakExtension$$
$$+\beta_6 LaborShortage+\beta_7 LackofCredit+\beta 8 Lowproduct\ Price$$

Results and Discussion

Demographic and Socio-Economic Characteristics of Households

The average age of the sampled household heads was 44.5 years and the average age of farmers who cultivated CBMC, WBMC and TCMC are found to be 41, 37 and 42 years, respectively (Table 1). As clearly stated in the table below, the clear majority of CBMC cultivators were at the age range of 46-65, WBMC and TCMC cultivators were at the age range of 36-45. This implied that elderly farmers based their life in the traditional way i.e. monocrop agriculture as compared to S. the fellow WBMC and TCMC cultivators.

Table 1: Distribution of sampled household heads by age group for the comparative economic analysis study

				CBMC Cultivators (n = 41)		WBMC Cultivators (n = 37)		TCMC Cultivators (n =42)		Total (n= 120)	
Land Use Type		Educational s		N	%	N	%	n	%	N	%
		Illiterate	Prim								
CBMC	Count	0	30								
	% within Land use types considered	0.0%	73.2								
	% within Educational status of the respondent	0.0%	39.5								
	% of Total	0.0%	24.6								
WBMC	Count	7	28								
	% within Land use types considered	18.9%	75.7								
	% within Educational status of the respondent	36.8%	36.8								
	% of Total	5.7%	23.0								
TCMC	Count	12	18								
	% within Land use types considered	27.3%	40.9								
	% within Educational status of the respondent	63.2%	23.7								
	% of Total	9.8%	14.8								
	Count	19	76								
	% within Land use types considered	15.6%	62.3								
	% within Educational status of the respondent	100.0%	100.								
	% of Total	15.6%	62.3								
	Chi – Square = 27.964***										
Age category											
20-35				8	6.67	7	5.83	4	3.33	19	15.83

36-45	14	11.67	14	11.67	21	17.50	49	40.83
46-65	19	15.83	11	9.17	15	12.50	45	37.50
>66	0	0.00	5	4.17	2	1.67	7	5.83
Chi-square = 134.056***								

**** Significant at 1% significance level*

The average family size of the respondents was 10 per household. About 14.17 per cent of the respondents were illiterate, 63 per cent attend primary school, the rest 19 per cent attend secondary school and about 3 per cent are above secondary school. The average educational level of the respondents was grade 2 (Table 2).

Table 2: Distribution of sampled household heads by educational level in the comparative economic analysis study

The mean total cultivated land of CBMC, WBMC and TCMC cultivators was 3.22, 4.97 and 2.17 hectare, WBMC cultivators were largest than the CBMC and TCMC. In the study areas, farmers obtained diversified benefits from the three land use types. For instance, straw, forage and other by-products from CBMC land use. Those who cultivate WBMC obtained all wood materials that can be used for construction, house utensils, farm implements, and energy source. Both wood and non-wood products are obtained from TCMC. These included fuel wood, fodder, construction material, and coffee. Coffee was primarily used as the source of income (cash crop). The shade trees (pruned branches and pollarded stem) are used for home consumption (fodder, fuel wood, and building materials) and income generation (pole, timber).

Economic Performance Evaluation of the Three Land Use Types

The study results showed that the aggregate economic return of WBMC over fifteen years is significantly higher as compared to CBMC and TCMC land use types (Table 4).

The mean comparative economic return of WBMC is about 13.21 fold of the TCMC and 32.16 fold of the CBMC land use types. Thus, from the economic analysis point of view, WBMC is the most feasible economic alternative among the three land use type.

Table 3: Post-Hoc-test LSD of Total NPV (ETB/ha) for three land use types at major town price (5 years, 10 years, and 15 years)

Dependent Variable	(I) Land use types considered	(J) Land use types considered	Mean Difference (I-J)	Sig.
Total NPV year 5	CBMC	WBMC	561.25	0.662
		TCMC	-729.715	0.557
	WBMC	CBMC	-561.25	0.662
		TCMC	-1290.96	0.313
	TCMC	CBMC	729.71	0.557
		WBMC	1290.96	0.313
Total NPV year 10	CBMC	WBMC	-12762.98***	0.000
		TCMC	-3046.29	0.202
	WBMC	CBMC	12762.98***	0.000
		TCMC	9716.69***	0.000
	TCMC	CBMC	3046.29	0.202
		WBMC	-9716.69***	0.000
Total NPV year 15	CBMC	WBMC	-101403.19***	0.000
		TCMC	-4667.64	0.698
	WBMC	CBMC	101403.19***	0.000
		TCMC	96735.55***	0.000
	TCMC	CBMC	4667.64	0.698
		WBMC	-96735.55***	0.000

*** *The mean difference is significant at the 0.01 level.*

Using the major town market price, the BCR of WBMC practice is 97.4 and 504.5 times higher than CBMC and TCMC practices respectively.

Table 4: Post-Hoc-Test of Total BCR (ETB/ha) for three land use types at major town price (15 years)

Land use types considered	(J) Land use types considered	Mean Difference (I-J)	Sig.
CBMC	WBMC	-24791.64**	0.031
	TCMC	207.41	0.985
WBMC	CBMC	24791.64**	0.031
	TCMC	24999.05**	0.029
TCMC	CBMC	-207.41	0.985
	WBMC	-24999.05**	0.029

* The mean difference is significant at the 0.05 level

During the first five years, the financial return from WBMC is relatively lower due to the high initial investment required for the establishment of this land use type. However, the outputs have increased positively after the first five years making the investment economically attractive afterward as compared to the TCMC and CBMC land use types (Table 3). The economic significance of *Eucalyptus* plantation is also indicated in the study by Belay and Muluneh (2016). Similarly, a study conducted in Goro Woreda of Bale Zone, Oromia by Zenebe (2013) revealed that *Eucalyptus* plantation was found to be more profitable land use option as compared to wheat (*Triticumae stivum*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), and teff (*Eragros tistef*) at 10% discount rate.

Input Costs

The total input costs of a given land use type comprise both establishment and management costs. Establishment costs are costs incurred during the beginning of the practice while management costs are life-cycle costs of each practice. Our study revealed that the mean establishment and management cost of TCMC was 1.03 and 1.3 times higher than CBMC and WBMC land use types respectively (Table 5). WBMC is the least input requiring land use type. This is mainly because of the minimum management cost requirement for this land use type, for example, *Eucalyptus* woodlot, despite the relatively high input cost at the beginning of establishing the plot. Thus, as indicated in table 3, the input requirement of WBMC significantly decreases across time.

Table 5: Total expenses/ha in 5 years, 10 years, and 15 years, for the three land use types

Dependent Variable	(I) Land use types considered	(J) Land use types considered	Mean Difference (I-J)	Sig.
Total discounted costs for 5 years	CBMC	WBMC	374.59	0.399
		TCMC	-285.49	0.506
	WBMC	CBMC	-374.59	0.399
		TCMC	-660.09	0.136
	TCMC	CBMC	285.49	0.506
		WBMC	660.09	0.136
Total discounted costs for 10 years	CBMC	WBMC	2278.89***	0.000
		TCMC	-409.67	0.495
	WBMC	CBMC	-2278.89***	0.000
		TCMC	-2688.55***	0.000

	TCMC	CBMC	409.67	0.495
		WBMC	2688.55***	0.000
Total discounted costs for 15 years	CBMC	WBMC	1876.69***	0.011
		TCMC	-266.26	0.707
	WBMC	CBMC	-1876.69***	0.011
		TCMC	-2142.95***	0.004
	TCMC	CBMC	266.25696	.707
		WBMC	2142.95211***	.004

***The mean difference is significant at the 0.01 level

The direct economic benefits from mixed cropping (TCMC) were positive across three-time horizons. On average, the NPV/ha of TCMC was superior to CBMC, but significantly inferior to WBMC. This was mainly because of high-input cost and severe component competition that exists within the TCMC system. Moreover, on average the economic return of TCMC is not very much different from CBMC except for the contribution of products from perennial components. Despite its lower economic return, farmers attach higher overall importance to multiple cropping mainly because of the usability of the products at the household level (for subsistence). In the study area, a mixed farming system is clearly linked with the socio-cultural tradition of farm households. Thus, under the current prevailing farming conditions, farmers attempt to balance the economic drive of producing cash crop and maintaining multiple crops. In line with this study, Getahun (2015) studied the economic performance of agroforestry based systems versus mono-cropping systems using economic performance indicators at the household level in Wondo District. The results from the three economic performance indicators showed that the fruit-tree based agroforestry system has the highest NPV, BCR and expected annual income (AEV) followed by monocrop of sugarcane, sequential monocrop of tomato with maize, and sequential monocrop of potato with maize, respectively. He concluded that the agroforestry land use is the best land use practice with the highest financial return than that of the monocrop land use (Getahun, 2015).

Table 6: Various constraining factors in practicing the three land use systems
A reference category is Tree Cereal Mixed Cropping (TCMC)

Land use types considered	Explanatory Variables	B	Std. Error	Wald	Sig.	e^{β}
CBMC	Land Shortage	-1.270**	.538	5.565	0.018	0.281
	Tenure	.857	.443	3.735	0.053	2.356
	Poor soil fertility	-1.034	.624	2.749	0.097	.356
	Low rainfall	1.809**	.657	7.580	0.006	.164
	Weakextension	.195	.411	.225	0.635	1.215
	Shortage of labor	1.949***	.455	18.388	0.000	7.023
	Lack of credit	.344	.713	.233	0.630	1.410
	Lowproduct price	1.983***	.742	7.149	0.008	7.265
WBMC	Land Shortage	-1.781***	.645	7.630	0.006	.168
	Tenure	1.578***	.530	8.858	0.003	4.847
	Poor soil fertility	.027	.700	.002	0.969	1.028
	Low rainfall	-1.634	.726	5.063	0.024	.195
	Weak extension	-.739	.470	2.466	0.116	.478
	Shortage of labor	1.965***	.537	13.379	0.000	7.133
	Lack of credit	1.247	.735	2.880	0.090	3.480
	Low product price	4.030***	.987	16.659	0.000	56.270

Log-likelihood (X^2) = 93.39
Correctly predicted percent = 60.2

, **, and * represents statistically significant at 10, 5 and 1% level of significance, respectively*

Constraints and Choice of Land Use

Out of eight explanatory variables included in the model, five variables were found to be significant in explaining the constraining factors in practicing the three land use types. Taking TCMC as a reference category, land shortage (negatively); labor shortage, rainfall variability and low product price (positively) affects CBMC cultivators. Moreover, land shortage (negatively); labor shortage and low product price (positively) affects WBMC cultivators (Table 6).

Land Shortage: was the more serious constraining factor to TCMC than CBMC growers. One of the main constraints to practice TCMC land use type is the perception that trees compete with agricultural crops for land particularly when land size per household is small. This finding is corroborated by Balana et al. (2012) and they indicated that the land size is less relevant when farmers' holding is large enough to accommodate both agricultural crops and trees. Therefore, having large land holding may help households to allocate parts of it for crop production and animal grazing and the remaining for planting trees. It has been proposed as the solution to land shortage and productivity due to its great potential for both forestry and agricultural products.

Rainfall Variability: was a more serious constraining factor for CBMC practitioners than TCMC. As various research findings indicated, TCMC such as Agroforestry is the best solution for the problem of low rainfall. According to Mbow et al. (2014), Agroforestry contributes to ecosystem functions in water recycling by increased rainfall utilization compared to annual cropping systems. The results confirm that agroforestry systems may greatly increase rainfall utilization compared to annual cropping systems. This complementarity between trees and annual crops extends possibilities of soil moisture uptake, hence making soil resource utilization more efficient than in monoculture (Balana, et al., 2012; Gebrehiwot, 2015).

Labor Shortage: was the more serious constraining factor for CBMC and WBMC practitioners than TCMC. This is due to the productive land holding equivalence of TCMC and mono-cropping (CBMC & WBMC). Through practicing TCMC, farmers can be profitable using a small parcel of land and labor input as compared to mono-cropping. This finding is similar to various results that show the labor costs as determining the factor to the adoption of *Eucalyptus* woodlots (Lalisa, 2012; Matthies and Karimov, 2014)**.**

Low product price: was the more serious constraining factor for CBMC and WBMC cultivators than TCMC. Since TCMC is the integration of trees with annual crop cultivation, livestock production, and other farm activities is a series of land management approaches. According to Muhammed et al. (2011), the combination of trees with the annual crops increases the overall farm income of per unit land area of farmland and reduces the risks and broadens the spheres of alternatives. A study conducted by Matthies and Karimov (2014) to evaluate the financial drivers of woodlot production in Amhara regional state shows that limited knowledge about marketing and low bargaining power are constraints on absolute profitability for many smallholders. According to this study, the sale price is highly variable and dependent on various factors such as the strength of informal relationships between the buyers and sellers, access to transportation, and a farmer's level of awareness about marketing the wood.

Land Tenure is a constraining factor for WBMC cultivators than TCMC. Tenure insecurity is defined here as the perceived probability of losing ownership of a part or the whole of one's land without his/her consent (Balana, et al., 2012). Land ownership in agrarian societies is not only the main means of generating a livelihood, but it is often also the primary means for accumulating wealth. The current finding is in line with the finding of Matthies and Karimov (2014) in Amhara regional state. Although some households may plant some trees that are enough for household consumption irrespective of the risk; insecure land tenure is not expected to encourage tree planting in Ethiopia. In the absence of the above containing factors, farmers were asked to state their ideal land use practice. Thus, about 65% of the farmers ranked first TCMC, 34% ranked the second WBMC and 63% ranked in third place CBMC practices.

Conclusion

This paper analyzed the comparative economic performances of three competing land use types and identified constraining factors affecting land use choices in Southern Ethiopia. The three competing land use types studied were Wood Based Mono-Cropping (WBMC), Tree Cereal Mixed Cropping (TCMC), and Cereal-Based Mono-Cropping (CBMC). The economic performances of these three land use types were compared across three-time horizons (5, 10 and 15 years) using economic performance indicators such as Net Present Value (NPV) and Benefit Cost Ratio (BCR). The output of this study is aimed to provide empirical evidence for making rational decisions in allocating scarce land resources.

Farmers in the study area obtain diversified benefits from the three land use types. In case of CBMC farmers obtain direct benefits such as grain, straw, forage and other by-products. Farmers who practice WBMC obtain all wood materials that can be used for construction, house utensils, farm implements, and energy source. Both wood and non-wood products are obtained from TCMC. These included fuel wood, fodder, construction material, and coffee. Our results showed that the aggregate economic return of WBMC over fifteen years was significantly higher as compared to CBMC and TCMC land use types. The mean comparative economic return of WBMC was about 13.21 fold of the TCMC and 32.16 fold of the CBMC land use types. Thus, from the economic analysis point of view, WBMC is the most feasible economic alternative among the three land use type. Moreover, the BCR of WBMC was 97.4 and 504.5 times higher than CBMC and TCMC practices respectively. The financial return from WBMC is relatively lower during the first five years due to the high initial investment required for the establishment of this land use type. However, the outputs have increased positively after the first five years making the investment economically attractive afterward as compared to the TCMC and CBMC land use types.

The direct economic benefits from mixed cropping (TCMC) were positive across three-time horizons. On average, the NPV/ha of TCMC was superior to CBMC but significantly inferior to WBMC. This was mainly because of high-input cost and severe component competition that exists within the TCMC system. Moreover, on average the economic return of TCMC is not very much different from CBMC except for the contribution of products from perennial components. Despite its moderate economic return, farmers attach higher overall importance to multiple cropping, i.e. TCMC, mainly because of the utility of many of the products from this land use at household level. In this study, we confirmed that mixed farming system is clearly linked with the socio-cultural tradition of farm households. Thus, under the current prevailing farming conditions, farmers attempt to balance the economic drive of producing cash crop such as *Chata edulis* and *Eucalyptus* in the form mono-cropping and maintaining the traditional multiple crops. In this regard, more than 65% of the farmers ranked TCMC as their priority land use type over WBMC (second) and CBMC (third) ranked land use types.

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Chapter Six: Forest Resources Utilization Research

Effect of Substituting *Dendrocalmus hamiltonii* Leaves Hay on Weight Gain of Arsi-Bale Sheep

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Abstract

Feeding and digestibility trials were conducted at Debre Zeit Agricultural Research Center, using twenty five yearling Arsi-Bale sheep weighing on average 22.9 ± 2.48 (mean ± SD) kg, to investigate the effect of substituting dry Dendrocalamus hamiltonii bamboo leaves in a concentrate mix on feed intake, digestibility and body weight (BW) gain of sheep. A randomized complete block design with five treatments and five replications was used to conduct the experiment. The treatments included feeding a basal diet of Tef straw alone (T1, control), and supplementation with concentrate mixture 100% (T2), 67% concentrate mixture and 33% bamboo leaves hay (T3), 67% bamboo leaves hay and 33% concentrate mixture (T4)and100% dry bamboo leaves (T5). The supplements were given at 300g DM/head/day. The concentrate mixture consisted of wheat bran (WB) and Noug seed cake (NSC) at the ratio of (2:1). The animals were housed in individual pens and daily offered Tef straw, allowing 20% refusal. Water and salt block comprising of sodium chloride were available free choice. The results indicated that there was higher (p<0.001) daily BW gain in the supplemented sheep (26.7-47.8 g /head/day) than in the control (-28.9 g/head/day) ones.

Keywords: *Bamboo leaf, body weight gain, Dendrocalamus hamiltonii, digestibility, sheep feed*

Introduction

There is a tremendous growth in meat consumption in developing countries, which is fueled by population growth, urbanization and increasing incomes (Delgado, 1999). The increasing human population and higher demand for food in Ethiopia is progressively forcing farmers to cultivate more land at the expense of natural grazing areas. Next to natural pasture, crop residues are the major livestock feeds particularly in the dry seasons and provide about 40-50% of the total livestock feed (Alemayehu, 1998). According to the same author, crop residues are nutritionally characterized by deficient in energy, protein and micronutrients. Shortage of feed supply and poor nutritional quality of available feed resources are the major constraints affecting livestock productivity in Ethiopia (Tolera, et al., 2012). Although many factors constrained sheep production and reproduction, feed shortage both in terms of quantity and quality constituted the lion's share (Getu, et al., 2012). In economic terms, feed cost accounts for about 70% of the cost of livestock production under Ethiopian condition. Thus, there is a need to look for locally available potential feed resources, which compete less with human food production and can provide the critical nutrients lacking in the main dry season feeds. One such potential feed resource is bamboo.

Introduction and utilization of exotic multipurpose fodder trees such as *Sesbania spp*., *Leucaena leucocephala*, *Calliandra spp*. and *Chamaecytisus palmensis* through integration with food crops cultivation in the mixed crop-livestock system in Ethiopia started in the 1970s to supplement the roughage feed resources (EARO, 2002; Alemayehu, 1998). Similarly, *Dendrocalamus hamiltonii* is one of the exotic bamboo species introduced in Ethiopia since 2007. It is well adapted in wide range of agro-ecology, fast growth and high biomass yield. Bamboo leaf is an excellent animal fodder as they have 18-22% protein (Denbeshu, 2010; Eyob, 2016). Despite the wide use of the plant, only little effort has been made to improve its utilization as feed to ruminants. Data on its nutritive value, digestibility and weight gain is scarce. Based on these, the objectives of this study were to assess the effect of substituting different levels of bamboo leaves for concentrate mix on feed intake, digestibility and body weight change of Arsi-Bale sheep.

Materials and Methods

Description of the Study Area

The study was conducted at Debre Zeit Agricultural Research Center (DZARC). Debre Zeit is located at 45 km south east of Addis Ababa. The area has an altitude of about 1900 m above sea level with maximum and minimum temperatures, and average annual rainfall of 24.3^{0}C and 8.9^{0}C, and 851mm, respectively. The climate of the area is mostly tepid to cool moist mid to high altitude.

Feeds and Feeding

The basal diet (*Tef* straw) from 2016 harvest was purchased from farmers residing around Ada. The straw was stored in a barn. One of the supplements used in the experiment was *Dendrocalamus hamiltonii* grown in Arsi Negelle site. The branches and leaves were transported back to the study site and separated from each other in order to make it more acceptable to animals. Tef (*Eragrostis tef*) straw on *ad libitum* basis (at 20% refusal) was offered to each animal as basal diet. Bamboo leaf hay and concentrate mix were offered on separate troughs at 800 h and1600 h, respectively. The experimental sheep had free access to salt block licks and water. The feed samples offered were taken on batches of feeds and refusals collected from each animal, weighed and sampled per animal daily. This was pooled over the experimental period and sub-sampled for analysis. Daily feed and water intake was measured and recorded for each animal. Intake was calculated as the difference between feed offered and refused corrected for DM content. Generally, daily feed DM and nutrient intake for each animal was calculated as follows:

Tef straw DM intake= (Tef straw offered % DM)-(Tef straw refused* % DM)*

Supplement DM intake= (Supp. offered % DM)-(Supp. refused * % DM)*

Daily total DM intake= basal feed DM intake + Supplement DM intake

Daily OM, CP, NDF and ADF intake were also calculated by the same method.

Animals and Animal Management

Twenty-five yearling male Arsi-Bale sheep with a live weight of 22.9 ± 2.48 kg (mean ± SD) (mean ± SD) were purchased from Adama market. The animals were treated against internal and external parasites using Ivermectin. They were also vaccinated against the common contagious diseases prevailing in the area (*i.e.*, anthrax, blackleg and ovine pasteurelosis) and housed in individual pens which were disinfected before 15 days. The animals were adapted to the experimental diets and the pen environment for three weeks (21 days) and then followed by 90 days of feeding trial.

Experimental Design and Treatments

A randomized complete block design was used to conduct the experiment. The experimental animals were categorized into five blocks of five animals based on their initial weight, which was determined as a mean of two consecutive weightings after overnight fasting. The five feed treatments (Table 1) were randomly assigned to each animal in a block, giving five animals per treatment. Daily voluntary feed intake was recorded daily for each animal. Experimental sheep were weighed every 10 days after overnight fasting.

Table 1: Experimental Treatments

Treatment	Basal diet	Supplements		Amount(g DM/d)
	Tef straw	Bamboo %	Concentrate mix %	
1	*ad libitum*	0	0	300
2	*ad libitum*	0	100	300
3	*ad libitum*	33	67	300
4	*ad libitum*	67	33	300
5	*ad libitum*	100	0	300

Results and Discussion

Body Weight Change

The initial, final body weight, total weight change and average daily gain of the experimental sheep are given in Table 2. In the present study the protein supplements had a significant effect (*p*<001) on final live weight of sheep. Compared to the control treatment, supplemented animals had higher (*p*<0.001) final body weight. Moreover, animals supplemented with 67% bamboo leaf hay and 33% concentrate mix had higher (*p*<0.001) final body weight than other supplemented ones. However, animals supplemented with 67% bamboo leaf hay and 33% concentrate and vise-versa did not differ significantly (*p*<0.001) in final body weight. Similarly, no significant difference (*p*<0.001) was observed between concentrate mix only and bamboo leaf hay only supplemented treatments (T_2 and T_5) in final body weight.

The daily body weight gain recorded by the supplemented sheep (26.7-47.8 g/day) in the current study was greater than 14.4- 34.9g/day reported by Eyob (2016) in local sheep fed lowland bamboo leaf hay with concentrate mix (WB and NSC) in different proportion. Whereas Mekuria et al. (2012) reported that the higher lowland bamboo supplemented groups showed higher average daily gain increment of protein intake in turn resulted in increased body weight gain in sheep. The body weight gain of supplemented experimental sheep during the first ten days of the feeding trial increased; indicating supplemented sheep have enough nutrients above their maintenance requirements. On the other hand, the control group dropped in their weight gradually linearly until the end of the experiment. The loss of weight in the control groups indicated that the basal diet *Tef* straw did not support their nutrient requirement, since the basal diet had a lower CP and a higher NDF content.

Table 2: Body weight gain of Arsi-Bale sheep fed *Tef* straw and supplemented with dried *D. hamiltonii* leaves and concentrate mixture at different proportions

Parameter	T_1	T_2	T_3	T_4	T_5	SEM	SL
Initial BW (kg)	22.8	22.6	22.5	22.8	22.8	0.48	ns
Final BW (kg)	20.2^{c}	25^{b}	25.4^{ab}	25.5^{a}	24.8^{b}	0.49	***
BW change (kg)	-2.6^{c}	2.4^{b}	2.9^{b}	4.3^{a}	2^{b}	0.33	***
Daily BW gain (g)	-28.9^{c}	26.7^{b}	32.2^{a}	47.8^{ab}	22.2^{b}	3.74	***

a, b, c = means within a row not bearing a common superscript are significantly different;** = (p <0.01) ***= (p<0.001); ADWG= daily weight gain; BWC= body weight change; FBW= final body weight; IBW= initial body weight; ns= non significant; SL= significant level; SEM = standard error of mean

Conclusion

The study was conducted at Debre Zeit Agricultural Research Center using twenty yearling intact male sheep weighing on average 22.9 ± 2.48 kg (mean ± SD) kg for 90 days of feeding trial, to determine the influence and response of local sheep in feed intake and BW gain when supplemented with sole dry bamboo leaves, concentrate mix (consisting of *Noug* seed cake and wheat bran at a ratio 2:1) and their mixture at different proportion on DM bases, respectively. The experiment was conducted using a randomized complete block design with five treatments and five replications. The treatments used in the experiment were; *Tef* straw alone (T1, control), and supplementation with 100% concentrate mixture (T2), 33% dry bamboo leaves and 67 % concentrate mixture (T3), 33% concentrate mixture and 67% dry bamboo leaves (T4) and dry bamboo leaves 100%. (T5). The digestibility trial was conducted after the end of feeding trial. Total collection of feces was undertaken for 7 consecutive days after 3 days of adapting the sheep to carrying of fecal bags.

Average daily gain of -28.9, 26.7, 32.2, 47.8 and 22.2 g was recorded for T1, T2, T3, T4 and T5, respectively; which showed sheep supplemented with bamboo leaf, concentrate, or their mixture concentrate mix had higher body weight gain compared to the control treatments, which lost body weight. There was significance difference in daily body weight gain between T3, T2 and T5, where as there is no significant difference between in other supplemented groups (p <0.001). Supplemented treatments had significantly higher (p<0.001) final body weight than the control.

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Effect of Tree Age on Nutritional, Anti-nutritional and Proximate Composition of *Moringa stenopetala* Leaves in South West Ethiopia

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Abstract

Moringa stenopetala is one of an indigenous agro forestry tree species cultivated in multi-storey inter-cropping system in the southern dry land areas of Ethiopia. It is economically important tree species in which most parts of the plants are used for different purposes. Leaves of the plant collected from age class of the tree are edible after it is processed. Despites its wider usage in the southern parts of the country, little is known about the nutritional composition of the leaves at different age of the tree. We investigated the effect of tree age on nutritional, ant-nutritional and proximate composition of M.stenopetala leaves and determined moisture content, Ash content, Crude Fiber, Crude Protein, Fat, Tannin, Phytate, Iron, calcium, Phosphorus and Potassium content. Representative M. stenopetala leave composite samples were collected from 3,4,5,6, and 7 years old tree in Dherashe valley of southern Ethiopia. The collected leaf samples were dried and subjected to physico-chemical analysis following standard methods of analysis. The laboratory results were analyzed by using SAS Statistical software. The analysis indicated a significant difference in the main effect of all nutritional and anti- nutritional composition parameters between the five classes at 1% significant level. However, there was no any difference in the cationic composition of iron and zinc between ages of trees. This study suggests that plant ages have clearly impact on nutrition, anti- nutritional composition and most of proximate elements. Trees that are grown up well and reached age of five had better Crude Protein, Crude Fiber, Phosphorus and Potassium elements, but anti-nutritional values such as Tannin and Phytate contents less amounts were observed than tree age 6 and 7, therefore this implying that leaf collection should be done on trees that have established and grown well and reached age at five years.

Keywords: *Moringa Stenopetala, nutrient content, proximate composition*

Introduction

The Eastern Africa region is predominantly a dry land with about 60% of the total land area classified as arid or semi-arid. The rural economy is dominated by subsistence agriculture or pastoralists that are dependent on the available natural resources. Drought poses the greatest challenge to the livelihoods of communities in this region. *Moringa* is a drought tolerant tree, fast growing and easily adapted to well drained soil and arid conditions (Yisehak, et al., 2010). *Moringa Stenopetala,* indigenous to Southern Ethiopia and Northern Kenya, is a member of the single genus family Moringaceae. The tree is popularly known as *Shifara* or *Shalchada* in Ethiopia. *M. stenopetala* is widely cultivated in Southern Ethiopia especially in Gamu-Gofa, Sidama, Konso and the adjoining provinces (Abuye, et al., 2003). Based on the review of the literature have discussed that the Moringa leaves are rich sources of minerals and amino acids (Anjorin, et al., 2010; Wakil and Kazeem, 2012). In the country information available on anti nutritional, nutritional and proximate value of *M. stenopetala* leaves studies different tree ages particularly its potential as a food or a feed resource is lacking. Therefore, the natural problem of the rural poor in any country can be overcome either by strengthening the households resources base (Erhabor and Emokaro, 2007; Ibrahim, et al., 2009) by diversifying alternate food sources (Ghosh, 2011). Therefore, the purpose of the present study is focused on designing of different options for production, value addition and promotion of this high value *M. stenopetala* tree is the most important as it is easily generate income for the household and contribute for the national economy., this research is to provide and generate technologies and information on impact of different age classes on nutritional value of *M. stenopetala* leaves.

Materials and Methods

Site description

The leaf sample for the experiment was collected from Segen People's zone, Dherashe woreda Southern Nations Nationalities and Peoples' Region (SNNPR). Dherashe woreda is one of the potential sites for *M. stenopetala* production. It is located in the Great Rift Valley, at 630 km southwest of Addis Ababa in Ethiopia, at $7^0 4^0$N latitude and $38^0 31^0$E longitude. The woreda has an altitudinal range from 500 up to 2500 meter above sea level and the mean annual l rainfall range between 601 – 1600mm. The mean temperature ranges between 15.4 to 27.50^0C (Nebyou and Mulunesh, 2016).

Sample Collection and Preparation

Three healthy *M. stenopetala* trees from age (3, 4, 5, 6 and 7) years were randomly selected from farmers' field/garden for the fresh leaves collection. Adequate leaf samples were collected in the morning by hand from the crowns of each selected tree in four directions (North, South, West and East) to capture possible variations in the leaf characteristics. Composite leaf samples per tree were taken for further analysis. The sample leaves were transported to the Wood Technology Research Center in Addis Ababa in plastic bags. The leaves were spread on thin canvas sheet placed in a greenhouse and dried in the open air until the leaves were dried uniformly. The dried leaves were hand-crushed and further grounded using mortar and pestle to 2 mm size. The powder leaves were then put in to the paper bug and were keeping at room temperature until the laboratory analysis was carried out (Abinet, et al., 2015).

Nutritional and Proximate Composition Analysis

Nutritional and proximate composition of *M. stenopetala* leaves were analyzed in the nutrition laboratory of Ethiopian Public Health Institute. The parameters analyzed include moisture content, ash content, crude fiber, nitrogen content, crude protein and mineral contents.

Determination of Moisture Content

Three replicates of grounded Moringa leave sample that weigh accurately 2 grams from each tree age was weighed and dried at 105^{o}C for 5 h. Oven dry weight was recorded after allowing the samples to cool in desiccators before reweighing. Moisture content was expressed as a percentage of the weight loss from the original weight (Yebeyen, et al., 2009; AOAC923.03, 2016).

Determination of Ash

Three replicates of grounded Moringa leave sample that weigh accurately 2 grams from each tree age were first heated on a burner in air to remove its smoke. Then each leaf sample was burned in a furnace at 550 °C. The ash content was expressed as a percentage ratio of the weight of the ash to the oven dry weight (AOAC923.03, 2016).

Determination of Total Nitrogen and Crude Protein

Exactly 0.5 gram of each Moringa leave sample, in three replicate for each tree age, was weighed and transferred to 2300 Kjeldahl digestion tube plus one Kjeldahl tablet, copper sulfate-potassium sulfate catalyst. Then 10 ml of concentrated nitrogen free sulfuric acid were added. The tube was then mounted in the digestion heating system which was previously set to 240^{o}C and capped with an aerated manifold. The solution was then heated at the above temperature until a clear pale yellowish-green color was observed which indicates the completion of the digestion. The tubes were then allowed to cool to room temperature. Their content was quantitatively transferred to Kjeldahl distillation apparatus followed by addition of distilled water and 30 % (w/v) sodium hydroxide. Steam distillation was then started and the released ammonia was absorbed in 25 ml of 2 % boric acid. Back titration of the generated borate was then carried out versus, 0.02 M hydrochloric acid using methyl red as an indicator. Blank titration was carried out in the same way. The percentage of nitrogen content was then calculated (Ibrahim, et al., 2009).The protein content was calculated using the nitrogen conversion factor of 6.25 as proposed by Greenfield and Southgate (Green field and South, et al., 2003).

Determination of Mineral Content

Ash from a sample of Moringa leave, three replications per each tree age, was prepared and dissolved in concentrated sulfuric acid. Then the solution was used for the determination of the minerals studied except for phosphorus. Appropriate standard solution was prepared for each metal and used by the model AAA-6800 atomic absorption spectrometer to prepare the graph for the determination of the amount of each metal from the prepared solution. Wet ash method was used for the determination of phosphorus in the leave sample. The ash was dissolved in vanadomolybdic acid reagent in which phosphate reacts to form a yellow molybdovanadophosphoric acid. Finally, the amount of phosphorus was determined using CECL 1021 model a UV–VIS spectrometer at 400nm in 1 cm cells, and expressed as % Na_3PO_4 (AOAC, 2000).

Phytate Determination

This was determined using the method described by Latta and Eskin (1980) 0.5 gm of dried *M. stenopetala* leave sample was extracted with 10ml of 0.2N HCl for 1hr. at an ambient temperature. 2ml of wade reagent solution was added in to 3ml of the supernatant extraction solution, and then the homogenized solution was centrifuged for 10 minute at 3000 rpm. Then the clear supernatant solution was taken and the absorbance was measured at 500nm using UV-VIS spectrophotometer (CECL 1021 model). The amount of Phytic acid was calculated using Phytic acid standard curve and the result was expressed as Phytic acid in mg/100gm sample (Burnss, et al., 2001).

Tannin Determination

This was determined using the method described by Burns et al. (2001). One gram of dried *M. stenopetala* leave sample was extracted with 10ml of 1% HCl in methanol using mechanical shaker for 24hr at room temperature and centrifuged for 5 minutes. 1ml of the clear supernatant solution was taken and mixed with 5ml of Vanillin HCl reagent and stand to 20 minutes until the reaction is completed. Absorbance of the clear supernatant solution was read at 500nm using UV-VIS spectrophotometer (CECL 1021 model). The amount of Tannin was calculated using the standard curve to find out the slope and intercept as per the mathematical equation (Gomez and Gomez, 1995).

$$\boldsymbol{Tannin\ in\frac{mg}{g}} = (\boldsymbol{As} - \boldsymbol{Ab}) - \frac{\boldsymbol{Intercept}}{\boldsymbol{Slope} * \boldsymbol{d} * \boldsymbol{w}}$$

Where: $\boldsymbol{As}$ *= Sample absorbance,* $\boldsymbol{Ab}$ *= Blank absorbance,* $\boldsymbol{d}$ *= Density of solution (0.791g/ml) and* $\boldsymbol{w}$ *= Weight of sample in gram*

Data Analysis

The nutritional value, Phytochemical and anti nutrient data were subjected to Analysis of Variance (ANOVA) statistical method using Generalized Linear Models Procedure (GLM) (Gomez and Gomez, 1995). Five age class treatments with 3 replications and 12 test parameters were designed in the experiment. Statistical analysis of data was carried out using SAS Software, Version 9 and Microsoft Excel computer software. Means that exhibited significant differences were compared using Least Significant Difference (LSD) at (*p <0.001*) level.

Results and Discussion

Nutritional and Anti- Nutritional Composition Parameters

The analysis of variance showed that the effect of all nutrition and anti- nutritional composition parameters differed between the five tree ages at 1% significance level. Exceptional to this was for the cationic composition of iron and zinc that did not show any difference between trees ages (Table 1).

Table 1: Analyses of Variance for characterization of *M. stenopetala* leave with different age for Nutritional and Proximate Composition Analysis

		Average Mean									
Source of Variation	DF	MC	AC	CF	CP	Fat	Fe	Zn	Ca	P	K
Age	4	8.98***	11.22***	35.74***	32.29***	0.38***	18.58 ns	1.44 ns	282.03 ***	352.05 ***	1710.46 ***
CV		2.13	5.73	0.53	0.48	4.27	22.13	20.43	7.89	2.56	0
R^2		0.98	0.91	0.99	0.99	0.88	0.45	0.08	0.55	0.99	1

**** Significant at p=0.001; ** significant at p=0.01*

Moisture Content

The overall mean moisture content for the *M. stenopetala* leave samples across the ages in the experiment were found 8.99%.Trees at the age of four had significantly higher moisture content (10.60%), followed by trees at the age of three (9.88%). The lower moisture content of leaves were obtained at trees with the age of five (7.79%) and six (8.07%) (Table 3). The moisture content of studied *M.stenopetala* leaves collected from Dherashe areas is more or less similar to the moisture content of *M.stenopetala* sample collected from different Places in Ethiopia (8.09%) (Abinet, et al., 2015).

Ash Content

The overall mean ash content for the *M. stenopetala* leave samples across the ages in the experiment was found 11.23%. Ash content of *M. stenopetala* leaves at tree age of four showed significantly higher ash content (14.33%) than all other tree ages (Table 2). No significant difference was observed in ash content between tree ages of 3, 6 and 7, but between tree age of 5 and 7 statistical difference was observed. The ash content of studied matured *M. stenopetala* leaves collected from SNNPR was 12.63% by Abinet et al. (2015) was reported on the nutritional profile of *M. stenopetala* studies. This is having the understanding might be contributing the increasing of Moringa tree leave maturity the nutritional element content in the leaves declined thereafter. The observed range of ash content in a powder leave (age = 4) of *M. stenopetala* in this study was comparable with studies by Abuye et al. (2003), which were reported Dire Dawa having the highest content 14.94% to 14.98% .

Crude Fiber

The crude fiber content ranged from 35.36% (age = 6) to 32.84% (age = 3) with the overall mean crude fiber content of 32.29%. This crude fiber content of *M. stenopetala* leaves were higher than the crude fiber reported as 11.62 to 12.92 by Abuye et al. (2003) and 9.1 to 24.2% by Abinet et al. (2015).

Fat

The fat content of *M. stenopetala* leave ranged from 0.35% to 0.44% with the over means fat content of 0.38%. Significantly higher fat content was observed at tree age of 5 (0.44%) and age of 4 (0.42%) than the other tree ages (Table 2). The mean fat content of *M. stenopetala* leaves at Derashe differs from other studies: 4-7% (mean 5.8%) by Abuye et al. (2003) and 0.7%reported by Abinet et al. (2015). This variation might be attributed to the difference in latitude, longitude, annual rainfall, humidity and soil type (Dechasa, et al., 1995).

Crude Protein

The crude protein content of *M. stenopetala* leave ranged from 31.16% to 34.4% with the overall mean crude protein content of 32.29%. Significantly higher crude protein content was observed at tree age of 5 (34.4%) and age of 4 (32.54%) than the other tree ages (Table 2). Statistically lower crude protein was recorded on leaves at tree age of 3 (31.53%) and tree age of 7 (31.16%), which is 10.40% lower crude protein content than the maximum (Table 2). The crude protein content in the present is better than other studies which suggests a higher contribution of *M. stenopetala*, for local people to get nutritious food. It has been recommended as a highly nutritious vegetable tree for food security in Southern Ethiopia by (Yisehak, et al., 2010).

Table 2: Main effects of different age class of *M. stenopetala* leave on Nutritional and Proximate Composition

Source of Variation	Mean Square							
	MC	AC	CF	CP	Fat	Ca	P	K
3	9.88[b]	10.53[bc]	32.84[e]	31.53[d]	0.36[b]	315.19[a]	304.61[d]	1713.15[c]
4	10.6[a]	14.33[a]	34.57[d]	32.54[b]	0.42[a]	262.21[b]	85.19[e]	1874[b]
5	7.79[d]	11.22[b]	35.31[c]	34.40[a]	0.44[a]	263.33[b]	467.24[a]	1878.12[a]
6	8.07[d]	10.07[bc]	35.36[a]	31.83c	0.35[b]	292.94[ab]	456.12[b]	1420.40[e]
7	8.59[c]	9.99[bc]	37.62[b]	31.16[e]	0.35[b]	276.52[ab]	447.11[c]	1666.67[d]
Mean	8.99	11.23	32.29	32.29	0.38	282.04	352.05	1710.47

Element Composition

A significant variation between tree ages was observed for Ca, P and K but not for Iron and Zinc (Table 1). The amount of phosphorus potassium, and Calcium in the *M. stenopetala* leave ranged from 85.19 mg/100gm to 467.24 mg/100gm, 1420.40 mg/100gm to 1878.12 mg/100gm and 263.33 mg/100gm to 315.19mg/100gm, respectively (Table 2). A significantly higher cationic composition phosphorus (467.24mg/100gm) and potassium (1878.12mg/100gm) were recorded on leaves from tree age of five. A higher cationic composition of calcium was recorded on leaves from tree age of 3 (315.19mg/100gm) (Table 3). The observed value of the different minerals in the present study differs from that of (Abuye, et al., 2003). These variations might be attributed to differences in the varieties used by researchers. Different ecotypes and varieties of *M. stenopetala* are found in Ethiopia (Eyassu, et al., 2014).

Table 3: Main effects of different age of *M. stenopetala* leave for Phytochemical and Anti Nutrient Analysis

Source of Variation	Mean Square

	Ta	Phy
3	244.04[c]	708.79[ab]
4	171.36[d]	676.27[ab]
5	163.89[e]	544.32[c]
6	403.94[a]	725.60[a]
7	264.44[b]	597.29[bc]
Mean	249.53	650.45

Ant-Nutritional Composition

The results of this study showed a significant difference in Phytate and tannin between tree ages (Table 3). Higher *M.stenopetala* leaves from tree age of 6 contains more Tannin (403.94 gm/100gm) and Phytate (725.60 gm/100gm). The lower Tannin (163.89 mg/100gm) and Phytate (544.32 mg/100gm) content was found in leaves from tree age of 5. The finding of the present study was comparable with the reports of Ijavotimi et al. (2013) for tannin content who reported the tannin content of 347.67mg/100gm. The Tannin content reported by Ijavotimi et al. (2013) is actually 52.86% higher than the lowest value we found from leaves from tree age of 5. Similar anti nutritional factors in plant foods were also reported by Habtamu et al. (2014).

The Phytate content in our study was higher that of the study by (Ibrahim, et al., 2013) who reported to be 378.44 mg/100gm from *M. stenopetala* leave samples collected from different parts of Ethiopia. The difference might be due to the different in geographical location and soil type between the study areas.

Conclusion and Recommendations

This study indicated that nutritional, anti-nutritional and proximate composition of *M. stenopetala* leaves varied between the tree ages. The nutrient composition of *M. stenopetala* leaves in most cases is found higher on trees at age of 4 and 5 compared to tree age 3, 6 and 7, while anti-nutritional composition, which are Tannin and Phytate of *M. stenopetala* leaves in most cases is found least tree age 5 compared to tree age with 3, 4, 6 and 7 and proximate composition have an adequate amounts on tree with age of 3 and 5, respectively. These variations among the ages might be attributed to genetic back ground of the plant, different ecotypes and varieties of *M.stenopetala* are found in Ethiopia (Eyassu, et al., 2014) and different management practices, which are includes weeding, cultivation and irrigation activities were done when required to facilitate effective establishment and growth of the Moringa trees between the farmers. The author Bamishaiye et al. (2011) reported MO leaves of all stages having varying percentages of nutritional composition. Therefore, in this study we were observed that, tree with age of 5 have better ant-nutritional, nutritional and proximate composition than other tree ages.

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Physical and Mechanical Properties of *Gmelina arborea*

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Abstract

Gmelina arborea (Beechwood) is introduced exotic fast-growing deciduous tree grows at Bonga Forestry research trial site. The objective of this study was to evaluate physical and mechanical properties of this timber species. About five cubic meter of G. arborea logs were harvested from Bonga and transported to Wood Technology Research Center in 2015. Logs were converted to standard size boards to prepare specimens for physical and mechanical properties tests. Specimens were prepared from, knot-free, straight-grained, defect free test specimens, which represent the maximum quality. Sap and heart sections specimens prepared from bottom, middle and top portions of a tree were used to evaluate density, modulus of rupture, modulus of elasticity, compression, impact and hardness strength properties according to ISO standards. The result indicates that tree section had no significant effects on density, modulus of elasticity, compression and impact strength properties. Whereas, tree height had high significant effects on these properties. Density and strength properties of G. arborea are increasing from bottom portion of tree height towards the top portion. In general, G. arborea is low density and easily processed timber species for furniture and veneer production. Tree sections had significant effect only on hardness properties. Heart section from bottom portion and sap section from top have high hardness values than the other sections and portions. G. arboreais considered a useful multi-purpose timber and its wood is used as raw material for various applications. Lumber produced from G. arborea has straight texture, pale yellow to cream and brown color and easily processed by wood working machines.

Keywords*: Gmelina arborea, modulus of elasticity, sap section, heart section, compression, side hardness*

Introduction

Gmelina arborea (Beechwood) is a fast-growing deciduous tree that grows in most of far-East countries. *G. arborea* (Melina) was introduced in large areas of tropical counties due to the well-known fast-growing characteristics and easily managed sylvicultural techniques. Melina tree is considered a useful multi-purpose species and its wood is used as raw material for various applications (Dvorak, 2004). This tree prefers moist fertile valleys with 750-4500 mm rainfall at altitude up to 1500 meters. The *G. arborea* tree attains moderate to large height up to 30 m with girth of 1.2 to 4 a chlorophyll layer. This species is considered a useful multi-purpose timber species and its wood is used as raw material for veneer production, structural applications and furniture manufacturing (Gonzalez, et al., 2004; Sicaden, 1987; Chew and Ong, 1989).

Timber and timber products are utilized widely for structural application and furniture production in Ethiopia. Due to high expansion of residential and commercial buildings in the country now a days there is acute shortage of timber supply for furniture and construction sectors. To satisfy the demands of timber the country is importing large quantities wood products from abroad. To solve this critical timber shortage supply fast growing industrial timber plantations should be expanded in the country. One of the promising timber species for this purpose is *Gmelina* species. This timber species was introduced and planted before 30 years by Forestry research center at Bonga experimental site. The seed of this species is not disseminated to the farmers. Before disseminating the species for various stakeholders and planting widely its properties should investigate. Based on this concept this experiment was imitated to test mechanical properties and identify its end user applications.

The general objective of this study was **t**o test basic properties and identify the end users of *G. arborea.* The specific objectives of this study was to evaluate static bending (modulus of rupture and modulus of elasticity), to evaluate compression strength parallel to the grain, to evaluate impact strength, to evaluate tangential and radial harnesses and identify the end uses of this tree based on the results.

Materials and Methods

Forestry research center was planted this tree species before 30 years at Bonga research trial site. About 5 m^3 logs of matured stands had been harvested in 2015 from Bonga research site and transported to wood technology Research center. Then all logs were converted to the required size of lumber to prepare sample boards for testing. Sap and heart sections specimens prepared from bottom, middle and top portions of both timber species with a dimension of 20x20x300 mm were used to evaluate modulus of rupture, modulus of elasticity and impact strength resistance according to ISO 3133 (1975) and 3348 (1975) standards. Specimens with a dimension of 20x20x60 and 20x20x45 mm were used to evaluate compression parallel to the grain and hardness strengths according to ISO 3387 (1976) and ISO 3350 (1975) standards.

Experimental Design and Analyses

Completely randomized design (CRD) with factorial experiment was used to conduct this experiment. Analysis of variance (ANOVA) was used to evaluate mechanical properties of *G. arborea* further analysis of the means was carried out by Duncan Multiple Range Test to determine the suitability of *G.arborea* to various value-added products.

Results and Discussion

In this study, density static bending, compression parallel to grain, impact strength, tangential and radial hardness tests were conducted from two tree diameter sections and three-tree height portions. Evaluating mechanical properties of *G. arborea* helps to analyze behaviors of lumber when subjected to loads. Static bending test is the key parameter for engineers when designing structures. Therefore, information of *G. arborea* lumber strength properties obtained from this study may be used to identify the end uses of this tree for various applications.

Density

Density is the important single factor influencing the strength properties of lumber. As indicated in Figure 1, *G. arborea* density is decreasing from bottom towards middle section and increasing again in the top portion.

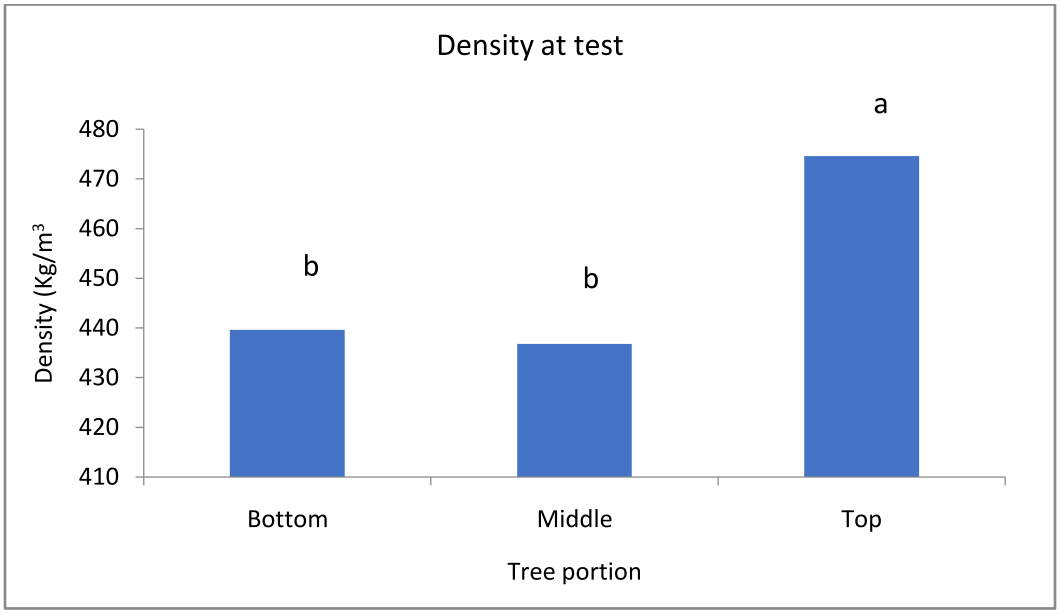

Figure 1: The effect of tree height on density

The highest density (471 kg/m^3) was observed in the top portion. The relative proportion of different types of cells distribution with the level of wall thicknesses of the fibbers may be responsible for high density in the top portion. Regardless of tree height, the average density of *G. arborea* was in the range of 440 to 471 kg/m^3.

Modulus of Elasticity and Modulus of Rupture

Measuring of stiffness (MOE) and bending (MOR) is helping to determine the resistance of applied external load on wood. The resistance of *G. arborea* from external loads is depicted in Figure 2 a and b.

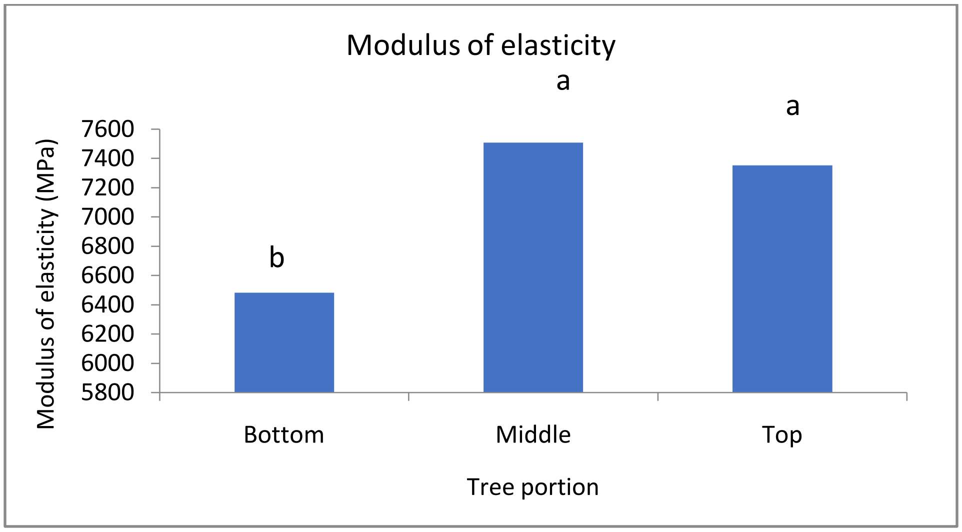

Figure 2 a: The effects of tree height on MOE

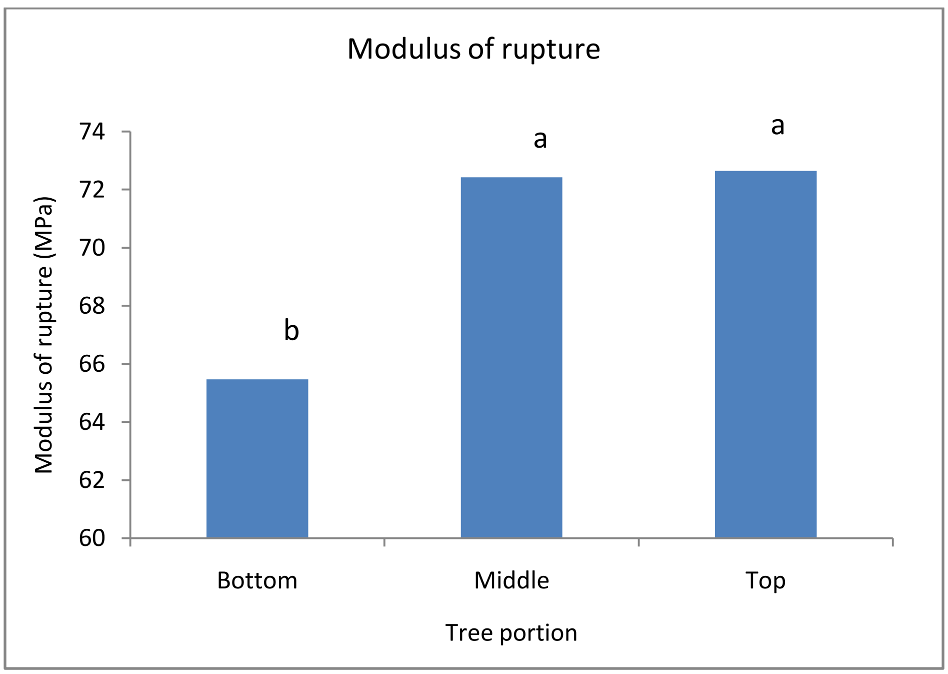

Figure 2 b: The Effects of Tree Height on MOR

As indicated in Figure 2a the middle portion of *G. arborea* has high MOE values in the middle portion than the other two portions. Regardless of tree height, the MOE values fall within the range of 6482 to 75081 MPa. On the other hand, *G. arborea* has high MOR values in the top portion than other two portions. Regardless of tree height the MOR values falls within the range of 65.47 to 72.64 MPa.

Compression Parallel to the Grain

Analysing compression strength parallel to the grain helps to determine the deformation resistances of lumber compressed or distorted under applied load. Figure 3 indicates compression strength parallel to the grain.

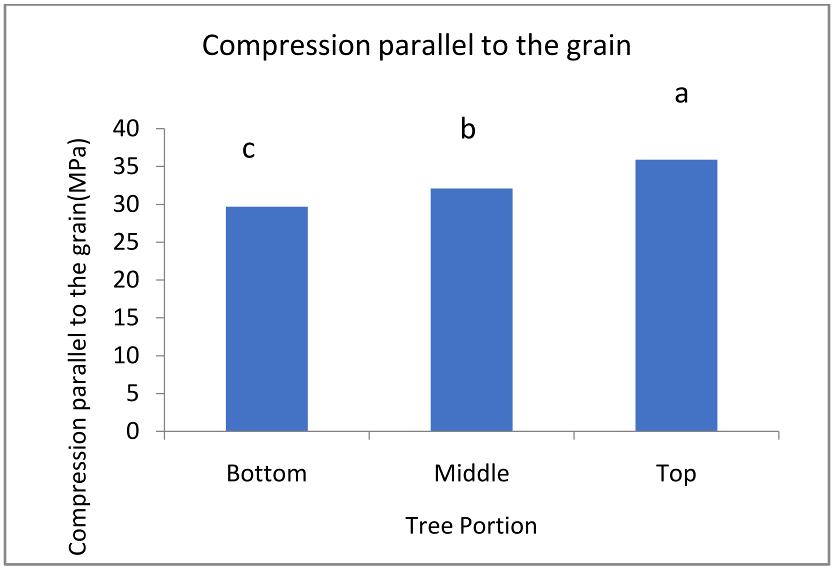

Figure 3: Effect of tree height on compression strength

The compression strength is increasing from bottom portion towards top portion. Regardless of tree height, the compression values fall within the range of 29.7 to 35.9 MPa.

Side Hardness

Analysing hardness property is important when timber is selected for paving blocks, floor ship decking and bearing blocks. Figure 4 shows side harnesses strengths of *G. arborea*.

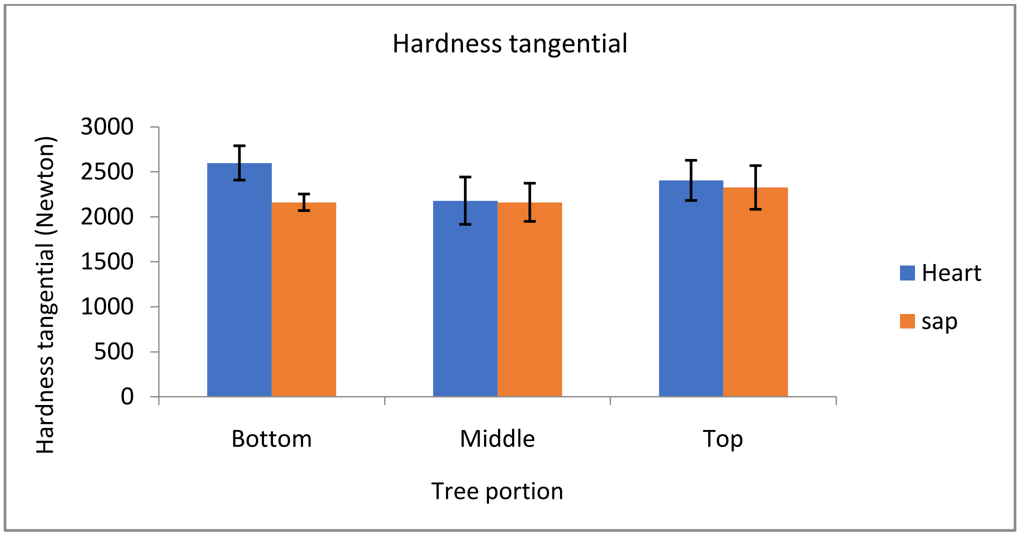

Figure 4: The effect of tree height and section on side hardness

As depicted in Figure 4 the heart section of bottom portions had high side hardness values than the other portions and sections. Regardless of tree diameter section and height, the side hardness values fall within the range of 2163.3 to 2593.3 MPa (Table 1).

Table 1: *G. arborea* strength properties comparison with some commercially important timber species grown in Ethiopia

Species	Density	MOE(Mpa)	MOR(Mpa)	Compression (Mpa)	Impact (Mpa)	Harddness (Mpa)
Anigeria adolfi friederici	560	1090	93	46	8677	4535
Podocarpus falcatus	550	6704	77	40	4680	4081
Olea wilwitischi	820	14194	124	67	16274	7434
Cypress	430	6145	61	33	5888	2761
E. saligna	680	11604	106	45	10021	3036
G. arborea	471	75081	73	36	-	2593

Conclusion and Recommendation

Based on the results of this study *G. arborea* can be recommended for the following applications: doors , windows , carriage , construction, furniture, boat building decks, sport equipment , tool handles , picture and slate frame, bent articles, turnery articles and veneer/plyboards.

Acknowledgements

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Seasoning Characteristics and Potential Uses of *Gmelina arborea* Lumber Tree Species Grown at Bonga

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Abstract

Quality and performance of wood and wood-based products have been seriously affected by the major factors, among which moisture content (MC), inappropriate drying (seasoning) and density are the preceding ones. A study was conducted on Gmelina arborea timber with the main objective of determining some imperative seasoning and density characteristics of the lumber that will help determine its wood quality and decide proper utilization. G. arborea logs were harvested in 2015 from Bonga growth trial site of Central Ethiopian Environment and Forest Research Center (CEE-FRC). The experimental design for seasoning and density was complete randomized design. The experiments were conducted using oven/microwave, air and kiln seasoning methods. Mean initial moisture content (IMC) of air seasoning stack was 143.80%, while for kiln seasoning was 120.19%. The mean IMC for both air and kiln seasoning stacks was 132%, while final MC was 12.99%. Air seasoning for G. arborea sawn boards of 3 cm thickness to reach to about 12% MC took 210 days, while kiln seasoning took 13.5 days. Kiln seasoning rate of G. arborea G. arborea lumber was 15 times faster than air seasoning. The species was classified as slow and fairly rapid air and kiln seasoning timber species, respectively. Kiln seasoning technology was better than air seasoning to minimize seasoning time, increase/maintain wood quality and suitability for different applications. When G. arborea lumber seasoned from green to 12% MC, mean shrinkage (%) characteristic values were: Tangential (3.63%), radial 1.58%), and volumetric (5.11%). Seasoning defects such as cup, bow, crook, end split, surface- and end-checks were observed, though the extent varies. Mean density of G. arborea lumber species at green (initial), basic and oven dry conditions and when seasoned to 12% MC G. arborea was 940,400, 430 and 420 Kg/m³, respectively. The density of G. arborea (420 kg/m³) at 12% MC, classified as light density lumber species. The density of G. arborea at green state and at 12% MC was 940 and 420 Kg/m³, respectively. Lumber of G. arborea shown good quality lumber characteristics, comparable with many indigenous and homegrown exotic timber species in density, seasoning rate and shrinkage characteristics.

Keywords: *Defects, density, lumber quality, seasoning defects, shrinkage and uses*

Introduction

The demand for timber to be used in 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 (CSA, 2012;

Habtemariam and Zeleke, 2014). 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 respectively (CSA, 2012; Habtemariam and Zeleke, 2014). 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. Ethiopia has been self-insufficient on producing different processed wood products (PWP) namely MDF, chipboard, veneer, cloth hangers, doors, toothpicks, paper and paper products. Thus, the country spend 55.2 million American dollar/year to import different PWP with an average increment of 13.7%/year between the years 2005-2013 (Shiferaw, 2016).

More than 300 indigenous and homegrown exotic tree species are available in different parts of the country. Yet the wood quality, suitability and potential as lumber are not investigated and realized. This was due to lack of efficient technologies for alternative use of less utilized and potential forest resources. Preference of limited tree species for every intended purpose paired with the low recovery rate of the saw mills and wood processing industries as well as inappropriate utilization due to lack of lumber properties (characteristics) information and/or processing and utilization technologies on different wood characteristics, and the rapid development of construction (industrial, commercial, and residential buildings) and demand for furniture in the country, have resulted in the degradation of the existing forests and selected tree species both in quality as well as quantity.

The quality and performance of wood and wood-based products have been seriously affected by the physical and mechanical properties of the wood. The moisture content (MC), inappropriate drying (here after, seasoning) and density have direct influence on different wood characteristics. More than 90% of all the problems 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 and 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, 2006; FPL, 2010).

Technical information on lumber seasoning, MC, density, mechanical, workability, anatomy, chemical characteristics and technologies of utilization would strongly determine rational utilization of each lumber species. Increasing efficiency of utilization of forest products can be attained 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 timber species. *G. arborea* is one of the exotic tree species introduced to Ethiopia. It is one of the species for which the wood characteristics and seasoning technologies is not studied and the timber is not widely planted and utilized in Ethiopia.

It is worth thus, to undertake integrated research on economically lesser known timber species such as *G. arborea* that is not yet known by the development, processing and construction sectors, manufactures and end users in the lumber market of the country. The hypothesis tested were: (i) Seasoning methods can make difference on lumber quality of *G. arbora*, (ii) *G. arborea* trees have quality and potential uses as lumber and (iii) *G. arborea* sawn lumber could be alternative source of raw material for forest industries and construction sectors.

The general objective of this study was to investigate the different seasoning and density characteristics, generate technical information on seasoning and density characteristics, appropriate utilization technologies, and assess potential uses of *G. arborea* sawn timber. Specific objectives were to: (i) appraise appropriate seasoning methods for the timber, (ii) determine appearance, moisture content, seasoning characteristics (seasoning rate, shrinkage characteristics, seasoning defects, possible remedies, handling techniques for seasoned lumber) and density of the timber at different MC levels (iii) observe bio-deterioration attack during and after seasoning, and (iv) search potential uses of the timbers. Therefore, this research report includes the results on imperative lumber seasoning and density characteristics, and potential uses of *G. arborea* lumber tree species grown in Ethiopia.

Materials and Methods

Highlights on research methodologies have been presented in brief. The detail methodologies on stacking of sawn boards, air and kiln seasoning technologies applied, moisture content determination and rate of seasoning, shrinkage and swelling characteristics, seasoning defects evaluation and handling of seasoned lumber as well as wood density test have been well reported by Getachew and Gemechu (2017).

Study Species and Growth Performance

The study tree species, *G. arborea* Roxb. (Family: Verbenaceae] has been known to be fast growing and provide high yield ranging from 20–25 m^3/ha/year) with impressive exceptions of over 30 m^3/ha/year (Adam and Krampah, 2005) and 18-32 m^3/ha/year (Webb, et al., 1984). The tree species has been introduced to Bonga, Aman and Tole Kobo and it showed good adaptability and good height and diameter growth performance at these sites), versatile timber and non-timber forest products, socio- economical/ cultural and ecological benefits and services.

G. arborea is native from Pakistan south to Sri Lanka and east to Myanmar, Thailand, Vietnam and southern China. It is extensively planted as a fast-growing tree in tropical areas of Africa, Asia and America. In tropical Africa, it is planted in many countries, and large-scale plantations are found in Senegal, Gambia, Sierra Leone, Côte d'Ivoire, Mali, Burkina Faso, Ghana, Nigeria, Cameroon and Malawi. The total area of *G. arborea* plantations in Africa has been estimated at 130,000 ha (Adam and Krampah, 2005; Orwa, et al., 2009).

In Ethiopia, seeds of *G. arborea* were introduced in early 1980. The Bonga growth trial site where sample trees harvested for this study was established 1983 summer time (Figure 1). *G. arborea* stamps were planted. It revealed about 100% survival after 17 years with a mean height of 15.4 m and diameter of 20.8 cm (Mebrate, 2004). The base of the trees was swollen and the bark thickened. Poor stem form with sweeps and crooks. There was no regeneration and no undergrowth in *G. arborea* stands, due to total canopy closure. The trees did not have clear bole and most of the stems were forked.

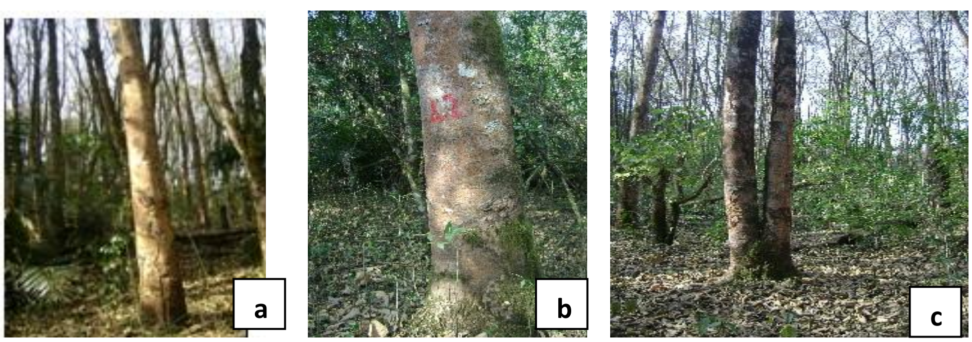


Figure 1: *G. arbora* trees with clear (Fig 1a, b) and forked (Fig 1c) boles at Central Ethiopia Environment and Forest Research Center growth trial research station at Bonga-Keja

Description: Mean height of sample trees harvested was 20.6 m, while mean breast height diameter (dbh) at 1.3 m was 36.2 cm. According to Adam and Krampah (2005), *G. arborea* is deciduous medium-sized tree up to (30–40) m tall; bole cylindrical, frequently bent, up to (80–140) cm in diameter, at base slightly swollen, without buttresses; bark smooth or scaly, corky, grey to yellowish grey or pale brown; crown with widely spreading branches. *G. arborea* is fast growing and comparatively cheap timber can supply local markets when there are no special requirements with regard to the wood (Webb, et al., 1984; Adam and Krampah, 2005; Orwa, et al., 2009). Form the tree poor to acceptable, light demanding, it has ability of coppice, frost and termite resistant (Webb, et al., 1984).

Bonga-Keja site located 449 km from Addis Ababa and 6 km west of Bonga town on the way to Mizan. Bonga site has an altitude of 1700 m, latitude 07°16 and longitude 36°15. The site has mean annual rainfall of 1700 mm and mean annual temperature of 21°C (Mebrate, 2004). In Ethiopia, *G. arborea* available at CEE-FRC growth trial research sites of Bonga, Bebeka, Tole Kobo, Aman (Mebrate, 2004).

Sample Trees Selection and Harvesting (Sampling Techniques)

In 2015, samples of *G. arborea* were harvested from Bonga site of CEE-FRC. The *Gmelina arborea* trees that have mean height of 20.6 m, mean breast height diameter (dbh) of 36.2 cm were harvested at the age of 32 years. A total of sixteen matured trees that have with a total volume of 9.3 m^3 at merchantable log size were used in the study. The selected had good morphological quality, straight and cylindrical stem, relatively free from visible defects. Trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 20 cm. Lumber seasoning and density tests were conducted in 2015.

Log Sawing and Sample Preparation

The sample trees were cut in to a size of 2.5m while green (> 30% MC) and transported to Wood Technology Research Center (WTRC) for the preparation and testing samples (Figure 2a, b). Logs were tangentially sawn into 3 cm thick boards at WTRC using mobile circular sawmill by applying through-and-through type of sawing method (Figure 2b). 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 (Burley and Wood, 1977; Lavers, 1983).

Figure 2: *G. arborea* logs (2a) arranged for sawing (2b)

Sawn boards were converted to samples with appropriate dimensions and numbers for each wood characteristic test. Samples were prepared proportionally from each log at 1 m interval along the height. Then, the sample was marked with identification codes using waterproof permanent ink. The types, dimensions and number of specimens in this study required to undertake the imperative wood characteristics and laboratory tests were conducted 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 sawn boards 24 defect- free samples with dimensions of 100 cm in length, 3 cm thickness and width equal to log-diameter were prepared. The samples were used to conduct the seasoning process and determination of the seasoning and density characteristics. The green (initial) MC of each timber species was determined from the two small sections (having 1.2 cm length and 3 cm thickness) cross-cut from both ends of sample boards. Specimens free from visible defects but clearly visible tangential and radial surface with 2 cm width x 2 cm thickness x 3 cm length 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 seasoning yard (Figure 3) and compartment kiln-seasoning chamber (Figure 3) areas. Boards of the species were stacked at 3 cm spacing between successive boards. The boards were stacked horizontally in vertical alignments separated by well-seasoned, squared, uniform sized and standard stickers. Long stickers with a dimension of 2.5x2.5x180 cm width, thickness and length, respectively were placed at an equal distance across each layer of lumber and were aliened one on top of the other from bottom of the stack to the top. This alignment helps to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process 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. The dimension of stickers adapted from Sweden standard.

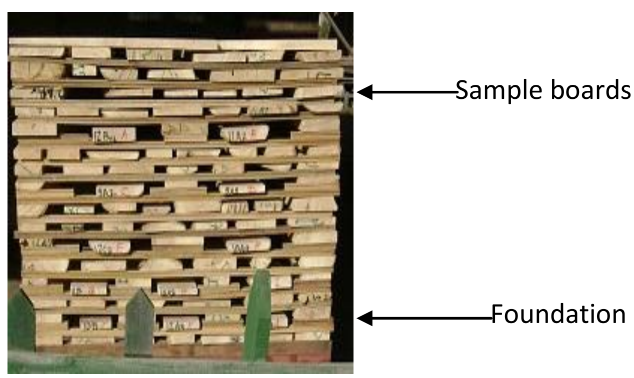


Figure 3: Seasoning stacks of *G. arborea* lumber

To minimize warping, top loading was applied (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 on stack at a spacing of 0.75 m. In each stack of the air and kiln seasoning, heartwoods, sap woods, radial and tangential boards were separated, and the heartwoods and radial boards, which have less moisture content, were placed in the middle while the sapwood and tangential boards were placed along the sides, top and bottom of the stacks. 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. The control sample boards were helping to determine the progress of seasoning (moisture reduction rate) and the final moisture content.

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 4) and tested one species at a time.

Seasoning Methods

The experimental design for seasoning and density was complete randomized design. The experiments were conducted using oven/microwave, air and kiln seasoning methods.

Air Seasoning

Natural air and artificial kiln seasoning methods were used for testing for drying the sample and determination of seasoning characteristics the specimen. To determine initial moisture content of the stack Green weights all control samples and small sections were taken immediately and dried using oven drying machine. Weighing of sections 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 (Brick wall) and has about 2.5 m^3 wood loading capacity. It has controlled air velocity, temperature and humidity that can be adjusted according to characteristics of each species. It has psychrometers (dry bulb and wet bulb thermometers) from both ends and has been equipped with fans to force air circulation, through the chamber and also air outlet at a temperature range of 40 -70ºC. The kiln seasoning schedules are steps/norms involving serious of temperature and relative humidity at different corresponding MC levels was selected based on the initial MC of timbers (Tack, 1969) adapted from England, Sweden and other schedules. While carrying out seasoning of boards of the species, kiln seasoning schedule Ethiopia 3 was applied (Table 1).

Table 1: Kiln Schedule Ethiopia

Initial MC (%)	Temperature (°C)		Relative humidity (%)
	Dry-bulb	Wet-bulb	
100-70	38	35	80
70-60	42	37	70
60-50	44	39	65
50-40	50	40	60
40-30	53	42	55

30-20	55	43	50
20-10	60	45	40

During kiln seasoning, steam was injected into the chamber to avoid splitting of the wood when the moisture content of wood reduced below fiber saturation point. 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 required final moisture content. 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).

Lumber Characteristics Determination

Moisture Content Determination

MC was determined for both air and kiln seasoning stacks of the timber species. The oven- dry weight method of MC determination (the standard way) (Haygreen and Bowyer, 1996; Reeb, 1997; Denig, et al., 2000; MTC, 2002; FPL, 2010) 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 (Denig, et al., 2000; FPL, 2010).

Rate of Seasoning Determination

Air and kiln seasoning rates of the species was 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 timber with a dimension of 2x2x3 cm (Denig, et al., 2000) was seasoned in the oven seasoning chamber to a constant dimension at a temperature of 105°c. Initial dimensions and weights of all the shrinkage samples was measured once per day. The measurements on shrinkage samples 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 was determined from green (≥ 100%) to 12% MC and from green to 0 % MC, respectively.

Shrinkage characteristic (tangential, radial and longitudinal directions, and volumetric) of values the timber 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) and FPL (2010). Shrinkage values from green to oven dry was classified based on Chudnoff (1984).

Seasoning Defects Determination and Handling of Seasoned Lumber

Initial and after seasoning defects of timbers including knots, cup, bow, twist, end split, end and surface checks were determined. Seasoned boards were properly piled in the air seasoning yard, board on board, without stickers between boards. 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 timber species 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 (ISO 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/cm^3 or 1000 Kg/m^3 (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 were 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).

Results and Discussion

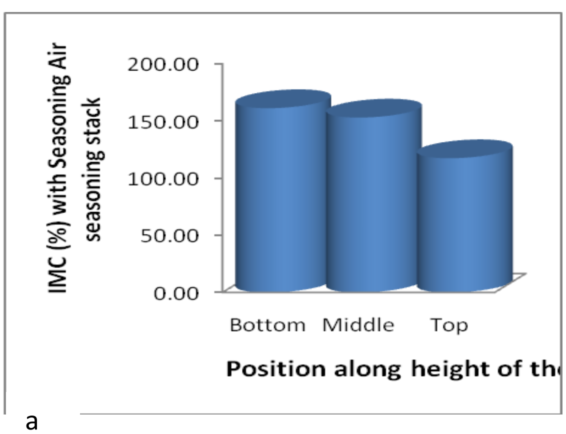
Appearance

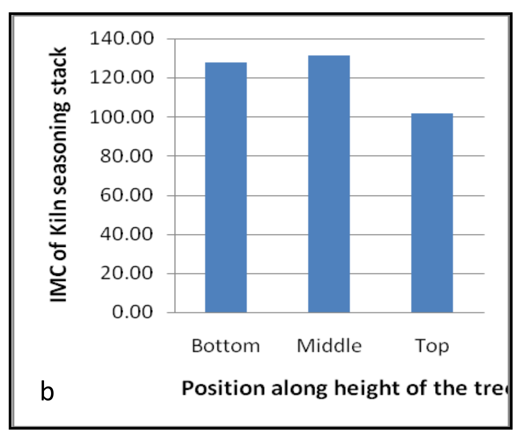
The appearance of heart wood and the sap wood is indistinctly demarcated from each other. The heartwood of *G. arboria* has pale brown to yellowish brown and sometimes with a pinkish tinge appearance. Whereas the sapwood has a whitish (sometimes), a greenish or yellowish tinge appearance (Figure 4) with a 5–7 cm wide. The grain is straight to interlocked, while texture is coarse. Growth rings are distinct in regions with a marked dry season, but not distinct in other regions. The wood is somewhat oily to the touch as Adam and Krampah, 2005 indicated.

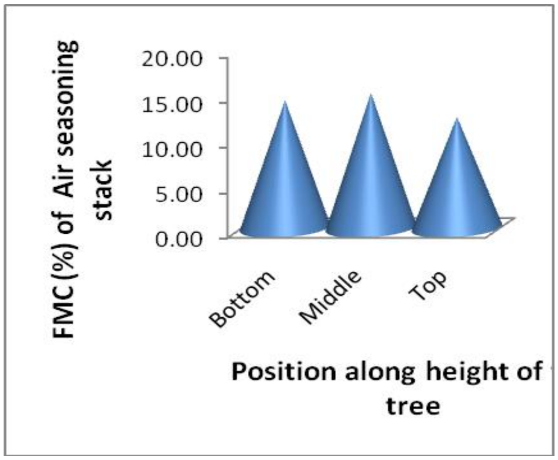
Figure 4: Lumber pictures of study tree species at Wood Technology Research Center sawmill before stacking

Moisture Content

Before air and kiln seasoning commenced, the mean initial MC (Figure 5 a, b) for the timber species was 132%, while the final mean MC (Figure 5 c, d)for both air and kiln seasoning was 12.99% (Table 1). After seasoning, the species attained 12.99% mean MC. This means that 0.13 times the weight of wood substance has been occupied by moisture/water, while 85% was only wood substance.







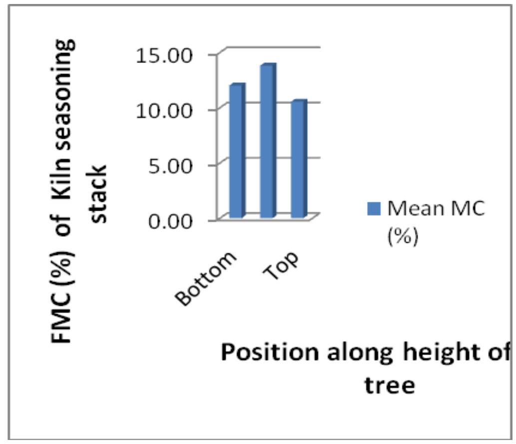


Figure 5: Initial MC (a, b) and Final MC (c, d) of *G. arborea* with seasoning air and kiln seasoning methods

Initial MC along height of timber during air seasoning varies slightly (Figure 5). *G. arborea* bottom part had 162.12% MC; middle part had 152.92% MC, while top part had relatively the least MC (117.35%). Kiln seasoning lumber stack had 127.70% initial MC for bottom part, middle part had 131.11% and top part 101.75% MC. Initial MC decreased along height.

Rate of Seasoning

When comparing the air seasoning and the kiln seasoning of *G. arborea* lumber, the kiln drying was 15 times faster. In other words, air seasoning took much time, i.e., it took 15 times greater than kiln seasoning. At controlled environmental conditions the seasoning defects was less likely in the air seasoning process. Air seasoning rate of *G. arborea* was 7.37%/day, whereas kiln seasoning rate was 0.61%/day. Based on the adapted rate of seasoning categories Longwood (1961) for air seasoning and Farmer (1987) for kiln seasoning this study revealed that the rate of air seasoning of *G. arborea* sawn boards of 3 cm thickness took 210 days (7 months) in air , while kiln seasoning took 13.5 days (about two weeks) to reach to about 12% MC. The species was classified as slow (189-

399 days) and fairly rapid (10-5-17.5 days) air based on Longwood (1961), and kiln seasoning timber species based on Farmer (1987). Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality mainly in terms of low shrinkage and seasoning defects of seasoned lumber.

According to Adam and Krampah (2005), seasoning of *G. arborea* is reported as either good and fairly rapid or slow with some risk of warping and collapsing that may result from either genetic variation or growing conditions. Air seasoning may take about 3.5 months for boards of 0.125 cm and about 11 months for boards of 3.8 cm thick. Kiln seasoning of the wood is satisfactory. It takes about 2 weeks to kiln dry boards of 2.5 cm thickness from green to 12% moisture content. Recommended temperatures to kiln-dry boards up to 3.8 cm thick vary from 42°C for green wood to 60°C for wood of 20% moisture content, and from 46°C to 66°C for planks over 7.5 cm thick. Once dry, the wood is in general very stable in service (Adam and Krampah, 2005).

Shrinkage and Swelling (Dimensional Changes)

When lumber of *G. arbora* timbers seasoned from green (138.06%) to 12% MC, the mean shrinkage percentage values was tangential (3.63%), radial (1.58%), and volumetric (5.11%), respectively. The mean shrinkage percentage values when lumber of *G. arborea* timbers seasoned from green (138.06%) to 0% MC was tangential (6.05%), radial (2.63%) and volumetric (8.52%), respectively (Table 2). Shrinkage percentage values of *G. arborea* timbers at 12% MC was classified tangential (3.63%) radial (1.58%), and volumetric (5.11%), respectively. The longitudinal shrinkage values of wood varies from 0.1%-0.3%; Radial shrinkage: 2.1-7.9%; Tangential shrinkage: 4.7-12.7%. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage.

Table 2: Mean shrinkage characteristics of *G. arborea* lumber species at 12% and 0% MC

Position along height	Shrinkage (%) at 12 % MC				Shrinkage (%) at 0% MC			
	Tangential	Radial	Longitudinal	Volumetric	Tangential	Radial	Longitudinal	Volumetric
Bottom	3.89	1.29	0	5.09	6.49	2.15	0	8.49
Middle	3.61	1.89	0	5.39	6.02	3.15	0	8.98
Top	3.38	1.56	0	4.85	5.64	2.60	0	8.09
Mean shrinkage values	3.63	1.58	0	5.11	6.05	2.63	0	8.52

The shrinkage characteristics of *G. arborea* along height (bottom, middle and top parts) did not vary significantly when boards seasoned from green condition (134.12 % - 140.84% MC) to 12% MC. Tangential shrinkage of *G. arborea* was 2.3 times greater than radial shrinkage. The shrinkage values of the lumbers up to oven dry (0%) MC compared at 12% MC was increased by about 1.67 times. Longitudinal shrinkage was negligible.

Tangential (3.63%) and radial (1.58%) shrinkage values of the study species *G. arborea* at 12% MC was compared with similar study of Adam and Krampah, 2005 indicated that the value of tangential shrinkage is between 2.4-3.5% and the radial shrinkage value is in a range of 1.2-1.5% ware found to be slightly high. The lower the shrinkage value, the higher the quality of timber for application. The respective mean tangential, radial, and volumetric swelling characteristics of *G. arborea* timbers at 12% MC were 7.10, 3.63 and 11.32%, respectively. The rates of shrinkage according to (Adam and Krampah, 2005) were low, from green to 12% moisture content tangential 2.4-3.5% and radial 1.2-1.5% while from green to oven dry tangential was 4.3-7.4% and radial 2.4–5.3% (Adam and Krampah, 2005).

Comparable timber species with the tangential shrinkage *G. arborea* was 3.63% at 12% MC, and this was comparable with species like *Celtis africana* (3.95%), *Grevillea robusta*

(3.42%), *Mimsopus kummel* (3.87), *Morus mesozygia* (3.45), *Olea welwechii* (3.97%), *Melica excelsa* (3.64%), *Eucalyptus globulus* (3.48%), *E. saligna* (3.63%), *Fagaropisis angolensis* (3.91%). Comparable timber species in radial shrinkage characteristics (1.58%) at 12% MC include *Cordia africana* (1.59%), *Warburgia ugandensis* (1.52%), *Pinus patula* (1.63%). Comparable timber species with *G. arborea* in volumetric shrinkage characteristics (5.11%) at 12% MC were *Croton macrostychus* (5.20%), *Celtis africana* (5.89%), *Diospyros abyssinica* (5.99%), *Morus mesozygia* (5.24), *Pinus patula* (5.27%), *Pinus radiata* (5.2%).Comparable species can be used as substitute when ever need arises for the purpose.

Seasoning Defects and Possible Remedies

Seasoning defects such as cup, bow, twist, end split and checks were observed, though the extent varies (Table 3). In some boards, heart rot was observed along the pith.

Table 3: Measurement on seasoning defects of the study species

Sample code	Warp					Checks					
	Cup (mm)	Bow (mm)	Twist (mm)	Crook	Spring (mm)	Surface check (mm)	End check	Surface split following pith	End split depth (cm)	Knots (Diameter mm)	Knots (Number
Mean	0.73 mm	1.08 mm	1.71 mm	4.67	None	Observed along pith	-	None	23.98 cm	4.94 mm	4.4 (Fine and dead knots)

In brief, preventions or remedies for seasoning to minimize these defects proper stacking using standard and well seasoned stickers, end sealants or plastic end cleats, top loading/ adjustable strapping are recommended.

Storing and Handling of Seasoned Lumber

Seasoned boards were properly piled board on foundation 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 density of *G. arborea* lumber species at green (initial), basic and oven dry conditions and when dried to 12% MC *G. arborea* (Table 4) was 940,400, 430 and 420 Kg/m^3, respectively (Table 3). The oven-dried density of *G. arborea,* 420 kg/m^3 at 12% MC, is classified as light density (300-450 Kg/m^3) lumber species. According to Adam and Krampah (2005), the density of *G. arborea* was 400–510 kg/m^3 at 12% moisture content. It has been found to increase gradually from the pith outwards in planted trees of 8 years old in Nigeria, and also upwards on the bole of the tree. Studies in Nigeria have shown that there is a high correlation between density and age (Adam and Krampah, 2005).

Table 4: Density characteristics (Kg/m^3) of *G. arborea* at different MC (%)

Position along height	Initial MC (%)	Density (gm/cm^3) At			
		Density at Test	Basic Density	Density at Oven dry	Density at 12 % MC
Bottom	140.84	920	380L	420L	410L
Middle	134.12	1010	430L	480M	470M
Top	139.12	880	370L	400L	390L
Mean	138.03	940	400L	430L	420L

G. arborea is a lightweight hardwood (Adam and Krampah, 2005). The density of *G. arborea* at 12% MC (420 Kg/m^3) were comparable with *Celtis africana* (410 Kg/m^3), *Cordia alliodora* (390 Kg/m^3), *Cupressus lusitanica* (430 Kg/m^3), *Eucalyptus deglupta* (410 Kg/m^3), *Pinus patula* (450 Kg/m^3), *Pinus radiata (450* Kg/m^3*)* and *Polyscias fulva* (440 Kg/m^3) (WUARC, 1995; Getachew, et al., 2012).

Potential Uses/Applications of G. Arborea Timber Species

G. arborea 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 the species recommended for the different potential applications/uses accordingly. The wood is suitable for general utility purposes, especially light construction and structural work, general carpentry, plywood (round wood), boxes, packaging, carvings, tools (sawn wood), utility furniture, building pole, and decorative veneers, with excellent woodworking properties (Webb, et al., 1984; Adam and Krampah, 2005).

Additionally, the wood has been used in light flooring, for musical instruments, matches, particle board, as a mine timber, in vehicle bodies and ships. It is suitable for telephone posts when treated with preservatives. It produces good-quality short fiber pulp; unmixed semi-chemical pulp is only suitable for carton board or low-grade writing paper, kraft pulp is suitable for higher grades of writing paper. The wood is often used as firewood (CV= 20757 KJ/Kg) and for charcoal (Webb, et al., 1984; Adam and Krampah, 2005).

NTFPS and Live Tree Uses

G. arborea is planted as an ornamental, avenue and shade tree in urban and peri-urban areas. It is also used in coffee and cocoa plantations to protect the young crop and to suppress noxious grasses. It is useful as a firebreak because it suppresses undergrowth and its leaves decay rapidly. It is often planted as a windbreak and hedge. It has potential for reforestation in dry forest regions. In tropical Asia roots, bark, leaves, fruits and seeds are used in Hindu medicine, honey flora; cattle fodder (fruits and leaves). Both the fruit and bark have medicinal properties against bilious fever. Leaf sap is taken as a demulcent to treat gonorrhoea and cough, and it is applied to wounds and ulcers. The roots are considered to have tonic, stomachic and laxative properties, and the flowers have been used to treat leprosy and blood diseases. The fruit is edible. The leaves are widely used as cattle fodder, and in silkworm culture. The wood ash and fruit yield very persistent yellow dyes. The flowers produce abundant nectar, from which a high-quality honey is produced (Webb, et al., 1984; Adam and Krampah, 2005).

Future Prospects of *G. Arborea* Timber Species

G. arborea for improved utilization and conservation considered very promising due to ease and cheapness of plantation establishment, rapid growth and thus expectation of early returns, and good wood characteristics. The usually poor form and tapering of the bole limit its use for sawn timber. Moreover, *G. arborea* performs very differently on different soil types. Breeding may overcome these problems, and the results of provenance trials suggest good prospects for improvement programmes, which should be accompanied by optimized methods of vegetative propagation. This offers possibilities for large-scale planting of *G. arborea* for a variety of purposes (timber, pulpwood, firewood) and in environmental conservation activities where the vegetation cover has to be restored in the shortest possible time. *G. arborea* also has opportunities for more widespread planting as a shade tree, windbreak and firebreak (Adam and Krampah, 2005).

Conclusions and Recommendations

This study revealed the lumber from *G. arborea* produce good lumber that have good characteristics and qualities. The species was comparable with many indigenous and exotic timbers in density, seasoning rate and shrinkage. It has multipurpose lumber and wood-based products, non-timber forest products and live trees have ecological uses/ cultural aspects. The lumber tree species *G. arborea* have to be well grown and managed, logs have to be properly harvested and sawn, boards stacked properly and seasoned to less than 20% MC. *G. arborea* boards seasoned preferably with kiln seasoning method that can help to minimize seasoning time, seasoning defects and shrinkage characteristics thereby increase quality. However, in the absence of kiln seasoning technology, air seasoning under shed, with proper stacking and top lading has been recommended. Seasoned lumber of the study species have to be properly handled and rationally utilized at specified MC and density for intended construction and furniture purposes. *G. arborea* lumber, to a certain extent can substitute comparable and endangered timber species in Ethiopia.

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Investigation on Energy Quality of Briquettes Made from Jatropha Husk

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Abstract

A briquette is a block of compressed coal dust, charcoal dust, sawdust, wood chips or agricultural residue and lignocellulosic biomass, and is used as a fuel in stoves and boilers. Successive utilization of waste biomass in developing countries occurs at poor level, despite the fact, that it has great potential in solid bio-fuel production and to protect environment and reduce air pollution. This study was undertaken to determine suitability of waste biomass originating from production of Jatropha and also to assess the energy quality of briquettes produced from Jatropha husk in the country. The binding material was prepared from soil, banana peel, potato peel, mixture of banana peel and soil binder, mixture of potato peel and soil binder. The grinded char powder of Jatropha husk feedstock was mixed with binder in ratio 3:1 for briquette produced. Combustion related properties namely percentage of moisture content, volatile matter, ash content, fixed carbon, bulk density and calorific value of the briquettes where determined. All processing variables assessed in this study were not significantly different except for percentage fixed carbon at five percent level of probability. The result shows that briquette produced from sample of Jatropha husk bonded with a mixture of banana and soil had the highest calorific value while briquette produced from sample of Jatropha husk bonded with banana as a binder had the least calorific value. Since the aim of briquetting is to produce briquette that will serve as good source of fuel and support combustion, the best briquette was produced when Jatropha husk was mixed with a mixture of banana and soil. Also the use of Jatropha husk for briquette production should be encouraged as this will provide an alternative to firewood for household cheap energy source.

Keywords: *Binding agents, calorific values, combustion properties, proximate composition*

Introduction

The world energy demand is mainly dependent on fossil fuel utilization, which is contributing to accumulation of greenhouse gases those are creating conditions for happening of climate change (Eijck, et al., 2006). Hence, due to this dilemma and its minimal toxicity to environmental pollution the world focus on searching of renewable sources of energy and biodiesel production is attracting the world for utilization of as alternative to fossil fuel (Parawira, 2010). *Jatropha curcas* L. is among the essential plant for biodiesel production (Insanu, et al., 2013) and it is non edible crop which is widely used for biodiesel production (Nahar and Ozores-Hampton, 2014).

It is already known that cultivation of *J. curcas* as source of energy for biodiesel production is supporting to ease the energy crisis as well as generate income (Benge, 2006; Nielsen, et al., 2013). Similarly, the plant have played great roll in the provision of land rehabilitation, mitigate climate change and avoid gender disparity. *J. curcas* is a tropical and sub tropical plant which is a promising to substitute diesel and now a day number of plantations and engines test has been demonstrated in the world (Parajuli, 2009). However, disposal of *Jatropha* husk after decortification of the seed were cause different environmental problem, which needs proper disposal. However, a key solution for such condition is utilization of them as source of energy.

Jatropha curcas is a tropical and sub tropical plant which is a promising to substitute diesel and now a day number of plantations and engines test has been demonstrated in the world (Parajuli, 2009). In the world 2.7 billion people depend on biomass energy (IEA, 2011) and it is the principal source of energy in developing countries (Misginna and Rajabu, 2014). Similarly, 90% of Ethiopia's energy consumption is tremendously dependent on biomass (Johnson and Mengistu, 2013) such as firewood, charcoal, crop residues and animal dung (Geissler, et al., 2013).

Likewise, exploitation of biomasses as source of energy assist dipping of greenhouse gas emissions by replacing oil (Omer, 2010), in the same way reduce vulnerability of its price, diminish poverty and promote sustainable development (Guta, 2012). However, over dependence on biomass source of energy such as fuel wood and agricultural residues have their own negative impacts (Geissler, et al., 2013). For instant, fuel wood exploitation is the most driver of forest degradation (Dresen, et al., 2014). Likewise, utilization of agricultural residues and cow dung as source of energy affects food security by depleting soil fertility.

As a result, probing of extra energy source is very important, not only to alleviate these problems but also to reduce poverty (Awash, 2014). Furthermore, it also helps to encourage sustainable development (Demirtas, 2013). So, searching of energy source from locally available biomass resources is preferable since, biomasses are environmentally friendly while biomasses are carbon neutral (Saidur, et al., 2011). Consistently, biomasses are the most promising and accessible renewable energy sources (Danjuma, et. al., 2013) that the world can be reliable on it (Roy, 2013).

Jatropha curcas is well known energy crop which have versatile importance such as the seed oil used for production of biodiesel (Jingura, et al., 2010). However, after production of biodiesel many parts of the species such as its wood, fruit shells, seed husks and press-cake were not gave much attention as source of energy. Therefore, this research full fills this gap and evaluates the energy quality of briquette produced from Jatropha husk.

So, utilization of this byproduct as source of energy helps to reduce their impact on the environment as well as used as management options. Despite the availability of enormous amount of *J. curcas* in Ethiopia, the species never been utilized effectively in the form of energy source other magnifying its problem. This research was initiated to fulfill this gap and diversify source of wood fuel as well as to develop management alternatives through briquette production. The objective of this study was to assess the possibility of briquette production from *J. curcas* and to determine their energy quality through determination of proximate analysis, calorific value, and density. So far studies showed that the quality of the briquettes is depends on the type of binding agent (Emerhi, 2011). So, this study was carried out to examine the physical and combustion properties of briquette produced from Jatropha husk using binders produced from soil, banana and potatoes peel.

Materials and Method

For this research the biomasses were obtained from *Jatropha* milling located in Amhara Regional State, Bati Woreda, based on the availability of the biomasses. While the binders i.e. soil, banana peel and potato peels were collected from Addis Ababa. The production of briquette from *Jatropha* husks involved the following steps. First, the required amounts of biomasses were allowed to dry under the sun and wind for removing the moisture before carbonization. Then after *Jatropha* husks were carbonized by using drum kiln Carbonizer, then grinded into char powders and finally briquetted by briquette press machine to obtain cylindrical shape briquette with a central hole as shown in Figure 1.

For this research purpose the binding material was prepared from soil (SB), banana peel (BB), potato peel (PB), mixture of banana soil binder (BSB), mixture of potato soil binder (PSB). The banana peel and potato peel were socked with water for two days to expose them for fermentation. Then after, the grinded char powder was mixed with this binder (banana, potato peel and soil) in 3:1 ratio. Based on the laboratory results this product deliver high amount of energy, which can substitute fuelwood.

Figure 1: Briquette produced from *Jatropha* Husk

Moisture content

The moisture content of biomass was measured by oven dry method. Initially the samples of briquette made from *Jatropha* husk with the known weight 1 g were kept in oven at 105°C for 24 hours. The oven dry sample is then weighed until constant mass was obtained. The moisture content of sample was calculated by following formula.

$$MC = \frac{M1 - M2}{M1}$$

Where: M_1 and M_2 were masses of briquettes samples in g before and after oven drying, respectively.

Volatile matter

The Volatile matter was determined by heating oven dried briquette (weight at 105°C) of the briquette samples until 950°C for six minutes. Volatile matter was calculated as a proportion of oven-dry weight of briquette samples.

$$VM = \frac{M3 - M4}{M1}$$

Where: M_3 and M_4 were masses of briquettes samples in g at 105°C and 950°C, respectively

Ash content

Ash content of the briquette was determined by heating the briquette sample in a crucible at 750°C for three hours in the oven. The ash content was calculated as the proportion of the weight of the ash in the briquette to the weight of briquette sample as follows

$$AC = \frac{M4 - M5}{M1}$$

Where: M_4 and M_5 were masses of briquettes samples in g at 950°C and 750°C, respectively

Percentage fixed carbon (PFC)

The PFC was calculated by subtracting the sum of percentage volatile matter (PVM) and percentage ash content (PAC) from 100.

$$FC = 100 - (MC + VM + AC)$$

Heating value (Hv)

This was calculated using the formula: Hv = 2.326 (147.6c +144v)

Where c is the percentage fixed carbon and v is the percentage volatile matter

Results and Discussion

The physical and combustion properties of the briquettes examined in this study were limited to the percentage of moisture content, volatile matter, percentage ash, and percentage fixed carbon and the heating or calorific value and bulk density. The results were therefore discussed according to the values obtained.

The quality determining parameter of briquette produced from biomasses expressed in terms of proximate analysis and physical properties. Because, these parameters were verifying the quality of briquette to decide for utilization. Hence, characterization of briquette for their proximate and physical properties is very important (Oladeji, 2010).

Grover and Mishra (1996) reported that many of the developing countries are producing huge quantities of agro and sawmill residues which are used inefficiently, causing extensive pollution to the environment. The major agro residues are rice husk, coffee husk, sugar cane bagasse, groundnut shells, maize cobs and cotton stalks. Sawdust is a milling residue that is also available in huge quantity. Apart from the problems of transportation, storage, and handling, the direct burning of loose biomass in conventional grates is associated with very low thermal efficiency and widespread air pollution. The summary of the effects of binders on briquette qualities is presented in Table 1. The mean percentage for the moisture content of the briquette, a general average of 7.9±% was obtained. However, briquettes produced with mixture of banana soil as binder had the highest value of moisture (11.00±1.35%) which is significantly higher than those produced with soil, banana and potato peels, and mixture of potato-soil binder. The % moisture content when potato peel, mixture of potato soil, and soil were used followed with 8.56±0.06, 8.55±0.13and 5.89±0.707% and the least was obtained with the use of banana (5.56±0.50%) as shown in Figure 2.

The mean percentage volatile matter of 17.71±% was obtained for the briquettes in general but it was observed that the briquettes produced with soil binder (SB) as binder has the highest percentage volatile matter of 19.78±1.19. This is followed by briquettes produced with banana binder (BB) with a value of 19.34±7.05% which is also significantly higher than the others produced with potato peel (PB), mixture of banana soil binder (BSB), and mixture of potato soil binder (PSB) as shown in Figure 3. The least percentage volatile matter was recorded for those produced with potato peel binder (15.67±0.38%). For the ash content of the briquette, a general average of 30.24±% was obtained. However, briquettes produced with soil binder as binder had the highest value of ash (31.22±3.19) which is significantly higher than those produced with mixture of banana soil binder and closely similar with banana, potato peel and mixture of potato soil binder. The % ash content when potato soil, potato peel and banana were used followed with 30.33±2.34, 30.22±10.37 and 30.00±2.52% and the least was obtained with the use of banana soil (29.44±2.68%) as observed in Figure 4 below. Even though there were no significant differences in the amount of carbon produced by the briquette for all the binders, the highest was obtained with the use of potato peel (45.56±17.17%), followed by those from potato soil, banana and soil binder (45.22±4.17, 45.11±2.00 and 43.11±3.86) and the least from mixture of banana soil binder (41.67±1.65%) as observed in Figure 5 below.

The minimum ash content recommended by DIN 51731 is 0.7% which is far lesser than the range obtained in this study. The percentage volatile matter of 67.98 and 86.53% for briquettes from rice husk and corn cob respectively, that were obtained by Oladeji (2010), are much higher to the mean volatile matter obtained in this study. He also obtained a carbon content that ranged between 19.42 and 42.10%, and ash content of between 1.4 and 18.6% which is lower than obtained in this study.

Table 1: Mean proximate analyses of the briquettes made from *Jatropha* Husk according to the binders

Binders	Proximate composition			
	% Moisture Content	% Volatile matter	% Ash Content	% Fixed Carbon
SB	5.89±0.707	19.78±1.19	31.22±3.19	43.11±3.86
BB	5.56±0.50	19.34±7.05	30.00±2.52	45.11±2.00
PB	8.56±0.06	15.67±0.38	30.22±10.37	45.56±17.17
BSB	11.00±1.35	17.89±2.81	29.44±2.68	41.67±1.65
PSB	8.55±0.13	15.89±1.84	30.33±2.34	45.22±4.17
Mean	7.9±	17.71±	30.24±	44.13±

There is significant difference in means with the same letter along the column

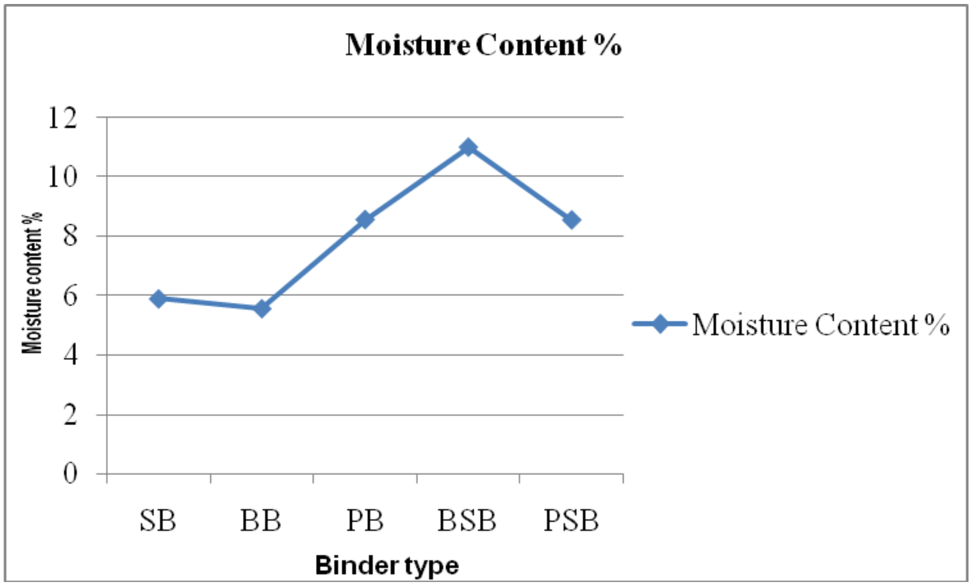

Figure **2**: Mean moisture content of the briquettes

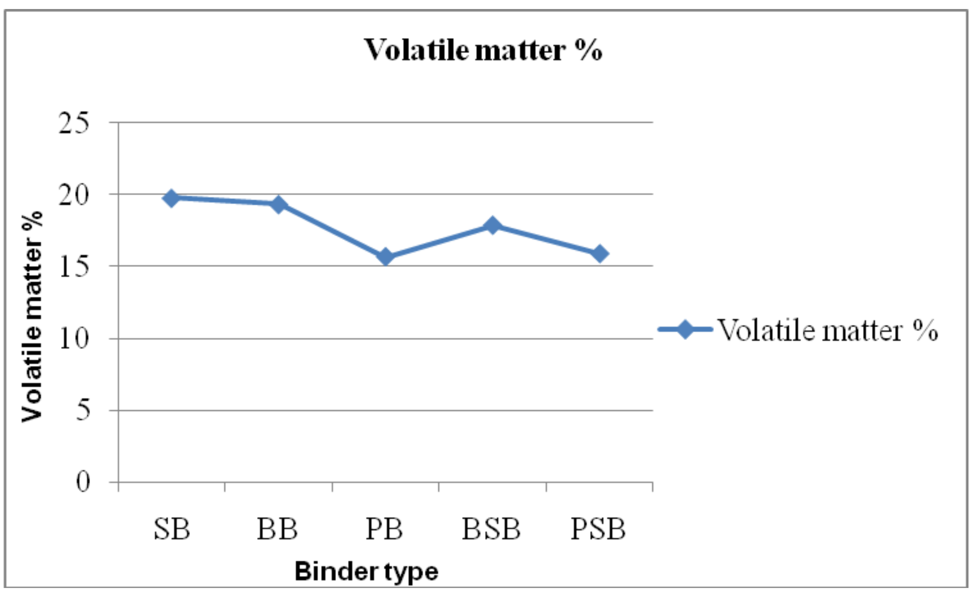

Figure 3: Mean percentage of volatile matter of the briquettes

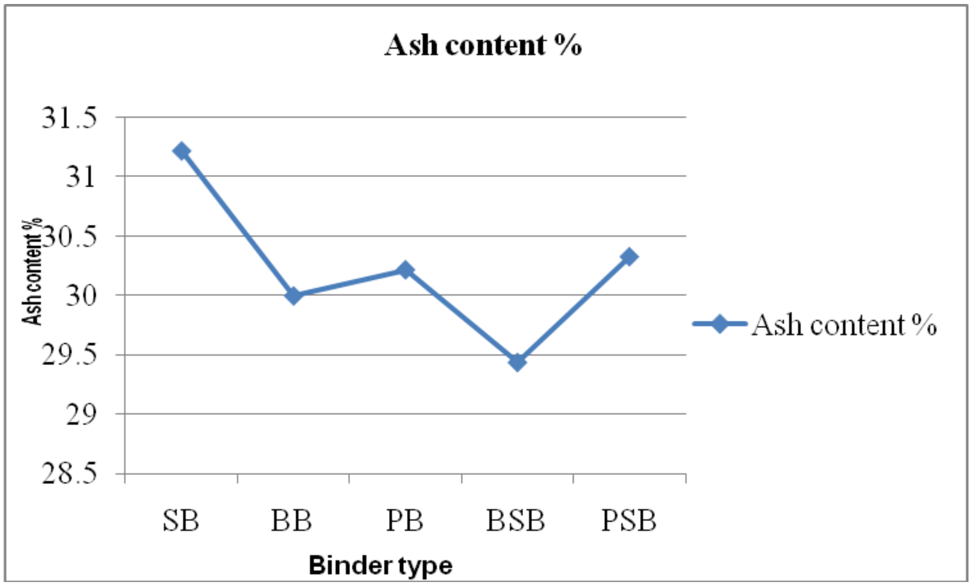

Figure 4: Mean percentage of ash content of the briquettes

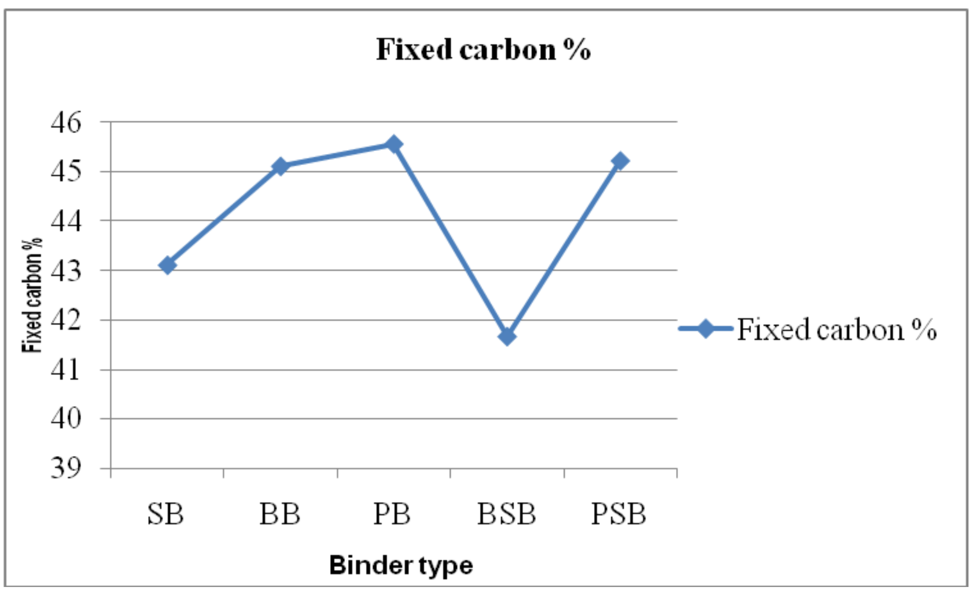

Figure 5: Mean percentage of fixed carbon of the briquettes

The density of loose biomass ranges from 0.1 to 0.2 g /cm^3. However, briquetting them they improve their density 1.2 g/cm^3 (Grover and Mishra, 1996). All briquettes in this research have with all binder type is larger than the densities of looses biomass.

Nevertheless, briquette made from *Jatropha* husk by using potato peel binder scores the highest density (Figure 6).

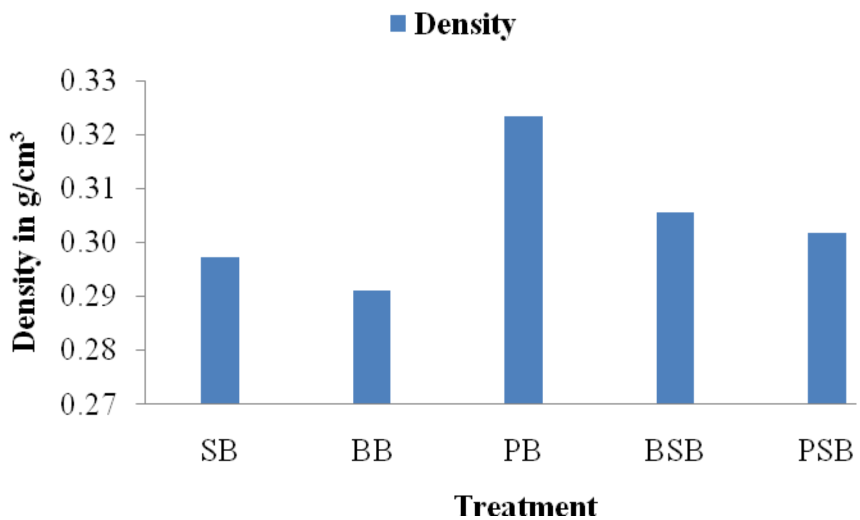

Figure 6: Mean density of the briquettes in g/cm^3 against the binder type

The heating values produced from the husk using these binders are above the required as described below. From this study, briquettes with mixture of banana soil as binder produced the highest heating value while the least was produced with the use of banana binder. The calorific value of briquette made in this research has good calorific value and all briquettes showed to be a promising alternative source of energy in the study area. On the other hand (Oladeji, 2010) reported that briquettes with heating value of 15,175 KJ/kg (3,626.91 cal/g) and 13,389 KJ/kg (3,200.05 cal/g) be able to provide an adequate amount of energy for household cooking and small-scale industrial cottage use. Therefore, all briquettes herein meet this conclusion. Thus, briquette with calorific value of more than 17.5 MJ/kg (4182.6 cal/g) satisfied the prerequisite for production of commercial briquettes and all briquette in this research fulfill this criteria.

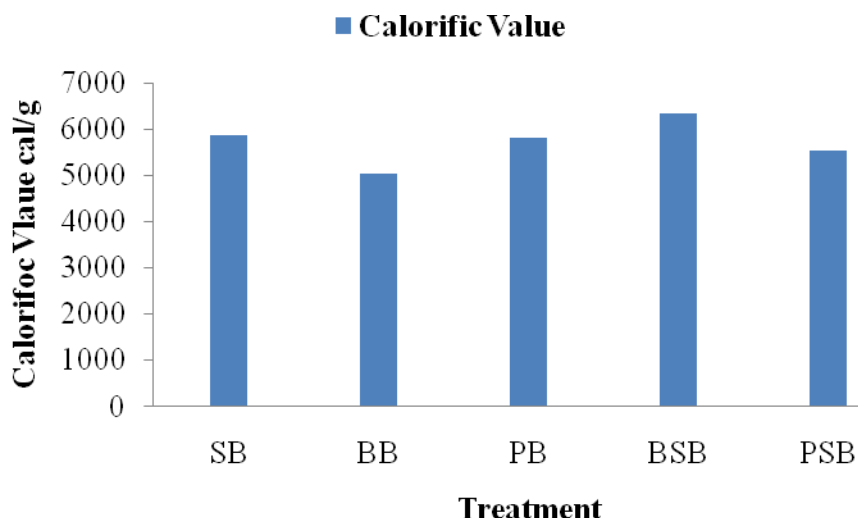

Figure 7: Mean Calorific Value of the briquettes in cal/g against the binder type

The energy values and combustion qualities of the briquettes produced in this study are sufficiently enough to produce the required heat for domestic cooking and also for industrial application especially the energy requirement of the small-scale industries (Figure 7). The physical properties, especial the low carbon content, make them to be environmental friendly and very safe for the users. There is less risk of lung infection as common with the use of fuel wood. To reduce carbon emissions and greenhouse gas effects, Panwar et al. (2011) reported that biomasses could be used to replace some coal in power plants. He reported further that briquettes are easy to transport, have better handling and storage, and are very efficient to use as an alternative fuel to coal and firewood. He claimed that the high temperature developed during the high pressure densification process usually assists the inherent lignin, which is the binder in the biomass, to bind the biomass and form a densified fuel called briquettes.

Conclusion

This work was carried out to examine the physical and proximate properties of briquettes produced from *Jatropha* husk collected from *Jatropha* milling located in Amhara Regional State, Bati Woreda, using different binding agents. The quality of the briquettes was influenced by the type of binding agent that was used. Overall evaluation of observed result values indicated suitability of investigated materials for combustion purposes, thus, proved their suitability for possible solid biofuel production. Specific parameters of tested samples exhibited satisfactory level. The quality of the briquettes that were produced using mixture of banana soil as binder was higher except moisture content following by potato peel binder than those bonded with the other types of binder used in this study. There was a little variation in the quality of the product from the *Jatropha* husk using different binders. The *Jatropha* husk with mixture of banana soil in terms of heating value is higher and lower in ash and carbon content where as potato peel binder is higher in terms of density and lower in volatile matters, which are very suitable for briquette production for domestic and industrial uses. The use of these types of binder for briquettes is environmental friendly, release lesser carbon to the atmosphere, reduce health hazard associated with the use of fuel wood and reduce deforestation and its attended complications.

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Latex Yield Variation among Hevea brasiliensis Clones Grown Under the Agro-climate of South-West Ethiopia

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Abstract

Hevea brasiliensis is the primarily commercial source of natural rubber in the world. Nine introduced and one already existing Hevea brasiliensis clones were evaluated under the climatic condition of Bebeka area, South-west Ethiopia, for their performance in latex yield for a year period. The studied rubber clones were PB86, RRIC100, RRIC101, RRIC102, RRIC121, PB2859, GT1, Malawi, Tulikobo and Mixed). The clones were evaluated in order to select those that gave better latex yield so as to select better clone for future plantation. The study was based on clone and clone x month interactions. For collection of data ten trees were selected randomly from each clone. Clonal latex yield was recorded in milliliter per tree per tapping (ml/t/t). There was significant variation of latex yield across clones, months of the year and interaction of clone x month. Based on these results and data available, it is inferred that rubber clones, Mixed and RRIC101 are superior in latex yield and they may be promising planting materials in future rubber production. An average of 89.60 and 88.97ml/t/t were recorded from the clones, respectively. Two clones (RRIC 102 and RRIC 121) were also gave better yield. The lowest yields were obtained from clones Tulikobo and GT-1. Among collecting periods, highest mean latex yields were obtained on the periods of April to June, with the pick at the month of June, 114.1 ml/t/t.

Keywords*: Clone, Hevea brasiliensis, rubber, latex, yield*

Introduction

Rubber is a valuable commodity in today's economy. A vast number of products are made from it, including washers, gloves, gaskets, tubing, waterproof clothing, toys, erasers, belts, elastics, bottle stoppers, and insulation for electrical wiring. The largest single use of rubber is in the manufacture of pneumatic tires, which consumes 60% to 70% of the total world production each year. Among commercially useful rubber-producing species, *Hevea brasiliensis* makes up 99% of the world's natural rubber production. In five to seven years of planting, *H. brasiliensis* trees are ready for tapping or harvesting of latex. Tapping can continue up to 40 years or beyond depending on the techniques of management.

History tells us that until the beginning of the 20th century, the importance of natural rubber was not fully understood by the people of Ethiopia, though it was growing in many parts of the country. Currently Ethiopia importing more than 6,000 tons of rubber at a cost of about 30 million USD from different Far East countries per annum. The country is fully dependent on imported raw materials for manufacturing rubber automotive and footwear goods. Moreover, it is obliged to compete for these materials with other foreign buyers. Ethiopia produces less than 30 ton of rubber per annum, which is an indication of a huge gap in supply of raw material of rubber to address the country's annual rubber demand.

Attempt was made to introduce and test the adoptability of this species in Ethiopia. Currently, about 12 clones of *H. brasiliensis* found as a plantation in the South-west Ethiopia. The majority of these clones were derived from Far East countries like Malaysia. These clones have been considered as the key contributing to the improvement of rubber tree in the country through tree breeding programs. Therefore, the characterization and evaluation of the existing clones are considered to be important aspects for further multiplication and expansion of *H. brasiliensis* plantation in the country. However, the information with regard to characterization and evaluation of *H. brasiliensis* clones in Ethiopia is scanty.

Commercially cultivated rubber plantations show less productivity than the potential due to yield variation found among the clones planted. There is clone to clone variation in yield within *H. brasiliensis*. The reasons for such variations need to be identified for further yield improvements. Estimates of genetic parameters revealed comparatively high heritability and scope for improvement of rubber yield by selection (Meenakumari, et al., 2015). The objective of the study was, therefore, to identify the latex yield variation among *Hevea brasiliensis* clones and select the best yielding clone for further expansion of rubber tree in Ethiopia.

Materials and Methods

This study was conducted at Bebeka locality, Gura-Ferda district, Bench-Maji Zone from July 2015 to June 2016. It is located at 651”30”-711”00” North latitude. Its altitude ranges from 800 to 1000masl. It receives an average annual rainfall of 1862.9 mm. It has 154 evenly distributed rainy days throughout the year. Annual sunshine hours are not less than 2,000. The area is mainly covered by secondary and primary deciduous tropical forests similar to those found in the rubber growing regions of the world (Ethiopian Investment Agency, 2012).

Already existing commercial rubber plantation site of National Rubber Nucleus Project of Chemical Industry Corporation of Ethiopia was chosen for the study. For the study nine introduced rubber clones and one already existing rubber clone were used (Table 1).

Table 1: Parentage of the experimental clones

Rubber clone types	Origin of clones	Year of plantation	No of plants for each clone
PB 86	Malaysia	2001 E.C.	648
RRIC 100	Sirilanka	2001 E.C.	822
RRIC 101	Sirilanka	2001 E.C.	335
RRIC 102	Sirilanka	2001 E.C.	250
RRIC 121	Sirilanka	2001 E.C.	313
PB 2859	Malaysia	1988 E.C.	NA
GT 1	Indonesia	NA	NA
Malawi	NA	NA	NA
Tulikobo	NA	NA	NA
Mixed	NA	NA	NA

All standard rubber agronomic practices were followed in the plantation. Spacing between trees and rows were 3 m and 6 m, respectively. More or less 10 identical trees from each of the tested clones were selected. Boarder trees were avoided from the experiment. An evaluation of clonal latex yield was carried out for one year period. The rubber trees from each clone were exploited for their latex yield by periodic excision (tapping) of the bark along a sloping groove placed spirally on the bark of the tree trunk. After tapping, once latex flow has completely ceased the volume of latex collected to the cup was determined using a measuring cylinder. Clonal latex yield was recorded in milliliter per tree per tapping (ml/ t/t). Latex yield data collection was throughout the year except for a one-month break in March each year. This is the period of severe defoliation of rubber trees in the study area. Latex yields were collected and measured at one-day interval.

Yield data collected were analyzed in this study. Analysis of variance (ANOVA) was conducted to test for statistical significance on the variability of latex yield between rubber clones and between different periods of the year. SAS Statistical Analysis System version 9.1.3, were used for the analysis. Least Significant Difference (LSD) test at $p < 0.05$ was employed for mean comparison with a probability threshold of 5%.

Results and Discussion

The study showed that there was a very high significant variation in latex yield among rubber clones, across tapping months and clone-month interactions (Table 2). Clonal variations were observed on latex yield in the study. During the study year superior latex yields were observed in clones Mixed and RRIC101 compared to other tested clones, 89.60 and 88.97 milliliter per tree per tapping time (ml/t/t), respectively. Rubber clone Tulikobo together with rubber clones GT-1, PB 2859 and PB 86 showed the lowest yield (Table 3). This result might be due to the clones are of medium metabolism cultivars. RRIC 102 and RRIC 121 could also be considered as the other top ranking clones 79.90 and 70.12 ml/t/t respectively. Clones Malawi and RRIC 100 showed intermediate yields.

Table 2: Mean Squares of Analysis of Variance of Latex Yield in Bebeka area

S.V.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Sample	9	22.5	2.495	5.274	4.83e-07***
Clone	9	101.1	11.236	23.749	< 2e-16 ***
Month	10	62.5	6.254	13.219	< 2e-16 ***
Clone:Month	90	66.1	0.734	1.552	0.00119 **
Residuals	981	464.1	0.473		

***: Significant at p = 0.001; **: Significant at p = 0.01 (F-test).

Other literature sources also confirmed that clone RRIC 101 was better yielding clone and PB 86 was lower yielder than RRIC 101 and RRIC 103 (Pathiratna, et al., 2006). At present, there have been other several comparative trials, all of which have shown that the RRIC 101 clones have better yield. The significant clonal variation of latex yield suggests the prospect of clonal selection for latex yield among the tested clones. The superior clones could serve as parents in crosses for the further genetic improvement of latex yield in *H. brasiliensis* (Omokhafe and Alika, 2003; Omokhafe, 2004). Heritability estimates showed prospects of improvement in rubber yield by selection. In rubber plantations, the replanting cycle is around 30 years. Therefore, high quality plants with promising vegetative characters must be selected for field establishment (Hettiarachchi and Nugawela, 2013).

Table 3: Mean Separation of Average Latex Yield between Different Clones

Clone	Yield ml/t/t	std	r	LCL	UCL	Min	Max
Mixed	89.60a	84.07	110	79.47	99.73	20.00	453.33
RRIC 101	88.97a	109.80	110	78.84	99.10	5.00	816.00
RRIC 102	79.90ab	66.80	110	69.77	90.03	5.00	332.00
RRIC 121	70.12bc	42.69	110	59.99	80.25	10.00	200.00
Malawi	67.23bcd	50.70	110	57.10	77.36	9.33	243.30
RRIC 100	65.47cd	40.69	110	55.34	75.60	17.89	273.33
PB 86	60.66cde	31.23	110	50.53	70.79	6.00	193.33
PB 2859	54.43de	48.45	110	44.30	64.56	5.00	260.00

GT-1	50.59e	31.62	110	40.47	60.72	10.00	214.67
Tulikobo	32.59f	28.91	110	22.47	42.72	2.00	146.67

Values with same alphabets are not significantly different from each other

In the case of the tapping periods, the high mean latex yield was obtained from April to June, where highest was at June (114.07 ml/t/t) followed by the periods from September to July and October to December. March was off-season from tapping. This was due to the month was the driest season in the area and trees shaded their leaves. The significant seasonal variation shows the importance of phenology and availability of moisture for the latex yield. In combined analysis, clone x month interaction was significant. The significant clone x month interaction was an indication of the importance of both clone type and season and unpredictable clonal response to the various environments. It also shows the response of the test clones to the seasons and prospects for the use of the test population for genetic improvement of high and stable latex yield of *H. brasiliensis* (Omokhafe, 2004).

Rubber yield being a complex polygenic trait, influence of genotype x environment interactions on the yield performance have been emphasized. High yielding cultivar that will perform consistently from year to year is preferred. Hence, the identification of superior varieties should not only depend on the mean yield per clone but also on the stability for yield. A genotype is considered stable if, in a given location, its yield remains more or less constant over the years (Meenakumari, et al., 2015). For further evaluation and selection in *Hevea brasiliensis* in addition to clonal selection, it should be based on individual selection (Omokhafe and Alika, 2003). Moreover, in order to express true yield potential of the clones, there is a need to use stimulants like *Ethephon*.

Conclusion

The latex yield of rubber trees were highly influenced by the type of rubber clones grown. From the results, it can be concluded that the two clones of rubber, Mixed and

RRIC101 gave the highest yield; whereas, Tulikobo and GT-1 resulted lowest latex yield in the region. Therefore, in order to increase the performance of the rubber plantations, better latex yielding clones should be selected and planted. There was also a difference in rubber latex yield between different periods of the year. Periods between April and June had maximum latex yield.

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Effective Lumber Seasoning Technologies and Uses of *Pinus patula* ssp *tecunumanii* Tree Species Grown at Bonga, Ethiopia

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Abstract

Pinus patula ssp *tecunumanii timber was investigated with the main objectives of determining seasoning and density characteristics of the lumber, and to evaluate best lumber seasoning technologies (air and kiln), lumber quality and appropriate utilization. Moisture content (MC) in wood, inappropriate drying (seasoning) and density are among the major factors that can affect quality, suitability, usability, stability, serviceability and performance of wood and wood-based products. Sample logs were obtained from the growth trial site from of Central Ethiopia Environment and Forest Research Center at Bonga. Lumber seasoning tests were conducted using microwave/ oven, air and kiln seasoning techniques. The mean initial moisture content for both air and kiln seasoning stacks was 58.81%, while the final MC was 11.94%. There was no much difference in quality of lumber between air and kiln seasoning technologies. The kiln technology was much useful to shorten very much the seasoning time required to season the lumber to 12% MC. Air seasoning time for sawn boards of 3 cm thickness to reach to about 12% MC took 49 days, while kiln seasoning took 4 days. Rate of seasoning in air was ~ 1%/day, while in kiln seasoning ~ 3%/day. Kiln seasoning rate of the lumber species was 12.25 times faster than air seasoning. The species was classified as very rapid air and kiln seasoning timber species. When seasoning pine from 78.16% to 12% MC, mean shrinkage (%) values of the tangential, radial and volumetric shrinkage were 3.70%, 1.88% and 5.45%, respectively and mean longitudinal shrinkage was nil (0%). High resin content and slight knots were observed. Seasoning defects such as slight crook (spring) and twist were observed during seasoning. Mean density of the lumber species at green condition and when seasoned to 12% MC were 690 and 410 Kg/m^3, respectively. The density of P. tecunumanii after drying was classified as light density lumber species. It had shown good lumber characteristics and qualities. It has several lumber, non-timber forest products and services. Uses of P. patula ssp tecunumanii lumber for different purposes can substitute comparable and endangered lumber species available in Ethiopia.*

Keywords: *Density, moisture content, seasoning defects, seasoning rate, shrinkage characteristics, utilization.*

Introduction

Demand of forest products sectors in Ethiopia highly exceeding the supply. For the year 2020, projected demand of forest products and supply for industries, construction and energy has been 132,500,000 m^3 and 28,710,856 m^3, respectively (CSA, 2012; Habtemariam and Zeleke, 2014; Shiferaw, 2016). Demand will exceed the supply by 4.6 times. To satisfy the ever-increasing demand of consumers, large quantities of lumber, panel and fiber products are being imported from different countries with hard currency. Utilization of limited tree species for every intended purpose coupled with the low recovery rate of the saw mills and further processing industries as well as inappropriate utilization due to lack of lumber technical experience and information on properties (here after, characteristics), processing and utilization technologies, and the rapid development of construction (industrial, commercial and residential buildings) and demand for furniture in the country, have resulted in the degradation (both in quality as well as quantity) of the existing forests and selected tree species.

Moisture content (MC), inappropriate drying (here after, seasoning) and defects, variations in density, mechanical, shrinkage characteristics (tangential, radial, longitudinal and volumetric), rates of seasoning and defects (natural seasoning) and types of chosen technologies of utilization are among the major factors that strongly determine the quality, suitability, service life and performance of wood and wood-based products in service (Kininmonth and Williams, 1980; Hodaley 1989; Simpson 1991; Denig, et al., 2000; FPL 2010).

Integrated research and promotion on economically potential timber species *P. patula ssp tecunumanii* that is not yet known by the development, product processing and construction sectors, manufactures and end users in the lumber market of the country has been paramount importance. When trees grow in different environment from that of their origin, a change in technical characteristics (such as density, seasoning, mechanical) would occur due to the influence of environmental factors (soil, rainfall, temperature), species-site- matching, silvicultural practices applied, altitude and geographic orientations (Evans, 1986; Addis, 1993; Haygreen and Boweyer, 1996). *P.*

patula ssp tecunumanii has been fast-growing and high-yielding industrial species with a single, straight bole and slender trunk (Gillespie, 1992; http://tropical.theferns.info/viewtropical.php? id=Pinus+tecunumanii).

The hypothesis tested were: Seasoning technologies, rate of seasoning, moisture content, shrinkage characteristics, seasoning defects, density, have influence on the quality, suitability, service life and overall performance of wood and wood-based products in service.

Investigation was conducted on seasoning and density characteristics of *P. tecunumanii* with general objective of generating technical information on appropriate utilization technologies and assesses potential uses. Specific objectives were to: (i) evaluate appropriate seasoning technologies for the lumber species, (ii) determine appearance, moisture content, seasoning characteristics (seasoning rate, shrinkage characteristics, seasoning defects, handling techniques for seasoned lumber), (iii) determine density of the lumber at different MC levels, (iv) assess biodeterioration attack during and after seasoning, and (v) indicate potential uses of the lumber species.

Therefore, the results on lumber seasoning and density characteristics, seasoning technologies and potential uses of *P. tecunumanii* lumber tree species grown at Bonga (Ethiopia) has been included in this research report. This tree species has to get attention of researchers and development sectors to plant widely and manage stands, promote its lumber quality, suitability for different purposes, recommend its appropriate utilization technologies and wide utilization in Ethiopia.

Materials and Methods

Highlights on research methodologies have been presented in brief. The detail methodologies on stacking of sawn boards, air and kiln seasoning technologies applied, moisture content determination and rate of seasoning, shrinkage and swelling characteristics, seasoning defects evaluation and handling of seasoned lumber as well as w density test have been well reported by Getachew and Gemechu (2017).

Study Species and Growing Site

The study involved lumber of the tree species *Pinus patula* ssp. *tecunumanii* (Eguiluz and Perry) Styles (Family: Pinaceae] from Bonga elimination trial site of Central Ethiopia Environment and Forest Research Center (CEE-FRC). Bonga-Keja site located 449 km from Addis Ababa and 6 km west of Bonga town on the way to Mizan. Bonga site has an altitude of 1700 m, latitude 07°16 and longitude 36°15. The site has mean annual rainfall of 1700 mm and mean annual temperature of 21°C (FRC, 1994; Negash, 1998).

Sample Trees Selection, Harvesting, Log Conversion and Sample Preparation

In 2016 six sample trees of *P. tecunumanii* were harvested from Bonga growth performance trial site at Bonga that was 30 years old. The sample trees have 40.8 m mean height 42.8 cm mean breast height diameter (dbh) and total volume 13.4 m^3. At the age of 14 years *P. tecunumanii* tree reveled mean height and diameter of 25.16 m and 21.2 cm, respectively with lowest volume of 373.6 m^3/ha (Progeny/Family no. 12091) and highest volume of 745.7 m^3/ha (Progeny/Family no. 12079) (Mebrate, et al., 2004). Trees/wood samples representative of merchantable log size were selected and harvested (Figure 1). The sample trees had good morphological quality, straight and cylindrical stem, free from visible defects.

Figure 1. *P. tecunumanii* trees during sample selection at Bonga

Trees were felled, cross- cut into a series of 2.5 m long logs up to top merchantable diameter of 12 cm. Logs were transported to Wood Technology Research Center (WTRC) while green (> 30% MC) for the preparation and testing of samples (Figure 2). Logs were sawn to 3 cm thickness tangential boards at WTRC using mobile circular sawmill by applying through-and-through type of sawing method (Figure 2).

Boards were converted to test samples with appropriate dimensions, quantity and quality for each wood characteristic (Moisture content, seasoning rate, shrinkage and density are the main characteristics) test. Lumber seasoning samples were selected and prepared proportionally from each log at 1 m interval along height of the sample trees and marked with identification codes using an indelible waterproof permanent ink. Wood characteristics and laboratory tests were conducted 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) and FPL (2010).

Figure 2: *P. tecunumanii* logs at Wood Technology Research Center sawmill area

Ten and 12 defect free samples sawn boards with dimensions of 100 cm in length, 3 cm thickness and width equal to log diameter were prepared for air and kiln seasoning tests, respectively. The samples were used to conduct the seasoning process and determination of the different characteristics. The initial MC of each sample was determined from the small log sections that have 1.2 cm length and 3 cm thickness. The timber was cross-cut from both ends of the log for air and kiln seasoning as well as for control sample boards. Twenty seven specimens free from visible defects, clearly visible tangential and radial surfaces that have 2cm width, 2cm thickness and cm length while green state were used to determine shrinkage characteristics (ISO/DIS 4469, 1975). The shrinkage samples and the measurements (weights and dimensions) were also used to determine the density values of the species at different MC using mathematical formulas.

Stacking Sawn Boards for Seasoning

Boards were transported from sawmill area to the air seasoning yard (Figure 3a) and kiln seasoning chamber (Figure 3b) areas. Boards were stacked at 3 cm spacing between successive boards. Boards were stacked horizontally in vertical alignments separated by well-seasoned, squared, uniform sized and standard stickers. Long stickers with a dimension with (2.5 cm width, 2.5 cm thickness and 180 cm length were placed at equal distance of 0.80 cm across each layer of lumber and aliened one on top of the other from bottom of the stack to the top. The stickers were used to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process. The short strips, 2.5x2.5x20 cm were placed up on the long stickers were used to easily access and measure weight of the control sample boards of each stack progressively.

Top loading using heavy stones weighing about 50 Kg/m^2 was applied on top of the air and kiln seasoning stacks at a spacing of 75 cm. Top loading was applied to minimize warping (Simpson, 1991; Denig, et al., 2000; FPL, 2010). In each stack of the air and kiln seasoning, heartwood, sapwood and tangential boards were separated in the stack when clearly differentiated. The heartwood boards, which have less moisture content, were placed in the middle, while the sapwood and tangential boards were placed along the sides, top and bottom of the stacks. 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 (bottom, middle and top) of each stack (Figure 3a, b).

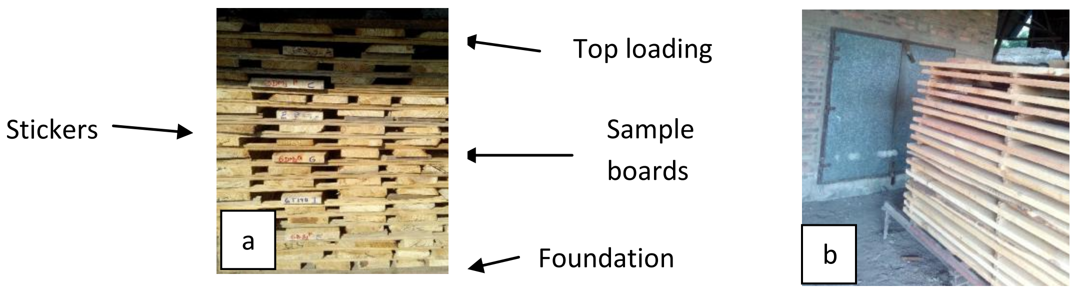

Figure 3: Seasoning stacks of *P. tecunumanii* lumber a) air seasoning, b) kiln seasoning stacks on rail carriage asymptote kiln seasoning chamber entrance

Boards for air seasoning were stacked under shed without direct exposure to moisture, rainfall or sunshine (Simpson, 1991; Denig, et al., 2000; FPL, 2010). Boards were stacked on firm level foundation/ yard having 45 cm clearance above the ground and dimensions were 1.80 width, 0.45 height and 4 m length. 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 temperature, wind and relative humidity. Boards for kiln seasoning were stacked out of the kiln on the transfer carriage having dimensions of 1.6 m width, 0.30 m height and 2.7 m length and then placed in the kiln-seasoning chamber by sliding the stack on the rail (Figure 3b).

Seasoning Technologies Applied

Air, microwave and artificial kiln seasoning methods were used fot testing and determination of the different seasoning and density characteristics of the lumber species *P. tecunumanii*.

Microwave Seasoning and Initial Moisture Content Determination

To determine initial moisture content of the stack, green weights and dimensions of all samples were taken immediately for seasoning test. Re-weighing of sections 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) and he process continued until the difference between two successive weights of each specimen became constant (0-0.2 g) and the final weights were taken as the oven- dry weight (ISO 3130, 1975; FPL, 2010). The MC of air and kiln seasoning stacks determined using formulas.

Air Seasoning

Air drying is process of drying lumber by natural conditions in a yard or in an open unheated shed. After initial MC determination, the control sample boards were weighed and, re-placed into the stack once in a week interval 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 artificial kiln seasoning machine used in this study has been well insulated with brick wall and has about 2.5 m^3 lumber loading capacity. The air velocity, temperature and humidity of the kiln and adjusted according to each species characteristics. It has psychrometers (dry bulb and wet bulb thermometers) were positioned indoor and outdoor of the kiln seasoning chamber. The kiln has been equipped with fans to force air circulation, through the chamber and also air outlet. The kiln operates at a temperature in range of 40-70^{o}C (Tack, 1969). This schedule adapted from England, Sweden and Russia schedules. In this study, kiln seasoning schedule Ethiopia 2 (Table 1) that was adapted from Sweden was applied. Kiln seasoning schedule was selected based on the species type (Hardwood or softwood), initial MC of lumber and density of the species.

Table 1: Kiln Schedule Ethiopia 2 applied.

Moisture content (%)	Temperature ((c)		Relative humidity (%)
	Dry bulb	Wet bulb	
100-70	41	38	80
70-60	45	40	75
60-50	48	42	70
50-40	52	43	65
40-30	55	44	60
30-20	60	46	50
20-10	65	48	40

During kiln seasoning samples were weighed, MC calculated, the direction of the fan was changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation, control the seasoning process and quality of the lumber seasoned. The process was continuous until the required final 12% MC reached (Haygreen and Bowyer, 1996; FPL, 2010).

Major Lumber Characteristics Determined

Collected Data

The major date item collected were dimensions and weight which were helped to determine Moisture content, Rate of seasoning of boards, Shrinkage and swelling characteristics, seasoning defects as well as density.

Moisture Content

The oven- dry weight method (the standard way) was applied for initial MC determination (Haygreen and Bowyer, 1996; Reeb, 1997; Denig, et al., 2000; MTC, 2002; FPL, 2010). The same method was applied for the determination of MC of the air and kiln seasoning stacks. The MC (%) was determined by the formula adapted from (Denig, et al., 2000; FPL, 2010).

Rate of Seasoning

Air and kiln seasoning rates of the species were estimated from the MC samples of the species using the formula adapted from Moya et al. (2013). Classification of air and kiln seasoning rates was done based on the adapted standards of Longwood (1961) and Farmer (1987), respectively.

Shrinkage and Swelling Characteristics

Samples of the lumber species with a dimension of 2x2x3 cm (ISO/DIS 4469, 1975) were seasoned in the oven seasoning chamber to a constant dimension at a temperature of 105°C. Initial dimensions and weights of all the shrinkage samples were measured once per day. Measurements of weights and dimensions were continuous until the difference between the two successive weights of each specimen was constant (0-0.2 g). Then, the final weights and dimensions were taken as oven dry weights and dimensions, respectively. Shrinkage rates of each specimen at tangential, radial, longitudinal directions and volumetric were determined from green (≥ 78.16%) condition to 12% MC and from green to 0% MC, respectively.

Shrinkage characteristics (tangential, radial and longitudinal directions and volumetric) values of the lumber species 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); FPL (2010). Shrinkage values from green to oven dry were classified based on Chudnoff (1984).

Seasoning Defects and Handling of Seasoned Lamber

Initial and after seasoning defects of the lumber were determined. Seasoned boards were properly piled in the air seasoning yard, board on board, without stickers between boards. 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 a year (March 2106-April 2017) and observations were recorded against seasoning defects and biodeterioration attack.

Density Test

The samples (2x2x3 cm), procedures and measurements applied during shrinkage tests were used to determine the density values of the species using mathematical formulas at different MC and sample conditions (green, oven dry and seasoned to 12% MC). 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 were converted to standard 12% equilibrium MC (Table 2) by applying the formulas adapted from Haygreen and Bowyer (1996); Denig, et al. (2000); MTC (2002). Density value of the species at 12% MC was classified based on the adapted standard classification (Farmer, 1987).

Results and Discussion

Appearance, one of the physical characteristics of the lumber *Pinus tecunumanii* (Figure 4) showed a white to yellowish white, with pinkish heartwood and this was in agreement with Gillespie (1992).

Figure 4. Radial surface appearance of the lumber of *Pinus tecunumanii*.

Before air and kiln seasoning commenced, the mean initial moisture content (IMC) of the lumber of moisture content of the species was 58.81%, while the final mean moisture content (FMC) for both air and kiln seasoning stacks was 11.94% (Table 2 and Figure 5). After seasoning, the species attained 11.94% MC. The mean 11.94% MC means that 0.12 times (0.12%) the weight of wood substance has been occupied by moisture/water, while 0.88 times (0.88%) was only wood substance.

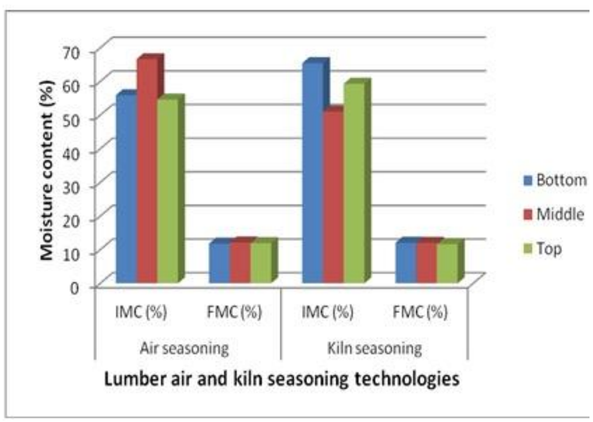

Figure 5. Initial and final MC of *P. tecunumanii* lumber stacks using air and kiln seasoning technologies IMC- Initial Moisture Content; FMC- Final Moisture Content

Initial MC along height of the lumber during air seasoning varies slightly. *P. patula* ssp *tecunumanii* bottom part had 55.9% MC; middle part had 66.61% MC, while top part had relatively the least MC (54.6%). Kiln seasoning lumber stack had 65.42% initial MC for bottom part, middle part had 51.04% and top part 59.31% MC (Figure 5).Trend of MC along height of the tree varies irregularly.

The time required for air seasoning of *P. tecunumanii* sawn boards that have 3 cm thickness to reach to about 12% MC was 49 days, while kiln seasoning took only 4 days (Table 2). In terms of final lumber quality of *P. tecunumanii,* no significant difference was found between air and kiln seasoning technologies. The kiln seasoning significantly shorten the seasoning time required to season the lumber to 12% MC. Air seasoning rate was 0.93%/day, while kiln seasoning rate was 2.58%/day. The species was classified as very rapid in air and kiln seasoning. Compared to air seasoning, the kiln seasoning was 12.25 times faster. Oak (*Quercus spp.*) lumber of 10 cm thickness has a maximum moisture loss rate of 2-4%/day; whiles maple (*Acer spp.*) loses 8-10%/day (Reeb and Brown, 2007).

Comparable timber species with *P. tecunumanii* in rate of seasoning by kiln technology were *Albizia grandibracteata* (3.5 days), *Albizia gummifera* (5 days), *Antiaris toxicaria* (3.5 days), *Blighia unijugata* (3.8 days), *Croton macrostachyus* (3.5 days), *Eucalyptus camaldulensis* (5 days), *Eucalyptus grandis* (3.5 days), *Pouteria adolfi-friederici* (3.5 days), *Eucalyptus viminalis* (4 days) and *Casuarina* species (4.4 days) (Getachew, et al., 2012; Getachew and Gemechu, 2017).

Table 2: Lumber seasoning and density characteristics (Kg/m^3) of *P. tecunumanii* at different MC (%)

Moisture content (%)		**Shrinkage characteristics (%) at 12% MC**				**Density (Kg/m^3)**	
Initial (at Green condition)	Final (at seasoned condition)	Tangential	Radial	Longitudinal	Volumetric	Green	At 12% MC
58.81	11.94	3.70	1.88	Nil	5.45	690	410

Shrinkage Characteristics

The mean shrinkage percentage values when lumber of *P. tecunumanii* seasoned from green (78.16%) to 12% MC was 3.7%1.88% and 5.45% in tangential, radial and volumetric, respectively. When lumber of *P. tecunumanii* was seasoned from green to

0% MC the tangential, radial and volumetric shrinkage characteristics were 6.1, 3.1 and 9%, respectively (Table 2 and Figure 6).

The longitudinal shrinkage values of seasoned wood at 12% MC varies from 0.1%-0.3%; Radial shrinkage: 2.1-7.9%; Tangential shrinkage: 4.7-12.7%. Tangential shrinkage is generally 1.5 to 2 times greater than radial shrinkage in line with the result obtained in this study (about two times). *Pinus patula* has radial, tangential, and volume shrinkage of 2.8 - 4.1%, 3.9 - 8.8%, and 7.3 -13.9%, respectively (Gillepise, 1992).

Shrinkage rates of the study species *P. tecunumanii* were less than *P. patula* indicating its better quality than *P. patula.* The shrinkage characteristics of *P. tecunumanii* along the tree height (bottom, middle and top parts) did not significantly differ when boards seasoned from green condition (78.16% MC) to 12% MC. The shrinkage values of the lumber up to oven dry (0%) was about 1.65 times more than that was obtained when it was dried only up to 12% MC. Longitudinal shrinkage was nil.

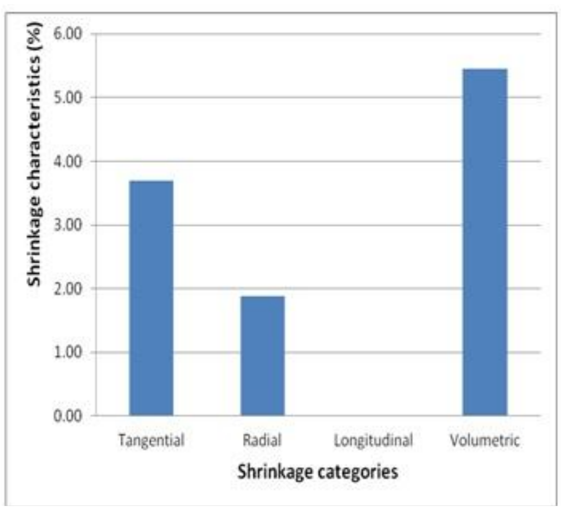

Figure 6: Shrinkage characteristics (%) when *P. tecunumanii* lumber seasoned from green to 12% MC.

Comparable timber species with *P. tecunumanii* in tangential shrinkage characteristics (3.7%) at 12% MC were *Celtis africana* (3.95%), *Grevillea robusta* (3.42%), *Mimsopus kummel* (3.87), *Morus mesozygia* (3.45), *Olea welwechii* (3.97%), *Melica excelsa* (3.64%), *Eucalyptus globulus* (3.48%), *E. saligna* (3.63%) and *Fagaropisis angolensis* (3.91%). Comparable timber species in radial shrinkage characteristics (1.88%) at 12% MC were *Cordia africana* (1.59%), *Warburgia ugandensis* (1.52%) and *Pinus patula* (1.63%). Comparable timber species with volumetric shrinkage characteristics (5.45%) at 12% MC were *Croton macrostychus* (5.20%), *Celtis africana* (5.89%), *Diospyros abyssinica* (5.99%), *M. mesozygia* (5.24), *P. patula* (5.27%) and *Pinus radiata* (5.2%) (Getachew, et al., 2012; Getachew and Gemechu, 2017).

Seasoning Defects

High resin content and slight knot were observed. Seasoning defects such as slight crook and twist were observed.

Storing and Handling of Seasoned Lumber

Seasoned boards were properly piled on board on board on foundation (under shed), without stickers and no top loading was applied. Boards were handled and conditioned well without direct access of rain and sunshine. Seasoned boards were inspected for more than a year (March 2106 - April 2017) and no further seasoning defects, neither infestation nor biodegradation attack were observed.

Density Characteristics

Mean density of *P. tecunumanii* lumber species at green (initial), basic and oven dry conditions and when dried to 12% MC were 940,400, 430 and 410 Kg/m^3, respectively (Table 3 and Figure 7). The density value 410 kg/m^3 at 12% MC classified under light density (300-450 Kg/m^3) lumber species.

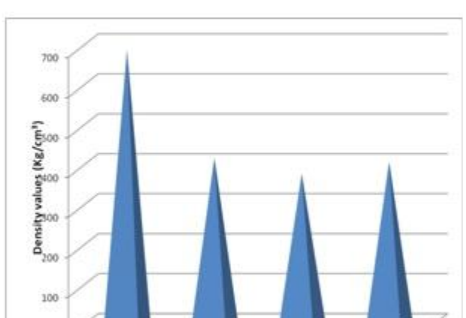

Figure 7. Density (Kg/cm^3) values at different moisture content.

In other studies, density (at 12% MC) of the wood from natural stands and at 30 years age ranged from 510 Kg/m^3 to 560 Kg/m^3 (Dvorak et al., 2000). Density (at 12% MC) of *P. tecunumanii* grown in plantations in southern Africa ranged from 400 to 520 Kg/m^3 (Gillespie, 1992).

Comparison of *P. tecunumanii* Lumber in Density Value at 12% MC with Commercial Timbers Available in Ethiopia

Comparable timber species with *P. tecunumanii* in rate of seasoning by kiln technology were *Albizia grandibracteata* (3.5 days), *Albizia gummifera* (5 days), *Antiaris toxicaria* (3.5 days), *Blighia unijugata* (3.8 days), *Croton macrostachyus* (3.5 days), *Eucalyptus camaldulensis* (5 days), *Eucalyptus grandis* (3.5 days), *Pouteria adolfi-friederici* (3.5 days), *Eucalyptus viminalis* (4 days) and *Casuarina* species (4.4 days) (Getachew, et al., 2012; Getachew and Gemechu, 2017).

P. tecunumanii is lightweight softwood (410 Kg/m^3) species. Comparable lumber species in density values at 12% MC (410 Kg/m^3) with an accuracy of ± 10% and belonging to the same light density classification (300-450 Kg/m^3) were (Figure 8) *Cordia alliodora* (390 Kg/m^3), *Cordia africana* (410 Kg/m^3), *Eucalyptus deglupta* (410 Kg/m^3), *Gmelina arborea* (420 Kg/m^3), *Cupressus lusitanica* (430 Kg/m^3), *Polyscias fulva* (440 Kg/m^3), *Pinus patula* (450 Kg/m^3) and *Pinus radiata* (450 Kg/m^3) (Getachew, et al., 2012; Getachew and

Gemechu Kaba, 2017). Density value of the study species at 12% MC were also in comparison with similar studies of Kamala et al. (2014) and Webb et al. (1984).

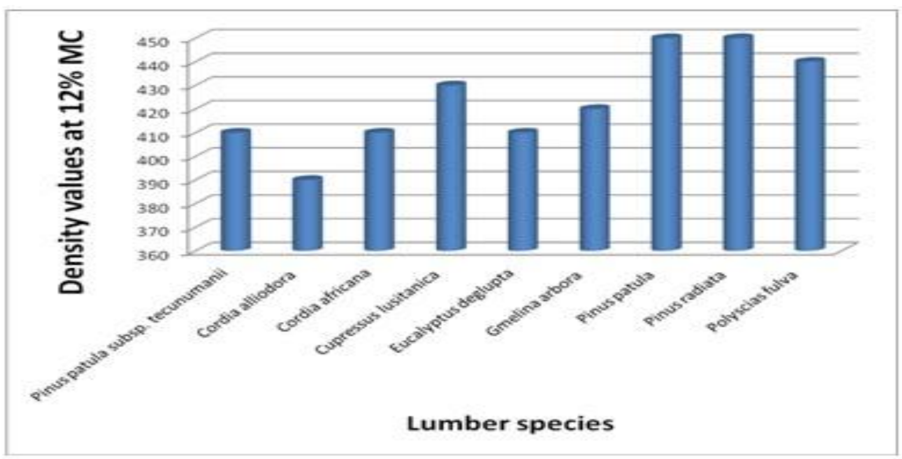

Figure 8: Comparison of *P. tecunumanii* lumber in density value at 12% MC.

The best comparable species with *P. tecunumanii* in density were I *Cordia africana, Eucaliptus deglupta, Gmelina agborea, Cupressus lusitanica* and *polyscias fulva*.

Potential Applications of *P. Patula* ssp *tecunumanii* Lumber

Industrial and Construction Uses

P. tecunumanii is an important timber tree in Central America, where it can grow to a straight bole with large dimensions. It has multipurpose lumber and non-timber forest products and services. This taxon has received considerable interest from foresters as a species for potential plantation forestry to be introduced in tropical countries. The wood of *P. tecunumanii* from both high- and low- elevation sources, when planted as an exotic, has proven in this study to be acceptable for sawn timber, light and general structural uses and flooring. Other studies further proved its suitability for vehicles, food containers, box or crate manufacture, shingles, furniture, cheap joinery, framing, pallets, broom sticks, poles, turnery, fuel wood and kindling for fires, veneer/plywood, particleboard, kraft and thermo-mechanical pulp and paper (Malan and Hoon, 1991; Eguiluz and Perry, 1983; http://tropical.theferns.info/viewtropical.php? id=Pinus+tecunumanii). *P. tecunumanii* wood is .suitable for general structural work while the inner juvenile wood is more suited to box or crate manufacture, shingles, and cheap joinery (Gillespie, 1992). In terms of wood properties, *P. tecunumanii*, grown in South Africa, generally has higher wood density than *Pinus patula, P. elliottii and P. taeda* and the lower elevation provenances have slightly higher wood densities than the high elevation provenances (https://www.researchgate.net/publication/45943564).

***Edible uses**:* A vanillin flavoring is obtained as a by-product of other resins that are released from the pulpwood (http://tropical.theferns.info/viewtropical.php?id=Pinus+tecunumanii).

Medicinal uses: The turpentine obtained from the resin of all pine trees is antiseptic, diuretic, rubefacient and vermifuge. It is a valuable remedy used internally in the treatment of kidney and bladder complaints and is used both internally and as a rub and steam bath in the treatment of rheumatic affections. It is also very beneficial to the respiratory system and so is useful in treating diseases of the mucous membranes and respiratory complaints such as coughs, colds, influenza and tuberculoses (TB). Applied externally, it is a very beneficial treatment for a variety of skin complaints, wounds, sores, burns, boils etc and is used in the form of liniment plasters, poultices, herbal steam baths and inhalers (http://tropical. theferns.info/viewtropical.php?id=Pinus+tecunumanii).

Agroforestry uses: The needles contain a substance called terpene, this is released when rain washes over the needles and it has a negative effect on the germination of some plants, including wheat (http://tropical.theferns.info/viewtropical.php?id=Pinus+tecunumanii). In general, the advantages and disadvantages of *P. tecunumanii* as seen by the CAMCORE (Central America and Mexico Coniferous Resources Cooperative) membership (Dvorak, et al., 2001):

Advantages:

- Grows quickly in the nursery.
- Captures sites rapidly when weeds are controlled.
- Shows better drought resistance than *P. patula* as was observed in other countries such as South Africa in the years following establishment.
- Better productivity than *P. oocarpa* and *P. caribaea* var. *hondurensis* on most sites in the tropics where rotation age is < 16 years.
- Higher productivity than *P. patula* in areas of infrequent frost.
- Higher productivity than *P. elliottii* at lower latitude, warmer and drier sites as was observed in the highlands of southern Africa.
- Lower bark content per unit volume than *P. taeda*.
- Lower extractive percent (approx. 4%) than some United States southern pines.
- Higher wood density than *P. patula* in Colombia and South Africa.
- Wood density more uniform within and between annual rings than *P. elliottii*, *P. patula*, and *P. taeda* in South Africa.

- Acceptable wood properties for pulp, paper and lumber.
- More resistant to *Sphaeropsis sapinea* (Diplodia) than *P. patula* and *P. greggii* in southern Brazil.
- Moderate to high tolerance to *Fusarium subglutinans* f. *sp. pini* (pitch canker) in seedling screenings
- Hybridizes easily with several pine species.

Disadvantages:

- Shallow rooted and prone to wind throw.
- Performs poorly on wet sites and when weed competition is severe.
- Frost tender.
- Does not re-sprout well after fire.
- Wood has lower tear and burst strength than *P. patula*.

The disadvantages can be overcome with improved silvicultural practices combined with selection and breeding of best provenances (Dvorak, et al., 2001).

Conclusions and Recommendations

P. patula ssp *tecunumanii* had shown high-quality lumber characteristics. It has multipurpose lumber and non-timber forest products and services. The species was comparable with many indigenous and home-grown exotic lumbers of Ethiopia in terms of density, seasoning rate and shrinkage characteristics. Trees and logs have to be properly harvested, sawn, boards stacked properly and seasoned to less than 20% MC. Boards shall be seasoned using kiln seasoning technology to minimize seasoning time, maintain wood quality and suitability for different applications. In the absence of kiln seasoning technology, air seasoning under shed, with proper stacking and top loading recommended.

Seasoned lumber of the study species have to be properly stacked and handled without direct access of moisture and biodeteriorating agents. Lumber has to be rationally utilized at specified MC and density for intended construction and furniture purposes. *P. tecunumanii* lumber applications can substitute comparable and endangered lumber species in Ethiopia. *P. patula ssp tecunumanii* has been fast-growing and high-yielding industrial species with a single, straight bole and slender trunk has to get attention of researchers and development sectors to plant widely and manage stands, promote its lumber quality, suitability for different purposes, recommend its appropriate utilization technologies and wide utilization of the species in Ethiopia.

Acknowledgements

Thanks to Negash Mamo for the recommendation to study lumber characteristics of the species. Thanks to Mindaye Teshome for providing physiognomic data and locating the plot of *P. patula ssp tecunumanii* during harvesting of sample trees at Bonga site. Sincere thanks to H.E Mr. Kebede Yimam, Dr. Wubalem Tadesse and Dr. Yonas Yohannes for their strong support to obtain log harvest permission from Sothern Nation, Nationalities and Peoples Region, Natural Resources Burea (Hawassa).Thanks to Bonga Environment and Forest Bureau and staff. Thanks to Eliyas Waritu for his assistance on proper sawing of logs at WTRC. The authors would like to thank all the coordinating, technical and supporting staff members and Sections of WTRC for their persistent support during the research period.

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Mechanical and Machining Properties of Pinus tecunumanii

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Wood Technology Research Center

Abstract

The main aim of this study was to evaluate mechanical and selected machining properties of Pinus tecunumanii. A total of 10 cubic meters of P. tecunumanii logs were harvested from Bonga Forestry Research Center experimental site in 2016 and transported to Wood Technology Research Center. Then all logs were converted to the required size of lumber to prepared sample boards for testing. For mechanical property tests boards were prepared from knot-free, straight-grained, perfect test specimens, which represent the maximum quality. Sap and heart sections specimens prepared from bottom, middle and top portions a tree were used to evaluate modulus of rupture, modulus of elasticity, compression, impact and hardness strength properties according to ISO standards. In addition to strength properties, specimens were prepared from bottom, middle and top portions to evaluated planning and nailing properties. The result indicates as tree section variability and tree height had significant effects on density, modulus of elasticity, compression, impact and hardness strength properties. Specimens prepared from sap section had high strength values than the heart sections. Tree height had no significant effect on modulus of rupture. Similarly, the sap section also had high modulus of rupture. Planing test results indicated that lumber produced from P. tecunumanii is free from machining defects and fits for high class standards furniture production. On the other hand Pinus tecunumanii has very good nailing properties; it does not split on front and back surfaces of the lumber. In general, sawn lumber produced from P. tecunumanii is light in weight and fine-grained Based on the results lumber produced from Pinus tecunumanii is recommended to use for light construction, high quality cabinet making, doors, door jumps, truss beam and rafter construction, sport equipment, bent articles, turnery articles and veneer/ply boards production.

Key words*: Pinus tecunumanii, modulus of elasticity, compressive strength, impact strength, hardness strength,*

Introduction

Pinus tecunumanii is one of the eight species of the subsection Oocarpae of the family Pinaceae. *Pinus tecunumanii* occurs naturally in Honduras, Guatemala, El Salvador and southern Mexico (Dyer, 1989). Pine species are the most important commercial timber planted in several countries. Pine timber yields a serviceable yellowish-white wood which is comparatively non-resinous and has an average wood density of about 450 kg/m^3 to 610 kg/m^3 (Poynton, 1979; Birks and Barnes, 1991; Wright and Malan, 1991).

Pinus tecunumanii was introduced and planted in 1983 at Bonga (Keja) Forestry Research Experimental site. *P. tecunumanii* and other exotic timber species were planted in different sites for selection of best provenances and adaptable tree species for industrial and fuel wood production by establishing permanent seed stands at different agro ecologies of the country. After 33 years growing period (in 2016) *P. tecunumanii* timber stands in all plots has good performance for industrial application. All trees attain moderate to large height up to 41 m and 19 to 54 cm breast height diameter. Before disseminating this timber stand seeds to small holder farmers and forest enterprises two major important properties (mechanical and machining properties) should be tested. Mechanical property testing helps to identify the end uses of any timber species such as uses for industrial application. The other important property to be tested is machining or working property. Timber obtained from plantation forests have different anatomical, physical and mechanical properties than mature timber obtained from natural forests. Due to this reason lumber produced from plantation forests shows different behavior when subjected to machines and tools. For this reason, machining tests need to be conducted on this type of wood to make better and proper use of it, thereby obtaining greater benefits from an economic and technical standpoint (Minoru and Toru, 1964).

Several factors are involved in wood machining quality, including: growth rate, moisture content, specific gravity, fiber direction, cutting speed, number of knives in the cutter-head, cutting angle, feed rate, depth of cut, penetration speed, turning speed, friction between the wood and the cutting element edge, and the type of bit used for boring (Koch, 1964, 1972; McKenzie, 1960, 1967). Minoru and Toru (1964) mention the effect of cutting angle, edge wear and surface finishing quality on planing. They noted that large angles produce poorer finishes, cause major mechanical difficulties and deform the knife edge more quickly.

The general objective of this study was to test mechanical and machining properties of *P. tecunumanii*. The specific objectives of this study was to evaluate static bending (modulus of rupture and modulus of elasticity), to evaluate compression strength parallel to the grain, to evaluate impact strength, to evaluate tangential and radial harnesses, to evaluate planing defects, to evaluate nailing defects and identify the end uses of this tree based on the results.

Materials and Methods

Mechanical Properties Determination

Ten cubic meter of *P. tecunumanii* logs were harvested from Bonga Forestry research center experimental plots and transported to Wood Technology Research Center in 2016. Then all logs were converted to the required size of lumber to prepared sample boards for testing. For mechanical property tests sample boards were prepared from, knot-free, straight-grained, and perfect test specimens, which represent the maximum quality. Sap and heart sections specimens prepared from bottom, middle and top portions with a dimension of 20x20x300 mm were used to evaluate modulus of rupture, modulus of elasticity and impact strength resistance according to ISO 3133 (1975) and 3348 (1975) standards. Specimens with a dimension of 20x20x60 and 20x20x45 mm were used to evaluate compression parallel to the grain and hardness strengths according to ISO 3387 (1976) and ISO 3350(1975) standards. Specimens from bottom middle and top sections were prepared according to ASTM (1992) for planing and nailing tests.

Machining Properties

Machining defects are mostly a problem of finished lumbers and they take place during machining processes. Machining defects decrease quality and price of wood and lumber-based products. In this section planing and nailing testing methods are presented.

Evaluating planing defects such as raised grain, fuzzy grain, torn grain, chip marks and blunting effect often occur in lumbers during planning process, is very important to determine the quality of dressed lumber. Any surface defects due to an improper machining process will also reduce the quality of the final product, resulting in an increase in the cost of the manufactured unit. Therefore, it is important to evaluate machining parameters and relate them to raw material characteristics. For this study, an experiment was carried out using a single-surface cabinet planer designed for fine work in woodworking shops. The cutter head, holding three 40 mm long knives, revolved at 3,600 r.p.m. *Pinus tecunumanii* test specimens were essentially clear, flat-grain material, 100 mm wide, 1200 mm long, and 22 mm thick were planed using this machine by fixing the feed rate at 8 m/min. Three depths of cuts 1 mm,2 mm and 3mm, and three planing angles 25, 30° and 35°.were used according to ASTM (1992). The moisture content of all specimens was 12%. The surface quality is visually graded on a scale of 1-5 (very poor to excellent or defect). Grading was based on the frequency and severity of defects occurring during the planing; namely, raised grain, chipped grain, fuzzy grain, chip marks and blunting effects. Twelve specimens were tested from each portion (bottom, middle and top) of a tree. Thirty-six specimens for each depth of cut and a total of 108 specimens were used to evaluate planing defects according to ASTM (1992).

It's well known that as nails are the most commonly used fasteners for structural construction such as trusses, as they are light and easily applied using hammers or nailing guns. Nailed joints are considered effective when nails are driven into the wood without visible splitting of the wood. To observe the split of nail at the front and back surfaces of *P. tecunumanii* 12 mm thick, 150 mm wide and 310 mm long test samples were used according to ASTM (1992). Twelve specimens from each portion (bottom, middle and top) of a three and a total of 36 specimens were used to observe nail split. Nail size with 4 mm and 857 gm weight claw hammer were used for testing.

Experimental Design and Analyses

Completely randomized design (CRD) with factorial experiment was used to conduct this experiment. Analysis of variance (ANOVA) was used to evaluate mechanical and machining properties of *P. tecunumanii.* Further comparison of the means was carried out by Duncan Multiple Range Test to determine the suitability of *P. tecunumanii* various value-added products.

Results and Discussion

Mechanical Properties Determination

As observed from sawn lumber *P. tecunumanii* is a light weight, fine-grained wood. In this study, density static bending, compression parallel to grain, impact strength, tangential/ radial hardness, planing and nailing tests were conducted to evaluate the end uses of this timber for various applications. Evaluating mechanical properties of *P. tecunumanii* helps to analyze behaviors of lumber products when designing structures and subjected to loads. On the other hand, identifying major defects arises during planing and nailing helps the furniture manufacturers to adjust their processing machineries in proper ways. Therefore, mechanical and machining properties information obtained from this study may be used to identify the end uses of this timber for furniture and construction purposes.

Density

To evaluate density at test the specimens were kept in an electrical oven at 105±3 ^{o} C for 24 h. Density is the important single factor influencing the strength properties of lumber. As indicated in Figure 1 the sap section of *P. tecunumanii* density is high in the bottom portion and low in the top. There is no density variation in the middle portion

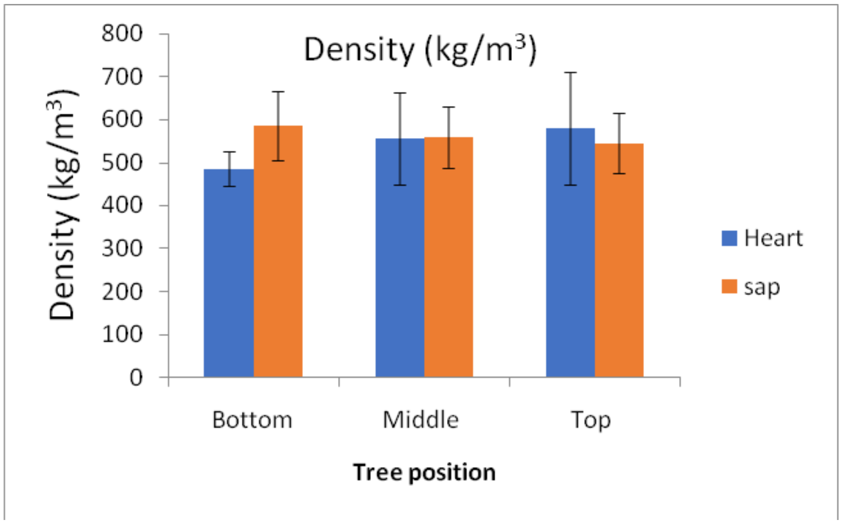

Figure 1: The effect of tree height on density of *P. tecunumani.*

The highest density (586 kg/m^3) was observed in the sap section of bottom portion. The relative proportion of different types of cells distribution with the level of wall thicknesses of the fibbers may be responsible for high density in the bottom portion. Regardless of tree height, and section the average density of *P. tecunumanii* was in the range of 485 to 586 kg/m^3.

Modulus of Elasticity and Modulus Rupture

Measuring stiffness (MOE) and bending (MOR) is helping to determine the resistance of applied external load on wood. The resistance of *P. tecunumanii* from external loads is depicted in Figure 2 a and b.

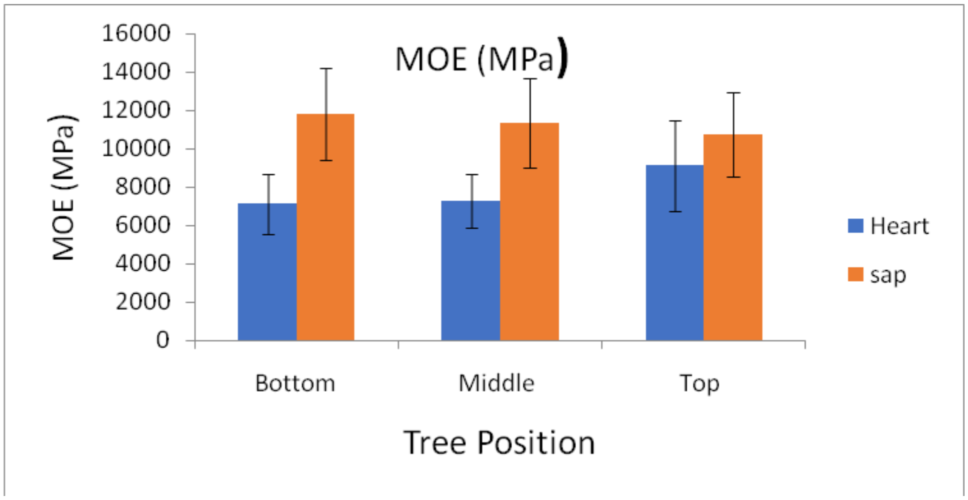

Figure 2 a: The effects of tree height and section on MOE of *P. tecunumani*.

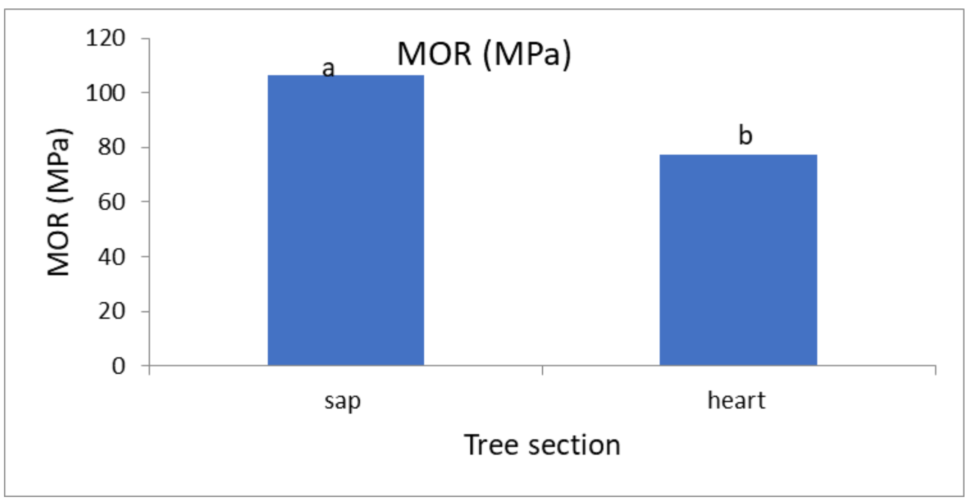

Figure: 2b. The effects of tree section on MOR of *P. tecunumani*.

As indicated in Figure 2a the sap section of bottom portion of P. tecunumanii has high MOE values than the other two portions. In all portions, the sap section shows high MOE values than the heart section. Regardless of tree height and section the MOE values fall within the range of 7104 to 11799 MPa. On the other hand, the sap section of *P. tecunumanii* has high MOR values than the heart section. Regardless of tree height, the MOR values falls within the range of 77 to 106 MPa.

Compression Parallel to the Grain

Analysing compression strength parallel to the grain helps to determine the deformation resistances of lumber compressed or distorted under applied load. Figure 3 indicates compression strength parallel to the grain.

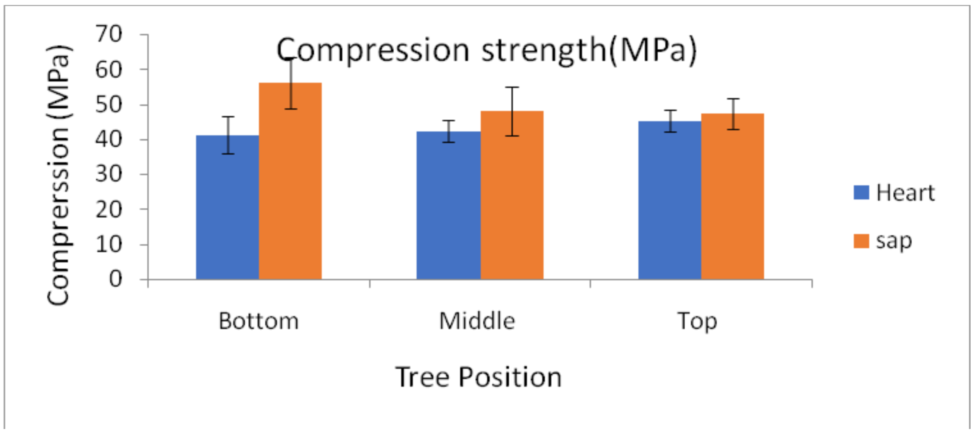

Figure 3. Effect of tree height and section on compression strength of *P. tecunumani.*

The sap section of the bottom portion shows high compression strength than the other sections and portions. Regardless of tree height and section the compression values fall within the range of 41 to 56 MPa.

Impact Strength

Evaluating impact strength helps to determine the amount of work expanded in breaking piece of wood or resistance of sudden force. Based on impact results it's possible to determine whether a wood can be used for a tool handles. As depicted in Figure 4 tree height and diameter section had a significant variation on impact strengths of *P. tecunumani*.

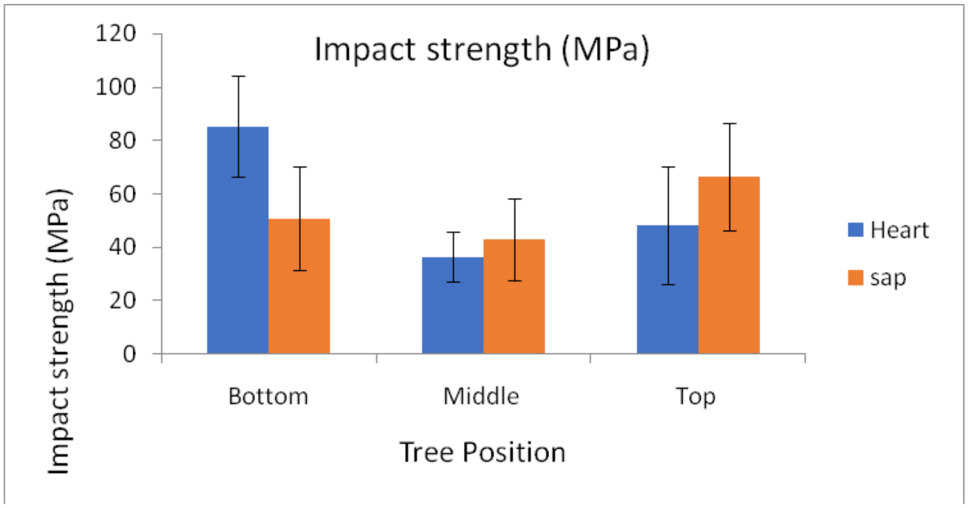

Figure 4. Effect of tree height and section on impact strength of *P. tecunumani.*

The heart section of the bottom portion shows high impact strength than the other sections and portions. The sap section has high impact strength in the middle and top portions. Regardless of tree height and section the impact strength values fall within the range of 3600 to 8500 MPa.

Hardness Radial and Tangential

Analysing hardness property is important when timber is selected for paving blocks, floor ship decking and bearing blocks. Figure 5a and b shows hardness's strengths of *P. tecunumani*.

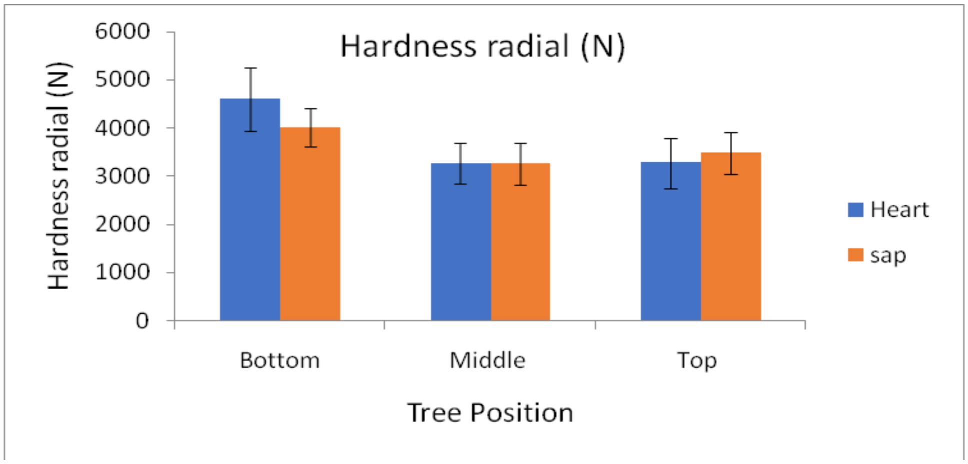

Figure 5a. The effect of tree height and section on radial hardness of *P. tecunumani.*

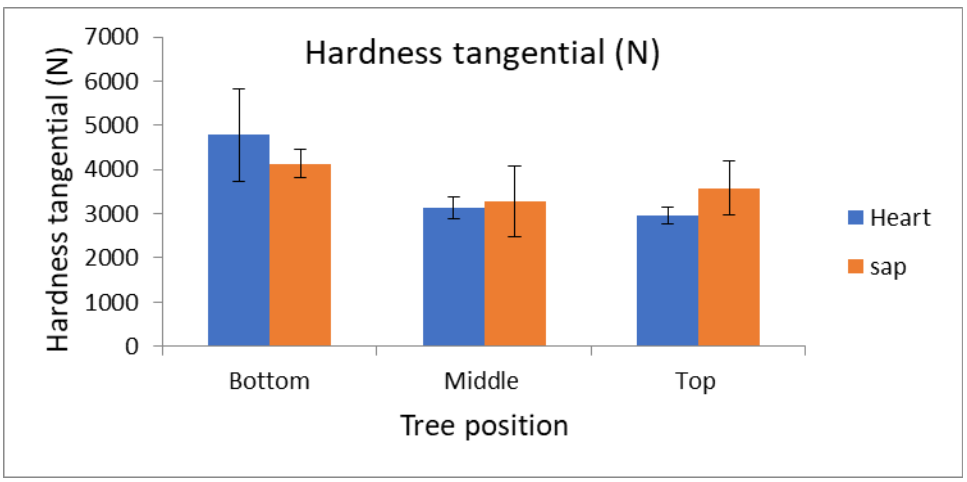

Figure: 5b. The effect of tree height and section on tangential hardness of *P. tecunumani.*

As depicted in Figure 4 the heart section of bottom portions had high hardness values for both radial and tangential hardness's than the other portions. Regardless of tree diameter section and height the hardness values fall within the range of 2163.3 to 2593.3 MPa and 2955 to 4980 MPa respectively, for radial and tangential hardness. As indicated in all figures the strength value of *P. tecunumani* is higher in the bottom portion than middle and top portions along the tree height (Table 1). This may be due to the fact that the bottom portion of the log has more mature wood than the top portion which consists of thin walls of the wood cells, lower cellulose content and crystallinity of the wood compared with that of the matured wood in the log at the bottom portion (Zobel and Talbert, 1984; Tsoumis, 1991; Dinwoodie, 2000).

Table1: *Pinus tecunumani* strength properties comparison with some commercially important softwood timber species grown in Ethiopia.

Species	Density (kg/m^3)	MOE(MPa)	MOR(MPa)	Compression (MPa)	Impact (MPa)	Hardness (MPa)
Pinus patula	450	8428	73	36	5187	2179
Podocarpus falcatus (Zegba)	550	6704	77	40	4680	4081
Pinus radiata	450	8983	77	40	5624	3168
Cupressus lustanica	430	6145	64	33	5888	2761
Juniperus procera	513	9081	87	38	-	1892
Pinus tecunumani	586	11799	106	56	8500	4980

Source: WUARC, 1995.

Machining Properties

Planing Test

According to observed planing results (Table 2) a majority of *Pinus tecunumanii* test samples were defect-free, and most of the defective samples were only slightly defective.

Table2: Planing defects of *P. tecunumanii*

Portion	Cutting angle	Raised grain			Chip marks			Torn grain		
		At depth of cut			At depth of cut			At depth of cut		
		1mm	2mm	3mm	1mm	2mm	3mm	1mm	2mm	3mm
Bottom	**25**	5	5	5	4.9	4.8	4.8	3.5	3.9	4.2
	30	5	5	5	4.8	5	4.6	3.9	4.3	4.0
	35	5	5	5	4.7	4.9	4.9	3.9	4.6	4.4
Middle	**25**	4.5	4.8	5	4.9	4.6	4.2	3.4	3.9	3.8
	30	5	5	5	4.3	4.2	4.6	4.2	3.9	4.4
	35	5	5	5	4.9	4.6	4.7	3.9	4.0	4.4
Top	**25**	4.5	5	4.9	4.8	4.6	4.5	3.8	3.6	3.9
	30	5	5	5	4.3	4.8	4.3	3.4	3.8	3.6

35	5	5	5	5	4.9	4.9	4.4	4.5	4.6

Pinus tecunumanii test samples have no totally fuzzy grain and blunting effect defects. Very slight raised grain defects were observed when samples were planing at 25°angle. This defect may improve by using 30°and 35°cutting angles for this timber. According to the results raised grain and chip marks of *P. tecunumanii* test, samples are graded excellent or defects free. Torn gain results that categorized as good grade may improve to excellent by changing the planing machine feed speed and during sanding.

Nailing Tests

As observed in Table 3 *P. tecunumanii* has less spilt at front and back of test samples.

Table 3. Nail split of *P. tecunumanii*

Portion	Split side	Split size (mm)
Bottom	Back split	47.28
	Front split	37.33
Middle	Back split	75.55
	Front split	62.30
Top	Back split	40.40
	Front split	38.40

As observed in the results the top and the bottom portion of *P. tecunumanii* test samples have less split than the middle portion. It is recommended to apply pre-boring to avoid totally splits from the samples. The density (485 to 586 kg/m3) *P. tecunumanii* and the nail sizes might be the cause for low split. High-density wood split easily hence limiting the end distances of members and nail diameters applicable to timber joints. Less dense wood like *P. tecunumanii* on the other hand, split less and can thus allow the use of more nails or nails of large diameters.

Conclusions and Recommendations

Based on the results of this study it is recommended to separate the sap and heart sections of *P. tecunumanii* during converting logs into sawn lumber. As indicated in the results lumber obtained from the sap section has high strength and durable. Sawn lumber from *P. tecunumanii* can be recommended for light construction, high quality furniture and cabinet making, doors, door jumps, truss beam and rafter construction, sport equipment, picture and slate frame, bent articles, turnery articles and veneer or ply boards.

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Assessment of Physico-Chemical Properties of Gum-Arabic from *Acacia senegal* Found in Different Localities of Ethiopia

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Abstract

A study was conducted to investigate the effect of growing location on the physico-chemical properties of gum arabic obtained from Acacia senegal. Authentic representative gum exudate samples were collected from Abederafi, Yabello, Awash and Filtu areas of Ethiopia. Laboratory analyses were employed to determine the physico-chemical characteristics. The physico-chemical characteristics studied included moisture content (MC), ash content (Ash), pH, relative viscosity (RV), Nitrogen (N), Crude Protein (CP) and mineral contents. The data were analyzed by using SAS statistical software. The analysis indicated that there is a significant difference ($p < 0.001$) in ash, pH, RV, Iron, Calcium, and Sodium contents of the gum arabic samples between the compared study sites. Significant difference ($p < 0.05$) was seen for N, CP, Cu, K contents, but no significant difference was observed for MC, Mn and Mg contents among the growing locations. The percentage MC of the gum arabic samples was between 12.64 and 13.41 %, while ash percentage was between 0.32 and 16.98 %. The mean pH values of the gum arabic samples, obtained by employing different concentrations of aqueous solutions ranged between 4.40 and 4.97. The relative viscosity of the samples studied fall between 0.9 to 4.2 centipose. Nitrogen and CP contents of the gum arabic samples were from 0.313 to 0.513 % and 1.943 to 3.21 %, respectively. The mineral compositions of the gum arabic samples, in descending order, were Mg, Ca, Na, Cu, Fe, Mn and K. As compared to international standards and prior studies on gum arabic, the gum-arabic samples from the study sites have comparable physico-chemical characteristics.

Keywords: *Acacia senegal, growing location, physico-chemical properties*

Introduction

The dryland areas in Ethiopia which fall within the range of UNEP's definition of desertification cover 71.5% of the country's total land area. Of the total estimated area of drylands in Ethiopia, 25 million ha is covered with woodland and bush land. Accordingly, the woodland and savannah region covers some 20% of the total land area of Ethiopia. From this woodland and savannah, the *Acacia* woodland and savannah occupy various environments and accounts for some 11% of the total land area of Ethiopia. Such woodlands are also known for their plant, animal, and habitat diversity. Nonetheless, they are also very fragile ecosystems that could be drastically affected by overexploitation and mismanagement.

The exploitation and management of "Non–Timber Forest Products" (NTFPs) is increasingly proposed as a potential means of ensuring sustainable management of forests and their biodiversity. NTFPs are frequently touted as important to household consumption, and as a way to maintain or to increase the value of standing forest and thus to discourage deforestation. Thus, management of NTFPs cannot be seen separately from general forest management, which, unlike forest plantation, affects vegetation and biodiversity in general.

In the dryland woodlands of Ethiopia several species in the genus *Acacia, Boswellia, Commiphora* and *Stericulia*, known to hold commercially important NTFPs such as gum arabic, frankincense and myrrh, are predominating the vegetation composition. Ethiopia is known as one of the world leading producers and exporters for some of these NTFPs with significant socio–economic contributions at both national and local levels. Apart from essential oils, which provide an array of flavours and fragrances, gums, resins and latexes are perhaps the most widely used and traded category of NTFPs other than items consumed directly as foods, fodders and medicines (FAO, 1995b), which indicates the potential for commercial promotion of the products in Ethiopia. Besides their economic significance several species of *Acacia, Boswellia* and *Commiphora* could be managed to provide, concurrently, multiple ecological services that will help to fight desertification and soil erosion by water and wind, contribute to the conservation and enhancement of biodiversity, improve soil fertility, and provide an opportunity for C–sequestration.

One of the most recognized NTFPs products of the dryland vegetation of Africa in general and that of Ethiopia in particular is gum arabic. The major source of presently traded gum-arabic is *Acacia senegal* (L) Willd. The use of gums has declined today, compared with the early part of the 20th century. The decline is a preference for raw materials of consistent, predictable quality, which are not subject to the vagaries of weather, insect pests, stability in producing countries, and price. Despite the changes the demands for gum will continue and even bound to increase in the future for several reasons such as consumers' preference for natural products (FAO, 1995 a, b). This is good news for people in the producing countries, provided that due attentions are given to such aspects as quality control and sustainable management of the resources.

One factor observed to influence the quality of gum arabic is botanical origin. Quality of gum arabic differs between and within species (Chikamai, 1997). Gums from different species exhibit characteristics that are intrinsically different. Even within the same species, different varieties produce gum with different characteristics. Because of the stringent regulations imposed on all food additives, gum arabic, like all other food ingredients, is subjected to extensive toxicological control by countries, organizations and users of the product, which aim to protect the consumer of processed foods containing additives, and thus to ensure the freedom of gum arabic from toxicological hazards. To achieve this end and get in to the market, gum arabic for commerce must conform to certain chemical specifications. Chemical analysis and quality assessment have been carried out on gum exudates from a large number of *Acacia* species (as well as gum– arabic– like exudates from other genera), but relatively little detailed information is available on the intra–specific variation of *A. senegal* gum. In–depth physicochemical screening is needed, to learn more about between–site, between–tree and seasonal variations in gum quality (FAO, 1995a, b). Moreover, compared to other producer countries, very little studies have so far been done on the physicochemical characteristics of gum arabic of Ethiopian origin. In order to promote the commerce of gums and gum resins, knowledge on the chemistry for each gum or resin type is crucial. However, very little work has been carried out for characterization of gums of Ethiopian origin. Thus, lack of such studies could be mentioned as one bottle neck for expanded commercialization of gums of Ethiopia. The objective of this study was, therefore, to investigate the effect of geographical origin in the physico-chemical properties of gum-arabic obtained from *Acacia senegal*.

Material and Methods

Description of the Study Area

The study was conducted in the *Abederafi, Yabello*, *Awash* and *Filtu* areas of Ethiopia. Representative sites were selected from different regions of Ethiopia so as to include different populations of *A. senegal*. Description of study sites is shown in Table 1.

Table 1: Description of the study sites

Study Site	Regional State	Altitude (m a.s.l)	Annual Rainfall (mm)	Mean Annual Temperature (^{0}C)
Abederafi	*Amhara*	550 - 950	885	27.8
Yabello	*Oromia*	1350 - 1800	588	19
Awash	*Afar*	980	567	25.8
Filtu	*Somalli*	1150	450	27

Sample Collection

Authentic representative *Acacia senegal* gum samples were collected from the study sites during the dry seasons. (The collected gum samples were put into perforated plastic bags, labeled and safely transported to Central Ethiopia Environment and Forestry Research Center. Impurities such as wood pieces and sand particles were carefully removed. The samples were then air dried for fourteen days and ground using pestle and mortar for physico-chemical analyses.

Physico-chemical Characteristics Analyses

Analyses on the physico-chemical characteristics of the gum arabic were done in the laboratories of Deberezeiet Agricultural Research Center and Addis Ababa University. The physico-chemical properties of the gum analyzed included moisture content, ash content, pH, viscosity, nitrogen content, crude protein and mineral contents. The laboratory procedures used for the analyses of physico-chemical properties of the gum arabic samples are presented in the following sub-sections.

Determination of Moisture Content

Accurately, 2 grams of grounded gum arabic was weighed and oven dried at 105 ^{o}C for 5 h. Oven dry weight was taken after allowing the samples to cool in a desiccator before reweighing. The measurement was done in three replicates and an average of the three replicates was taken. Moisture content (MC) was expressed as a percentage of the weight loss from the original weight (Yebeyen, et al., 2009).

Determination of Ash Content

Accurately 2 grams of the gum arabic sample was first heated on a burner in air to remove its smoke. Then, it was burned in a furnace at 550 °C for 12 hours. The ash content was expressed as percentage of the weight of the ash to the oven dry weight (Yebeyen, et al., 2009).

Determination of pH

A 25% aqueous gum solution was prepared and the pH meter was calibrated with a standard solution of known pH. The pH of the gum solution was read from the instrument (Yebeyen, et al., 2009).

Relative Viscosity

The relative viscosity of the gum arabic samples was measured at 25^{0}C by using a viscometer (Gashua, et al., 2013). The viscosity in centipose was calculated as follows:

$$\text{Viscosity } (25^{0}\text{C}) = T–T_o\ /T_o$$

Where T= Flow time of 1% of 100 gL^{-1} gum arabic solution and T_o = Flow time of distilled water. (Time for both T and T_o was measured in seconds).

Determination of Total Nitrogen and Crude Protein

Exactly 0.5 gram of each gum arabic sample was weighed in duplicates, and transferred to Kjeldahl digestion tube plus one Kjeldahl tablet, copper sulfate-potassium sulfate catalyst. Then, 10 mL of concentrated, nitrogen free, sulfuric acid was added. The tube was then mounted on the digestion heating system which was previously set to 240 ^{o}C and capped with an aerated manifold. The solution was then heated to the above temperature until a clear pale yellowish-green color was observed which indicated the completion of the digestion. The tubes were then allowed to cool to room temperature. Their content was quantitatively transferred to Kjeldahl distillation apparatus followed by addition of distilled water and 30 % (w/v) sodium hydroxide. Steam distillation was then started; and, the released ammonia was absorbed in 25 ml of 2 % boric acid. Back titration of the generated borate was then carried out with 0.02 M hydrochloric acid using methyl red as an indicator. Blank titration was carried out in the same way. The percentage of nitrogen (N) content was then calculated (Ibrahim, et al., 2013).The crude protein (CP) content was calculated using the nitrogen conversion factor of 6.25 as proposed by Greenfield and Southgate (2003).

Determination of Mineral Content

Ash from a sample of gum arabic was prepared and dissolved in concentrated sulfuric acid. Then the solution was used for the determination of the minerals studied, except for phosphorus, by an atomic absorption spectrometer. Wet ash method was used for the determination of phosphorus as described below. Appropriate standard solution was prepared for each metal and used by the atomic absorption spectrometer to prepare the graph for the determination of the amount of each metal from the gum solution. In the determination of phosphorous, the ash was dissolved in vanadomolybdic acid reagent in which phosphate reacts to form a yellow molybdovanadophosphoric acid.

Finally, the amount of phosphorus was determined using a UV–VIS spectrometer at 400 nm in 1 cm cells, and expressed as percentage of Na_3PO_4.

Experiment Design and Data Analysis

A total of four location treatments with three replications and nine physicochemical parameters were designed in the experiment. The physico-chemical data were subjected to Analysis of Variance (ANOVA) statistical method using Generalized Linear Models Procedure (GLM). Statistical analysis of data was carried out using SAS software, version 9. Mean values were compared using Least Significant Difference (LSD) at ($p < 0.001$) level.

Results and Discussion

A number of physico-chemical methods were employed to characterize the *A. senegal* gum arabic samples. It was found that a very high significant difference in ash, pH, viscosity, Iron, Calcium, and Sodium contents for the gum arabic samples among study sites (Table 2). There was also a significance difference for nitrogen, crude protein, cupper, and potassium contents. Moisture content, manganese and magnesium compositions showed no significant difference for the samples between locations. Table 3 presents the data for the physico-chemical characteristics of the gum arabic samples collected from the four study sites.

Table 2: Analysis of Variance for characterization of gum from *A. senegal* for different test parameters

SV	DF	Mean Square												
		MC	pH	VS	ASH	N	CP	Cu	Mn	Fe	K	Ca	Na	Mg
LOC	3	0.41ns	0.17***	0.07***	159.2***	0.02*	1.01*	6793*	41673.7ns	8826.4***	0.56*	475166***	51205***	128369ns
CV		2.95	1.32	12.05	23.18	14.41	14.37	0.76	16.81	15.56	25.46	13.13	30.59	24.27
R^2		0.5	0.95	0.96	0.97	0.72	0.72	18.5	0.98	0.88	0.73	0.93	0.89	0.27

****: Significant difference at p = 0.001; **: Significant difference at p = 0.01 (F-test).*

The international specifications state that quality parameters of gum arabic must conform to certain chemical specifications. The parameters are meant to identify and characterize the toxicological risks and hazards and provide the assurance that gums have not come from other tree species so as to maintain and sustain high gum quality in the world market. The percentage moisture content of the gum arabic samples was between 12.64 and 13.41 %, while ash percentage was between 0.32 and 16.98 % (Table 3). FAO food and nutrition paper 52 specifies that the loss on drying and total ash percentage as a purity test for gum arabic should not exceed 15% and 4% respectively (FAO, 1995a). The moisture content of the gum arabic samples from the study areas fit the international standard. While the ash contents from most of the study areas were in agreement with recommended specifications of quality parameters of gum arabic. However, the ash content found in one of the study sites, *Abederafi*, was far out of the range. This might be due to edaphic factors in the area. The least ash content was also observed from *Awash,* 0.32% (Table 3).

The mean pH values of the gum samples, obtained by employing different concentration of aqueous solutions from three readings, ranged between 4.40 and 4.97 (Table 3), which were to some extent acidic. The values were in good agreement with the reported pH values of gum arabic studies by previous authors such as Chikamai (1997), Karamalla et al. (1998) and Yebeyen et al. (2009). The relative viscosity of the gum samples studied was between 0.9 to 4.2 centipose. The RV values obtained for all gum samples were in agreement with the values found in Mhinzi and Mrosso (1997) except the samples from *Abederafi* area. Viscosity is a measure of the resistance of flow due to internal friction when one layer of fluid is caused to move in relationship to another layer.

FAO food and nutrition paper 52 (FAO, 1995a) included, in its definition of gum arabic that it consists mainly of high molecular weight polysaccharides and calcium, magnesium and potassium salts. Table 3 shows that Calcium, Magnesium, Sodium, Iron, Manganese and Copper are the most abundant elements in the gum arabic samples from the study areas. In all mineral parameters measured there is a significant difference between gum arabic brought from different geographical locations except for Manganese and Magnesium (Table 2). The high significant difference could possibly indicate that there is a considerable variation in soil parent material from one area to another Lelon et al. (2013). According to Lelon et al. (2013), there is a strong correlation between soil chemical properties and gum arabic mineral compositions proving the effect of soil conditions as factors influencing quality parameters of gum arabic.

Table 3: Physico-chemical properties of gum arabic samples from the study sites

Location	Parameters												
	MC	ASH	N	CP	VC	pH	Cu	Mn	Fe	K	Ca	Na	Mg
Yabello	13.41^{a}	4.04^{b}	0.49^{a}	3.11^{a}	2.5^{b}	4.4^{a}	116.55^{b}	28.22^{b}	192.12^{a}	0.86^{bc}	901.84^{b}	1.16^{c}	1333.6^{a}
Abederafi	12.64^{b}	16.98^{a}	0.513^{a}	3.21^{a}	0.9^{d}	4.88^{a}	226.66^{a}	273.54^{a}	130.87^{a}	1.7^{a}	445.04^{c}	145.2^{b}	1723.2^{a}
Awash	13.27^{ab}	0.32^{bc}	0.313^{b}	1.943^{b}	4.2^{a}	4.64^{b}	139.13^{b}	34.36^{b}	178.2^{a}	1.32^{ab}	1355.9^{a}	288.33^{a}	1578.7^{a}
Filtu	13.41^{a}	4.04^{b}	0.497^{a}	3.11^{a}	3.9^{a}	4.97^{a}	161.84^{b}	42.61^{b}	55.7^{c}	0.6^{c}	1233.6^{a}	252.2^{a}	1850.4^{a}

Values with same alphabets are not significantly different from each other

The amount of Copper for the gum-arabic samples of the study sites analyzed in the -study were found between 116.55 and 226.66 mg/Kg. The values were higher than the concentration of Copper found from previous studies on gum arabic from *A. senegal var. senegal* from Sudan, 52 to 66 mg/Kg (FAO, 1990). Higher Iron content was recorded for gum arabic samples from *Yabello* (192.12 mg/Kg) while the least iron content was observed from *Filtu* (55.7 mg/Kg) (Table 3). The Iron content for the gum arabic samples collected from all the sites are lower than the international specification, 730 to 2490 mg/Kg (FAO, 1990).

Significantly higher cationic composition of potassium were obtained at *Abederafi* (1.7mg/Kg) and *Awash* (1.32 mg/Kg) than *Filtu* (0.6 mg/Kg) and *Yabello* (0.67 mg/Kg) (Table 3). The values were lower than what was reported on our previous work and other reports on gum arabic (Yebeyen, et al., 2009; Mhinzi and Mrosso, 1997). Highly significant cationic composition but statistically similar values of calcium were recorded both for *Awash* and *Filtu* areas (1355.9 mg/Kg and 1233.6 mg/Kg, respectively). Least values were recorded at Abederafi with the value of 445.04 mg/Kg. In all study sites, the experimental data were found lower than the same reports referred above. Except, gum arabic samples from *Yabello* site, all study areas had statistically similar sodium content (Table 3). In this study, the sodium content of the gum arabic from *Abederafi* (145.2 mg/Kg) is within the value reported by Mhinzi and Mrosso (1997) (100 to 200 mg/Kg). The sodium content values from *Awash* and *Filtu* sites are also not far from the report.

Nitrogen and crude protein contents of the gum arabic samples from the study areas are shown in Table 3. As indicated in the table, the nitrogen and protein contents of the samples were 0.313 to 0.513 % and 1.94 % to 3.21 % respectively. From the study, it was observed that there was a significant difference in the nitrogen and crude protein content for gum arabic samples brought from different locations (Table 2). Highest and identical values were observed for samples from *Yabello* and *Filtu* areas and the least from *Awash* (Table 3). The nitrogen and crude protein values are in good agreement with the international specification of quality parameters of gum arabic and with the values obtained from other studies (FAO, 1990; Chikamai, 1997; Yebeyen, et al., 2009).

Conclusions

From this study, it can be concluded that gum arabic samples from *A. senegal* trees of the study areas met most of the specification given by the 'Joint Expert Committee for Food Additives for Gum Arabic. It was also found that there is a significant difference in many of the physicochemical characteristics analyzed for the gum arabic samples brought from different locations. In-terms of viscosity and ash contents, the gum arabic samples brought from *Abederafi* site were different as compared to the gum arabic samples brought from the rest of the study areas and International standard values for gum arabic. Hence, further study is needed as to the effect of edaphic factors and species variety identification of the *A. senegal* trees found in the *Abederafi* area. The gum arabic found from most of the study areas, therefore, can be considered to be truly gum arabic from *Acacia senegal* trees from the dry land areas of Ethiopia. It can also be considered as a potential source of quality gum arabic that can be exploited for commercial purpose, based on the physico-chemical properties analyzed. However, It is recommended that gum arabic from these areas is subjected to broader analysis in terms of molecular characterization and emulsification properties for the purposes of quality control.

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Chapter Seven: Environmental Pollution Management Research

Evaluation and Characterization of Tannery Wastewater from Unit Operations and Process at Batu and Modjo Tannery, Ethiopia

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Abstract

This study aimed at identifying and comparing the major pollutants released at each stage of tanning process and evaluates the effluent discharge quality. Accordingly, wastewater samples were collected from Batu and Modjo tannery in Ethiopia. The samples were collected from all stages of processing viz., soaking, liming, deliming, pickling, Chrome tanning and retanning. The physicochemical parameters of the wastewater such as pH, alkalinity, acidity, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total solids (TS), total dissolved solids (TDS), suspended solids (SS), chlorides and sulfides were determined. The result showed that the pH values of both tanneries are in the range 3.25-12.64 which is above the limit set by US EPA (6.0-9). The BOD (190- 4500mg/L) level in both industries from different tanning processes such as: soaking, liming and unhairing, deliming and bating pickling, chrome tanning and retanning was found high and greater than the limit set by US EPA (200 mg/l). Generally, Total Solids (TS), Total Suspended Solids (TSS), Chloride, Sulfide, Total Alkalinity and Hexavalent Chromium exceed the US EPA standard significantly. The results indicated that the wastewaters from the tanneries do not satisfy the legal ranges of selected parameters discharge from each unit operations and processes. Therefore, economic analysis should be carried out to compare whether modifying specific manufacturing process is feasible or constructing treatment plant for final wastewater discharge

Introduction

Currently 26 tanneries are operating in Ethiopia among which 10 are specialized in both hides and skins, and 16 in skins only. 5 new tanneries are under construction implying that in the future there will be a total of 31 tanneries in the country of which 20 tanneries will be located in Modjo leather city. The tanning industry is characterized as disposing of solid, liquid, gaseous and sledges in the environment. Characteristics of the effluent vary from tannery to tannery and in any one tannery with respect to time. The wastewater from beam house process viz. soaking, liming, deliming etc.

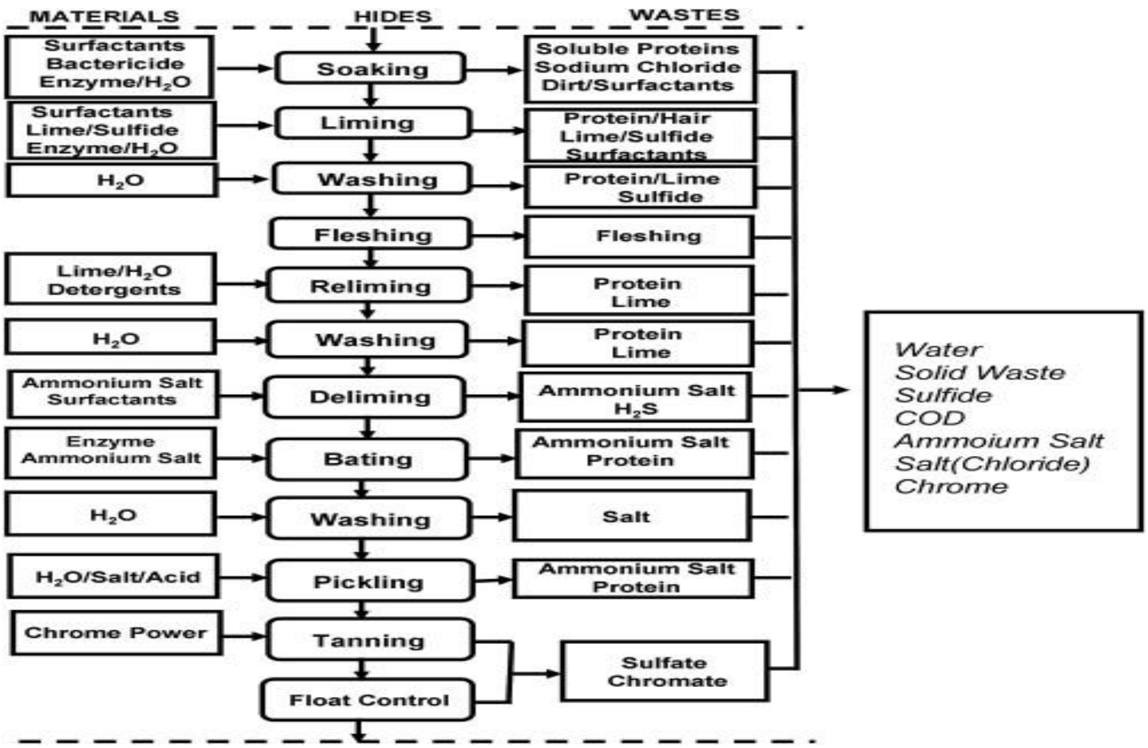

Figure 1: flow chart showing typical tanning process

Objective

To assess the major pollutants released at different processes (i.e. unit operation and unit process) in tannery industries, and evaluate the effluent discharge quality.

Materials and Methods

For the present study effluent samples were collected from tanneries in Batu and Modjo, Ethiopia. The effluent samples were collected from all unit operations and processes of tanning processing viz., soaking, liming, deliming, pickling, chrome tanning and retanning. The effluent was collected in polythene containers of two liters capacity and brought to the laboratory with due care and stored at 4^{o}C for further analysis. Chemicals used for the analysis of spent liquor were analytical grade reagents. The physical and chemical characteristics of tannery effluents parameters viz. pH, total alkalinity, COD, BOD_5, total solids(TS), total dissolved (TDS), total suspended solids (TSS), chlorides, sulfides and chromium were analyzed as per standard procedures .

Result and Discussion

Analysis of physical and chemical characteristics of the tannery wastewater collected from different tanning processes viz. soaking, liming and unhairing, deliming and bating pickling, chrome tanning and retanning are listed in Table 1 and 2 respectively

Table 1: Analysis from Batu Tannery

Parameter	Soaking	Liming	Deliming	Pickling	tanning	Re-tanning
pH	8.37±0.988	12.00±0.707	8.63±0.989	3.25±0.212	4.09±0.141	4.11±0.127
Total alkalinity	9157±5503.5	15172±4282.2	11150.6±7140.8	-	-	-
BOD_5	1700±141.42	1710±56.66	1625±66.47	190±36.77	277.5±88.39	280.5±77.075
COD	11640±1484.92	18578±1827.15	7485.1±1808.07	2707±687.34	1716±619.43	4487.1±1121.61
Total solid	36160.5±9772.95	21961.35±1695.4	25002.1±11543.58	23588±12215.97	13553.5±16899	6272.95±8345.2
Total dissolved solid	27067.5±9853.5	15157±1636.24	19199.95±11596.48	23130±12204.6	13148.5±16897.7	6100.95±8342.37
Suspended solid	9093±80.61	6804.35±59.18	5802.6±52.89	458±11.313	405±1.41	172±2.82
Chloride	31127.37±849.05	5581.2±72.14	3862.12±140.89	41568.9±1423.37	2719.7±364.202	2666.15±436.49
Sulphide	0.035±0.0014	2.267±0.583	1.365±0.275	0.905±0.487	0.35±0.125	0.280±0.226
Chromium	-	-	-	-	.006	1.22

- The pH values of both tanneries are in the range 3.25-12.64 which is above the limit set by EPA (6.0-9).
- BOD level from different tanning processes such as: soaking, liming and unhairing, deliming and bating pickling, chrome tanning and retanning was found high and greater than the limit set by EPA (200 mg/l).

Table 2: Analysis from Mojo Tannery

Parameter	Soaking	Liming	Deliming	Pickling	tanning	Re-tanning
pH	8.23±0.68	12.64±0.00	8.52±1.01	3.93±0.38	3.96±0.212	3.98±0.113
Total alkalinity	3463.1±1220.61	10187.15±3392.18	3684.5±1321.61	-	-	-
BOD_5	3161.25±147.4	4275.1±568.66	3232.1±626.64	786±124.451	870.5±149.2	847±88.4
COD	11695±1704.13	13535±2354.67	6401.5±1808.072	2707±510.34	1716±456.43	4487.1±8021.61
Total solid	19090.33 ±4679.8	19267.36±4787.2	18130.75±3896.6	18329.25±3987.13	17751.69±3662.77	5864.5±1461.03
Total dissolved	23171±4625.15	23380.4±4575.05	20971.8±3268.14	25508.5±5324.54	17963.2±3662.8	7288±1562.17

solid						
Sulphide	1.7±0.23	0.54±0.09	0.5±0.013	0.4±0.08	0.3±0.02	
0.8±0.1						
Chromium	-	-	-	-	1.46±0.556	4±1.03
Chloride						

- COD level from different tanning processes exceeds the permissible COD level of EPA (500mg/l). This indicates that the effluent is unsuitable for the existence of the aquatic organisms, due to the reduction in the dissolved content.
- Generally, Total Solids (TS),Total Suspended Solids (TSS),Chloride, sulfide, Total Alkalinity and hexavalent chromium exceed the EPA standard significantly

Conclusions

Generally the study found out that the tannery wastewater from different tanning processes viz., soaking, liming and unhairing, declaiming and bating, pickling, chrome tanning and retanning was highly with a disagreeable pH, alkalinity, acidity, total solids, total dissolved solids, suspended solid, chemical oxygen demand, biochemical oxygen demand, chlorides and sulfides. Conclusively, the wastewaters from different units of the investigated tannery industries do not comply the legal ranges of selected parameters.

Estimation of gaseous emissions and biomass burnt from sugarcane field burning in Ethiopia

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Abstract

Sugarcane field burning has been carried out worldwide before harvesting to get rid of leaves and tops which would impede the harvest operation. However, field burning has environmental consequences. The main objectives of this study was to estimate the air pollution and emission level of gases from pre harvesting burning of sugarcane and estimate the resource burning in the country every years. The study was conducted by direct measuring of ambient air during burning time in different distance from the burning areas by using aeroqual measurement. The second method was estimating or measuring the emission gases by using 2006 IPCC soft ware. In 2008E.C(2015/2016 G.C), a total 0f 26903.49 ha of sugar cane plantation were burning in five operating factories in Ethiopia, and A total of 1.51 million tons of trash biomass fuel, i.e., dead, dry and fresh leaves, were burning. The mean values of ambient air measurement result for emission factors (g kg^{-1} of burned dry biomass) were 1,303 ± 218 for CO_2, 65 ± 14 for CO, 1.5 ± 0.4 for NO_X, 2216 ± 632 for VOC, and 6.6 ± 1.6 for SO_2. From 2006 IPCC Guidelines software results obtained showed that the total emission of CO_2, CO, NO_2, N_2O, and CH4 were 3.24, 6.3, 2.3, 0.54 and 2.01 of Gg in the study year respectively. So pr-harvest burning of sugar was major source of air pollution and degrading resource (trash) which can be used for energy source, animals feed and soil fertilizer. Moreover, new green harvesting technologies will be applied on cane harvesters for improving air qualities. It is highly recommended that Sugar producer and supply countries should be used green harvesting technology and utilizing trash to safe environment and resources.

Keywords: *IPCC, emission, sugarcane, air pollution*

Introduction

Traditionally, sugarcane has been burned prior to harvest in order to eliminate leafy no sucrose containing material so that it does not have to be transported and milled (Kanokkanjana, 2010). This burn, while quick, efficient and relatively clean but in terms of air quality effects, has caused concern regarding the impact of smoke and ash on adjacent environments. Open burning in sugarcane fields has been practiced for quite a long time as a result of increasing national demand for sugarcane production. The practice, referred to as pre-harvest burning, is generally performed to burn most of the residues associated with sugarcane, e.g., dead, dry, and fresh leaves in the field to facilitate manual harvesting operations. In addition, the residues resulting from green-cane harvesting, this represents the harvesting technique without burning to remove tops and leaves. Pre harvests burning of sugarcane contribute to emissions of air pollutants that may adversely impact human health and the environment (Bangkok, 2006).

Ethiopia is one of the few countries to have formally merged its aims of developing a green economy and greater resilience to climate change under a single policy framework in support of its national development objectives. While the government is still preparing its climate resilience objective, the Green Economy component of the CRGE has already been developed (Ethiopian Sugar Corporation, 2012). Ethiopia sugar corporation 2014 report showed that Sugarcane is one of the most important industrial crops in Ethiopia. It is cultivated over 40,000 hectares of land on the existing Sugar Factories (Wonji, Metahara and Finchaa) and currently about three new factories (Kessm, Tendaho and Arjo Dedhessa) are becoming operational while others are under construction and up on the finalization of the new sugar development projects the area will dramatically increase to over 400,000 ha. From this the Sugar Corporation is targeted to produce 2.25 million tons of sugar and 181,604 meter cube ethanol upon the finalization of the projects with the productivity of 155 tons (t) cane ha^{-1} (Ethiopian Sugar Corporation, 2014). Accordingly, greater attention is given for improving sugarcane and sugar yield. On the other hand, as the volume of sugarcane and sugar yield increases the volume of by-products such as cane tops and trash, bagasse, filter cake, ash, molasses and vinasse was also increases proportionally. Currently, only part of the by-product (molasses) and bagasse is utilized for the production of ethanol and electric power generation, respectively. The remaining considerable amount of wastes is disposed (Neto, 2005).

Emissions from pre-harvest burning of biomass include a wide range of gaseous compounds and particles that contribute significantly to the troposphere budgets on a local, regional, and even global scale. The emission of CO, CH_4 and VOC affect the oxidation capacity of the troposphere by reacting with OH radicals, and emissions of nitric oxide and VOC lead to the formation of ozone and other photo oxidants. To avoid air pollution impacts from pre-harvest burning of cane, developed countries have been start using mechanical green harvesting technologies in order to improve human and environmental problems, Global sugar markets, sugar producer and supplier countries have signed an agreement called "Green protocol" to stop pre-harvesting burning of sugarcane. An agreement also state that all developed countries should be stop pre harvest burning of sugarcane at the end of 2017G.C. and for developing countries also gave gross period from 2017- 2021G.C. Ethiopia and other developing countries has been continued working business as usual. Moreover this study can be used as baseline information about disadvantages of pre harvest burning of sugarcane, and inform the amount of trash has been burning or degrading that can used for energy source, animals feed and soil fertilizer. Also, it gives hint on alternative green harvesting technologies. In order to release the full package of the technology, the remaining activities are socio economic impacts of pre harvest burning and green cane harvest and trash initializing technology of need assessment will be give fulfillment of the research ideas and important for decision and policy makers.

Materials and Methods

Description of the Study Area

The study was conducted in five Ethiopian Sugar Factories namely, Wonji-Shoa, Metahara and Finchaa, Kesem and Arjo Sugar Estates (Figure 1).

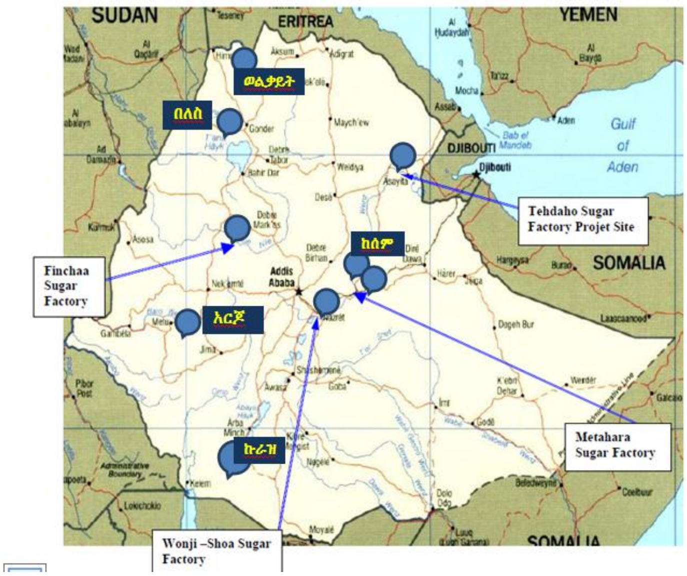


Figure 1: Location of the governmental sugar factories and projects in Ethiopia

Wonji-Shoa is located at $8^{0}31'$ N and $39^{0}12'$ E with an altitude of 1500 m.a.s.l., annual rainfall of 830 mm, and means air temp of 20.8^{0}C and relative humidity of 56 %. In general, it has a sub humid climate having major rainy season in summer, from July to September, and thus, irrigation is practiced in the rest of the months to grow sugarcane.

The area around Metahara Sugar Estate has a semi-arid climatic characteristics; it is located at about 200 km southeast of the capital city, Addis Ababa, situated at 80 53′ N latitude and 390 52′ E longitudes at an altitude of 950 m a.s.l. Finchaa sugarcane plantation is located at 9030′ -10000′ N and 37015′ -37030′ E with an altitude of 1350-1600m.a.s.l. The major soil types of the plantation are Luvisols (70%) and Vertisols (30%). The soil are slightly acidic in reaction, with low total N, Olsen-P, and organic carbon content; while the available K values were relatively high. On the other hand, Kuraz Sugar Development Project is located between 5^{o} 8′ 18″ – 6^{o} 16′ 59″ latitude and 35^{o} 43′ 37″ – 36^{o} 13′ 54″ longitude and its elevation ranges from 370 – 500 mils. It is located 918 km away from Addis Ababa in the south direction. It is found in South Omo Zone in the plain areas of the lower Omo basin of the Southern Nations Nationalities and Peoples Region. In the project area five reference soil groups (Cambisols, Vertisols, Fluvisols, Solonetz and Leptosols) are identified.

Data Collection Methodology

Experimental Design and Layout

Wonji and Methara were purposively selected for the primary data collection area and from these two factories 12 sampling area was selected by stratifying; Soil type, cane variety category (Trashy, medium trashy and low trashy) and cane type (plant cane (pc), ratoon$_{1-3}$) were Conducting on commercial fields ready for harvesting (i.e. the fields that are in the last week of drying off). A preliminary survey sampling was undertaken to identify varieties level of trash.

Table 1: Sugarcane varieties and soil types selected for crop modeling field experiment

SN	Sugar Estate	Cane Variety	Soil Category	Cane type
1	Wonji-Shoa	N14, B52298, NCo334	A1, C1	Pc, ratoon(r_5, r_3)
2	Metahara	NCo334, B52298, C86/56	F1, F2 soil fertility unit	

Method 1

Data like combustion factor, moisture content , biomass fuel load and trash to stake ration were collected as described by Sornpoon et al. (2014). This method of data collecting were including different activities; Such as estimating the total biomass of sugarcane were harvesting every year and the trash generated per hectares , combustion factor, trash to stake ratio and moisture content of trash were measured to feeding IPCC Guidline 2006 soft ware.

Sampling and Data Collection

Well managed fields with good growth condition was selected and data was collected from homogenous fields of randomly selected five spots using' X ' shape from two soil types for each. All the necessary data was collected from randomly selected on sixty spots and a total of 120 spots were taken from two sugar factories. Precaution was taken to avoid sampling from border of the field, therefore sampling spots was from the interior of the fields it was at least 2.7mx2.14m sampling area was taken in replicate samples from (planting cane, c_1, c_3 and c_5) were selected. 2.7mx2.14m was entered from harvest road as well as drain. Each sampling spot was 2 furrows of 2.14 meter length and area of 5,8m^2, plot from each. The weight of green leaf, dry leaf, dead leaf and stake was weighed separately on field.

Total number of treatments was 12 and (soil type = 2 levels, variety = 3 levels, crop type 2 levels) and number of replication was 5. Treatment combinations and designations are as follows: (S for soil type, V for variety of cane, and C for sugar cane crop type).

T1 = $S_1V_1C_1$,	T2 = $S_1V_1C_{2,}$
T3 =$S_1V_2C_1$	T4 = $S_1V_2C_{2,}$
T5= S1V3C1	T6 = S1V3C2,
T7 = $S_2V_1C_1$,	T8= $S_2V_1C_{2,}$
T9 = $S_2V_2C_{1,}$	T10 = S2V2C2,
T11 =$S_2V_3C_1$	T12=$S_2V_3C_2$

Method 2

On the Other methods of data collecting the ambient air pollutant concentration which can be generated from the burning of sugar cane was down by using arousal monitoring instruments. The ambient air measurement was considered;

- Time of measuring was : during burning; one hour after burning,
- Distance from the burning: +on spot of burning, -100 meter, 200meter, 500meter and one kilometer.
- Controlling site was measuring during off season

Data collecting was down by measuring ambient air gas concentrations by using arousal monitoring instruments, such as CO_2, CO, SO_2, VOC, and NO_2 gases. Arousal monitoring instrument like all our hand held monitors the Series 500 portable air quality sensor takes advantage of the unique sensor head format. Sensors are housed within an interchangeable cartridge ("head") that attaches to the monitor base. The head can be removed and replaced in three seconds difference, allowing users to measure as five above mentioned gases measuring. Sensor heads feature active fan sampling which ensures a representative sample was taken and therefore increase measurement.

Results

Ambient air measurement

The ambient air measurement was taken in different intervals of time and different burning areas during burning season and off season as control. The mean value was given in Table 2 below.

Table 2: Result of mean value ambient air measurement in two sugar factories at different time and different places

Study area	Parameters (ppm)														
	CO_2			CO			NO_2			SO_2			VOC		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site1	Site 2	Site 3	Site 1	Site 2	Site 3
Wonji	1200.6	1906.4	1205.3	65.8	100.4	82.2	4.4	3.5	6.7	10.8	6.3	4.98	2151.4	1980	2320
Methara	1600	1320	1423.5	34.67	43.68	57.23	4.505	5.89	3.8	12.8	7.42	6.5	2341	2330	2290
Control	220	240	230	0.5	0.09	0	0.02	0.4	0.08	0.04	0.021	0.01	250	265	245

Results on Table 2 shows that the concentration of ambient air in the burning area during burning time was higher than Ethiopian ambient air standards, especially for cane cutters those exposed for minimum for eight hours. But at control result which measured during burning off time highly less and very small result were recorded.

Figure 2: Sugarcane burning and its outlook

Table 3: Moisture content of surveyed sugarcane biomass collected from 12 sampling sites from selected two sugar factories surveyed sites were summarized below.

Sampling site	Dead leaf	Dry leaf	Green leaf
S1	0.012	0.049	0.66
S2	0.07	0.07	0.63
S3	0.04	0.069	0.67
S4	0.032	0.1	0.68
S5	0.034	0.12	0.64
S6	0.062	0.037	0.60
S7	0.012	0.013	0.63
S8	0.063	0.09	0.67
S9	0.058	0.058	0.61
S10	0.11	0.068	0.66
S11	0.067	0.068	0.69
Mean value	0.047	0.054	0.59

The moisture content of different components of the above trash of sugarcane, including, fresh leaves, dry leaves, and dead leaves of sugarcane was cultivated in Ethiopia, as collected from pre-harvest burning surveyed sites was summarized in table 3, result show that green leaf has high moisture content than dead and dry leaf. Dead and dry leaf has very small moisture content but the cumulative moisture content determine the burning tendency of trash.

Table 4: The trash to cane ratio values collected from 12 sampling sites at Methara sugar factory

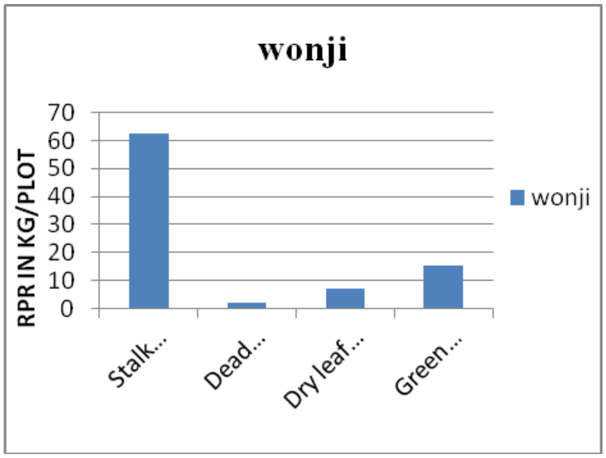
Site	**cane mass in kg/m²**	**mass of trash in kg/m²**	**Trash cane ration in methara**
S1	15	4.18	0.28
S2	7.36	3.1	0.42
S3	16.8	4.5	0.27
S4	7.48	2.18	0.29
S5	7.2	4.05	0.56
S6	6.63	3.36	0.5
S7	7.24	3.55	0.48
S8	9.41	3.67	0.39
S9	14.55	4.12	0.28
S10	10.13	2.76	0.27
S11	13.58	2.1	0.155
S12	7.27	4.9	0.68
Mean±S.D 10.33± 6.2		3.54 ± 1.36	0.34±0.3

The trash cane ratio mean values collected from 12 sampling sites and sixty plot from selected two sugar factories surveyed sites were summarized in table 4 result showed that the mean value of the trash was 34% of the total biomass mass.

Table 5: The trash to cane ratio values collected from 12 sampling sites at Wonji sugar factory

Site	cane mass in kg/m2	mass of trash in kg/m2	Trash cane ration in wonji
S1	21.46	8.24	0.38
S2	11.08	4.76	0.43
S3	10.39	3.51	0.342
S4	6.62	2.91	0.44
S5	9.18	3.66	0.399
S6	9.6	4.04	0.42
S7	12.96	5.98	0.46
S8	9.26	3.48	0.376
S9	9.74	4.3	0.44
S1O	11.9	5.1	0.427
S11	6.5	2.46	0.378
S12	10.7	3.87	0.36
Mean±S.D	10.8 ± 10.7	4.32 ± 3.9	0.37±0.09

The trash cane ratio values collected from 12 sampling sites from selected two sugar factories surveyed sites were summarized of Wonji result showed that the mean value of the trash was 37% of the total biomass mass. The trash cane proportion in wonji was greater than methara it might be due to soil fertility and climatologically effects. But the mean value of wonji and methara was 35.5%. Generally, the trash stake rations indicate that cane in Ethiopia was highly trash than other countries.



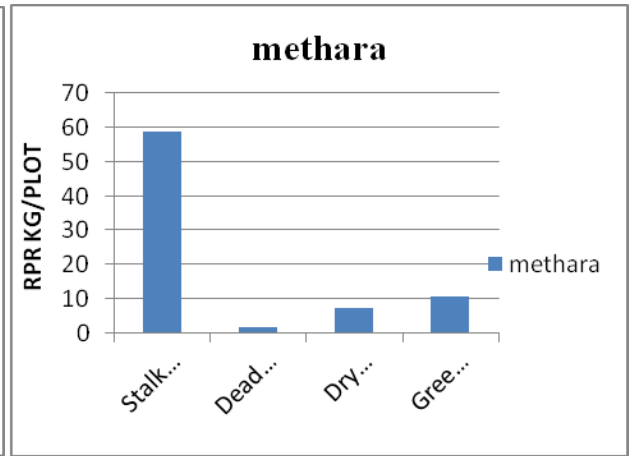
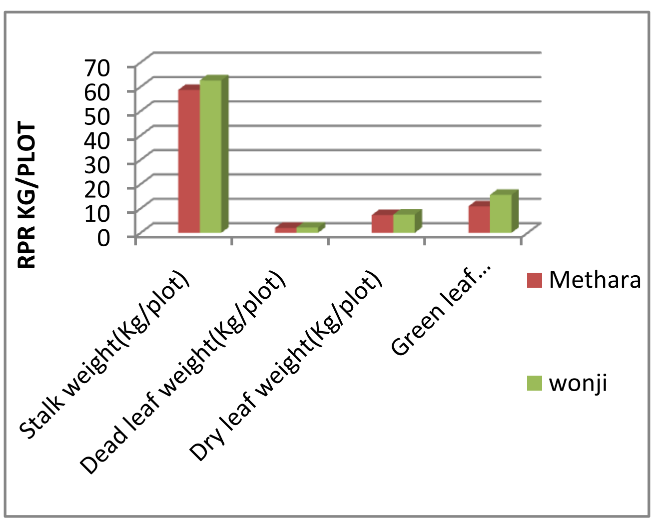


Figure 3: trash to cane ratio per sampling plots in Wonji and Methara (plot area 5.8m^2).

Results showed that the proportion of each biomass weight in specific areas of plot (5.8m^2), the mass of green leaf was higher than dry and dead leaf. It is due to high moisture content.



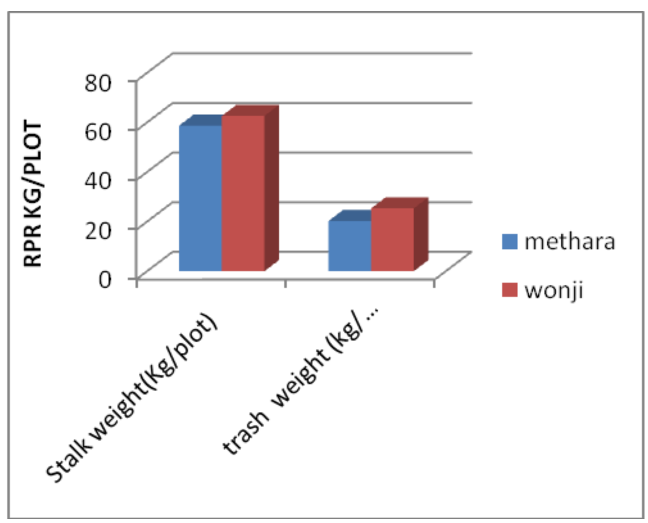
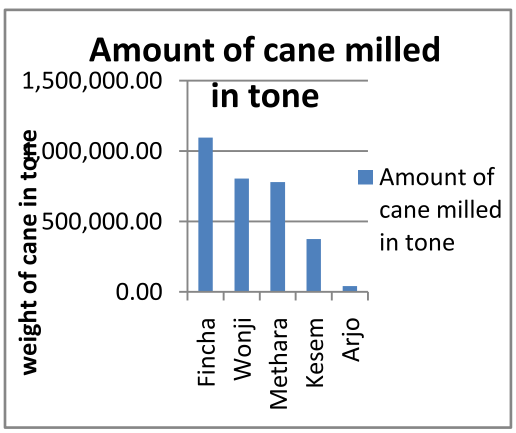


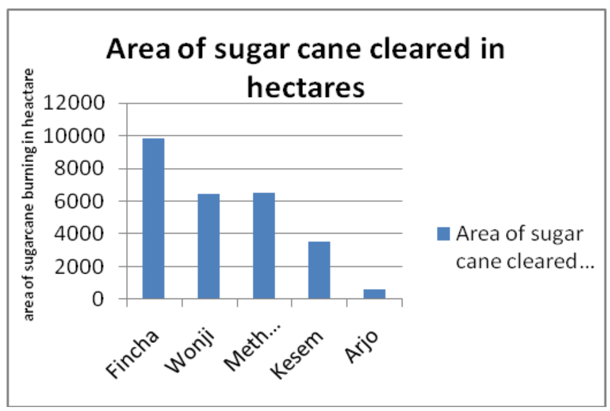
Figure 4: stake to trash ration in wonji and methara sugar factories

The above figure result show that the comparison of each biomass mass in the two sugar factories in each sampling plots showed that wonji sugar factors plantation was higher mass of stake, green leaf, dry and dead leaf than methara.

Table 6: Sugarcane harvesting areas and associated sugarcane biomass residues

Sugar factory	harvesting Area (ha)	Biomass fuel or trash (tons)	Biomass fuel load kg/m^2
Fincha	9850.6	405475.322	1.30
Wonji	6408.69	297587.52	0.94
Methara	6533.8	288746.917	1.27
Kesem	3,514.9	138946.809	0.92
Arjo	595.5	24172.953	1.503





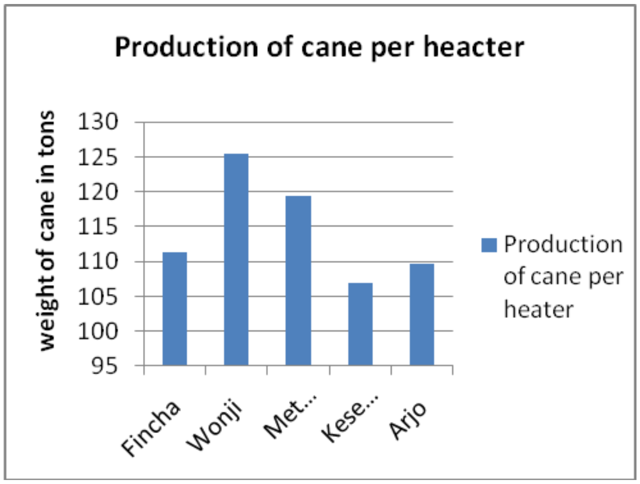


Figure 6: The 2008 EC Ethiopia sugar factories annual production of cane in hectare and estimation mass of trash was generated in every sugar factories.

The average biomass of sugar cane obtained was 107.93 tons of stake and 43.6 tons of trash was product per hectare in Wonji. Similarly, the average mass of sugar cane in Methara was 101.22 tons of stakes, and 34.8 tons of trash was generated per hectare. The average cane production in Ethiopia was 105.5 tons and 39.2 tons of trash was generation per hectare. These five operating sugar factories were harvesting a total of 26903.49 hectares of cane plantation in the study years. In the total mass of trash burning in five sugar factories in 2008 EC was around 1.5 million tons.

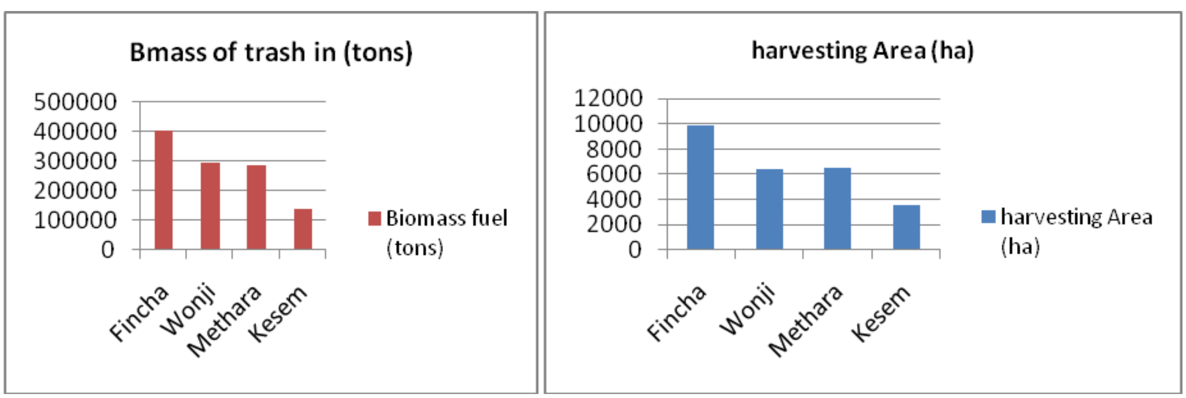


Figure 5; biomass fuel (trash) generated per hectares of land

Table 7: Combustion factor *vs.* sugarcane field burning practice in Ethiopia

Dry leaf	Dead leaf	Green leaf	Total mean
0.86	0.92	0.42	0.73

The experimental results of the above table showed that the mean value of combustion factors of dead leaf, dry leaf and green leaf was 0.73. Green leaf has less combustion factor than dry and dead leaves but dry and dead leaves have high combustion factors. Which indicate that 92% of dead leaf and 86% of dry leaf were burning completely and 42% of the green leaf can be burning (Table 7).

Table 8: Comparison of emission fluxes from sugarcane open burning estimated from default values of 2006 IPCC guidelines and results obtained in this study

Gases	emission level Gg	Defult value Gg	EF
CO2	3.24	3.24	1515
CO	68.63	12.86	92
N2O	0.05	0.01	0.07
NOX	1.85	0.35	2.5
CH4	2.01	0.38	2.7

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After feeding necessary information to the IPCC soft ware, the result was compiled in table 8 above was obtain emission fluxes for key greenhouse. Therefore, the emission of gas was indicating that sugar cane burning has its own contribution for green house gases and environmental pollutions (Table 8).

Due to the absence of country-specific emission factors associated to sugarcane field burning in Ethiopia, default values recommended in the 2006 IPCC Guidelines was used. As expected, the fluxes using IPCC default values and those estimated from the pre-harvest burning system biomass fuel consumption are very close, *i.e.*, with only 13% difference. This finding underlines the importance of using country-specific information concerning sugarcane field burning practices. Although pre-harvest burning is more frequently practiced and concerns larger plantation areas, so using the IPCC recommended default values would significantly underestimate the overall emissions, as pre-harvest burning would be considered. However, pre-harvest burning can be monitored using the amount of burned canes delivered to sugar mills for all sugarcane producing countries, the global emissions from sugarcane field burning are expected to be underestimated.

Discussions

During harvesting time there was a high concentration of smoke, soot's and particulate matter were affecting the sugarcane worker (cutters).Similar research conclude that Pre-harvesting straw burning of sugarcane generates a huge amount of air pollutants such as aerosols, fine (PM2,5) and coarse (PM10) particulate matter, gases such as carbon monoxide (CO) and carbon dioxide (CO_2), aldehydes (acrolein, formaldehyde), methane (CH_4), nitrogen oxides (NOx), nitrous oxide (N_2O), other hydrocarbons and polycyclic aromatic hydrocarbons (PAHs) (Arbex, et al., 2004).

On the other hand, the incompletely oxidized compounds, such as CO and soot, were generated in greatest concentration in the smoldering phase. The matter increases due to sugar-cane burning alter positively the air concentration of substances as nitrite, sulfate, oxide of carbon and others. The literature also demonstrated that short- and long-term exposition to classical pollutants (matter, sulfate, nitrite, oxide carbon etc) can negatively human health capital, especially for young and elderly people (Farhat, et al., 2005; Roseiro and Angela, 2006).

Due to the absence of country-specific emission factors associated to sugarcane field burning in Ethiopia, default values recommended in the 2006 IPCC Guidelines was used. The obtained emission fluxes for key greenhouse gases are reported in Table 8. As expected, the fluxes using IPCC default values and those estimated from the pre-harvest burning system biomass fuel consumption are very close, *i.e.*, with only 13% difference. It should be noted that the biomass fuel load found in this study is approximately higher than the default value provided in the 2006 IPCC guidelines because cane in Ethiopia highly denser and highly trash.

On the other hand, high variability of the combustion factor can be observed for all components and from one site to another. This underlines a certain relationship between combustion factor and biomass fuel moisture content. All sugarcane workers have been working in this area for minimum of eight hours in a day and minimum of 5 days in a week, so worker are highly affected by the pollution.

The government of Ethiopia has mandated the Environmental Protection Authority to set such standards and this document represent the Authorities guideline standards with respect to the ambient environment. Ambient environmental quality standards are set with a goal of safeguarding public health and protecting the environment. Both objectives have very high quality requirements which complement each other to a great extent.

Conclusions

These five operating sugar factories were burning a total of 26903.49 hectares of sugarcane plantation in the study year (2008EC/2015-16 G.C). Based on our investigation the trash cane production ratio of average value was 0.35. In other hand the average mass of trash in hectare is 38 tons per hectare, therefore when 26903.49 hectares of Sugarcane was burning 1.51 million tons of trash was also burning in the study year. Using the obtained average trash cane ratio value, the overall mean sugarcane biomass fuel load was estimated to be 1.2 kg $\cdot m^{-2}$ on a dry mass basis, which is about 80% higher than the default value recommended by IPCC in the 2006 IPCC Guidelines.

The combustion factors associated with pre-harvest burning was 0.73. It was found that the sugarcane biomass moisture content significantly affects the combustion factor. Indeed, dry sugarcane biomass components were determined to have higher combustion factor values as compared to fresh ones, *i.e.*, average combustion factor of 0.95 for dry leaves and 0.94 for dead leaves *vs.* 0.21 for fresh leaves. Finally, the mean value trash combustion factor obtained in this study was found to be almost similar to the IPCC default value, *i.e.*, 0.73 *vs.* 0.80, and underlines that the harvesting in Ethiopia is practiced when a large part of the biomass residues, and consequently is of high moisture content.

Although the biomass fuel load estimated for the pre-harvest burning in this study was higher than those recommended in the 2006 IPCC Guidelines, as the default values recommended by IPCC are for the case of pre-harvest burning, it is expected that the current global estimation of the emissions from sugar cane residues open burning is lower than the actual emissions. Local air quality affects how we live and what we breathe. Like the weather, it can change from day to day– sometimes from hour to hour. The known and recognized health effects of air pollution include the increased risk of the exacerbation of respiratory symptoms such as increased asthma attacks and reduced lung function, increased hospital admissions for respiratory and cardio-vascular diseases, and increased mortality. In order to release the full package of the technology, the remaining activities are socio economic impacts of pre harvest burning and green cane harvest and trash utilizing technology of need assessment will be give fulfillment of the research ideas and important for decision and policy makers.

Recommendation

Ethiopia Sugar Corporation, ministry of Environment, forest and climate change and other stakeholders should be working together for the transformation of sugarcane harvesting system in to green harvesting technology. As the measurements of these parameters are easier to perform in comparison to the emission factors, it is highly recommended that the countries conduct field surveys to collect these country-specific data. To avoid air pollution and to safe sugarcane worker using green harvesting technology and utilizing the resource (trash) for energy source; animals feed and soil composting instead of burning. Policy makers and environmentalist should support this transformation in to green harvesting safe environment and resources.

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Perception gap assessment on obsolete pesticides in Ethiopia

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Abstract

Ethiopia unlike to developed countries has been suffering by obsolete pesticides accumulated throughout the country. Disposal practices of obsolete pesticides had been inadequate and significant quantities of obsolete pesticide stocks are found accumulated in substandard storages, presenting potential risk to public health and the environment. This assessment study on obsolete pesticide stocks' status was aimed at evaluating the condition and effects of obsolete pesticide stocks on public health and the environment and indicates a corrective action. The methodology employed was field observation, interviews and questionnaires dispatched to study site residents. Results of the study indicated that obsolete pesticide stocks were depreciated, kept in substandard storages, indiscriminately mixed up with non-pesticide chemicals, exposed to sunlight, rain and runoff water and easily accessible to animals and humans. Inefficiently secured obsolete pesticides are potential to cause a threat not only to public health and the environment but also to the fast growing economy of the state. Training given to residents on the dangers involved with obsolete pesticide stocks was inadequate. This situation could lead to the vulnerability of the community to the effects of pesticides exposure. Therefore, further research to ascertain the actual condition of obsolete pesticide stocks across the country need to be carried out before the present situation causes more social and environmental problems.

Introduction

The economy of developing countries is agriculture dependent and used pesticides to protect pests against insects, fungi, weeds as well as to increase agricultural yields. Pesticides become obsolete with the passage of time and lost their efficacy to be used for their intended original purpose and therefore require disposal. Ethiopia has accumulated obsolete pesticide stocks due to prolonged storage of pesticides, inadequate control over pesticide importation and lack of monitoring system for pesticide use in the country. The objective of this study was to assess the status of obsolete pesticide stocks in selected parts of Ethiopia.

Methods and Materials

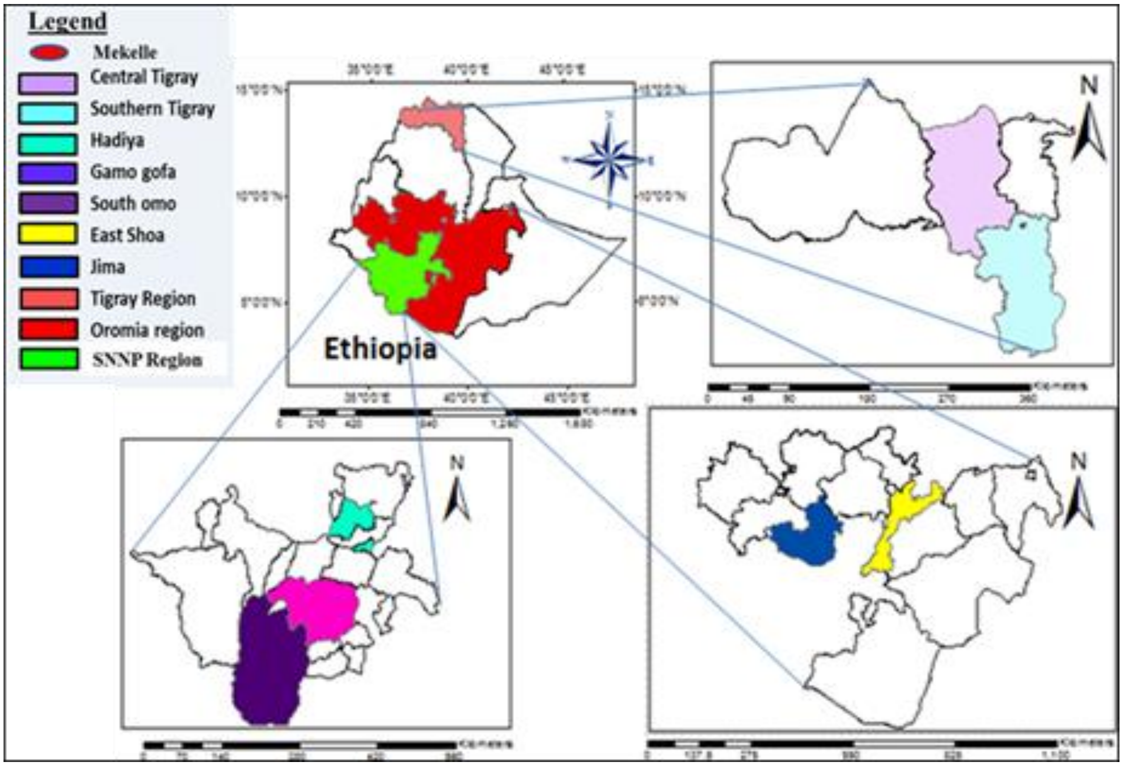

Figure 1: Map of study area

- Three regional states (Tigray, Oromia, and South Ethiopia) were selected for study based on the availability of research facilities and access to the pesticide storage sites.
- Pesticide stores from each region were also selected on the basis of obsolete pesticides overstocking, duration of accumulation, and condition of storages and proximity to residents.
- Data were collected using questionnaire, observation, and interview.
- A total of 422 within 0.5 kilometers distance from pesticide stores were used as source population.

Results and Discussion

Status of obsolete pesticide stocks:

- Obsolete pesticide stocks were deteriorated and exposed to animals, humans and external damaging conditions like rain and floods.
- Stores were ragged tin sheet walls and roofs leaking contaminating natural resources.
- Obsolete pesticide stocks were kept amassed with other chemicals and contained in metal drums, wooden boxes and burst open sucks with no labeling.
- Storekeepers were without protective clothing and none of them had received trainings on impacts of pesticides.

Perception of participants to obsolete Pesticides and their impacts:

The study indicated:

- 115 (27.3%) respondents to use chemical pesticides and empty pesticide containers with 79 (68.7%) of them using safety tools and 36(31.3%) failed to use safety tools due to lack of safety tools (63.70%) and lack of awareness (36.29%).
- 238(56.4%) respondents only heard about the harmful effects of pesticides and 184(43.6%) had no any knowledge on the impacts of pesticides on health and environment.
- 328(77.7%) participants took no training on pesticide effects.
- 351 participants dispose off obsolete pesticide stocks by [burning (25.6%), burying (23.7%), dumping on open spaces (33.9) and (16.8%) did not know how and where to dispose of obsolete pesticides.

Pesticide use and environmental effects:

The study result showed:

- 171(40.5%) participants perceived pesticides as useful and used them nearly always (31.0%), each year (33.9%), and rainy seasons (35.1%).

- 161, 45 and 188 participants indicate obsolete pesticides to affect humans, animals and the environment respectively.
- Major effects due to obsolete pesticides and leakages were: 138 (32.7%) respondents said bad odor, 17(4.0%) health problems, 148 (35.1%) air, water and soil quality degradation and 119(28.2%) damage to all environmental segments.

Conclusion

- Obsolete pesticide stocks were in a bad condition, stored in unsafe place close to residents, uncontrolled and unprotected, and stocked with other utilities.
- Obsolete pesticides and empty pesticide containers were haphazardly used by residents without any protective equipment.
- Disposal of obsolete pesticides practice was environmental unfriendly.
- Obsolete pesticide stores were poorly facilitated with ragged walls and roofs letting in light and rain that speeded up their deterioration and leak off into ground and surface water and disperse into the air exposing entire populations' to harmful health risks.
- Residents are also exposed to obsolete pesticide hazards through the food and water they used and the air they breathe from the immediate contaminated environment.

Recommendation

The effects of obsolete pesticide stocks is expected to be high even though removal of outdated stocks is far-off due to limited technical resources and the high cost involved. Therefore:

1. Further research to ascertain the actual quantity and situation of obsolete pesticide stocks across the country is required.

2. Pesticide Stocks should be collected, sorted and removed to a place far from urban and rural residents.

3. Procure quantities of pesticides that could be used in one year and avoid purchase of pesticides than needed during pest out breaks.

4. Make demand driven planning of pesticide requirement for each agricultural areas and seasons.

5. Raise public awareness on risks of pesticides on health and the environment.

6. Establish an entity that controls importation, distribution and application of pesticides in the country.

Experimental evaluation of water hyacinth as potential energy source alternative

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Abstract

The spread of invasive water hyacinth (Eichhornia crassipes) is one of the world's worst aquatic weeds that infest rivers, dams, lakes, wetlands and irrigation channels. Water Hyacinth affects the multidisciplinary uses of Lake Tana and creates series environmental imbalance. Water hyacinth is a potential biomass material for the production of briquettes. The study was undertaken to investigate the potential of water hyacinth for production of briquettes and evaluate the physicochemical properties of briquettes produced from water hyacinth. The water hyacinth biomass was harvested, dried, and carbonized. The char yield was mixed with clay soil and compressed into briquettes in a manually operated mould machine.The proximate analysis and combustion characteristics of the briquette samples were determined. Data were analyzed using analysis descriptive statistics. The study revealed that the average calorific value of water hyacinth briquette samples was 3727.04 Kcal/Kg. Moisture content, volatile matter, ash content, and fixed carbon of the samples were 10.14 %, 42.85 %, 40.65 %, and 6.36 % respectively. It was also found out that water hyacinth biomass can be converted into briquettes. The combustion and physical characteristics of water hyacinth briquettes demonstrate its potential for use as an alternative energy source. Converting water hyacinth into briquettes can provide an alternative energy source to the people and can be one of the solutions for environmental problems.

***Key words*:** Biomass, briquette, calorific value, fixed carbon, weeds

Introduction

Water hyacinth (*Eichhornia crassipes*) is one of the world's worst aquatic weeds that infest rivers, dams, lakes, wetlands and irrigation channels (Villamagna and Murphy, 2016). As a result, it becomes a threat to the aquatic ecosystem by aggravating losses of biodiversity (EBI, 2014) specifically the water reservoirs (MoWR, 2004).

The exact time and place of introduction has been debated, but the plant is native to South America, and therefore reached Lake Victoria due to human activity (Phiri, 1997). In Ethiopia, water hyacinth was officially reported in 1956 in Koka Lake and the Awash

River (Daniel, et al., 2011; Tegene and Ayele, 2014). In addition, water hyacinth has been recognized as the most damaging aquatic weed in Ethiopia since 1965. However, in case of Lake Tana its presence has been recognized since 2011 (Wondie, 2013; Wassie, et al., 2015).

Water Hyacinth affects the Lake Victorian population in many negative ways. There are economic impacts when the weed blocks boat access. The effects on transportation and fishing are immediately felt. Water hyacinth also interferes with water treatment, irrigation, and water supply (Opande, et al., 2004). It has blocked supply intakes for the hydroelectric plant, interrupting electrical power for entire cities. The weed also interrupts local subsistence fishing, blocking access to the beaches (LVEMP, 1996). Similarly, the problem is serious in Lake Tana.

Nevertheless, in recent times, awareness has been devoted to the utilization of water hyacinth while the efforts to control its growth by means of chemical, biological and mechanical methods have met with little success (Abdel-Sabour, 2010). Moreover, converting water hyacinth in to energy is being used as management and controlling prospects of it invasion. Bergier et al. (2012) reported that water hyacinth can be used for biofuel production. Bioethanol production, biogas production, pyrolysis, gasification, pellet and briquette production were among the major technologies used to convert biomass into energy.

Therefore, using water hyacinth as alternative source of energy is one of important ways of managing its problem and contributing to environment management. This study was conducted to produce briquette from water hyancith and to use as one management and controlling options. Converting water hyacinth into energy is believed to overcome the pollution problem of aquatic ecosystems and provides renewable, clean and sustainable energy sources and can substitute forest biomass, which is the major source of energy for the majority of Ethiopians (Stefan, 2009).

Hence, production of energy from water hyacinth not only helps to control it spread but also grant environmentally friendly, economically feasible and socially acceptable source of energy (Akowuah, et al., 2012). In Ethiopia, despite the availability of huge amount of water hyacinth, it never been utilized effectively in the form of energy source. Therefore, this research was conducted with the objective of filling this gap and investigating the potential of water hyacinth for production of briquettes and evaluates the physicochemical properties of briquettes produced from water hyacinth.

Material and Methods

The study was conducted in Lake Tana which is the largest Lake in Ethiopia which accounts for 50% of the fresh water resource of the country. The Lake has a surface area of ca. 3111 km^2, 284 km^3 volume, and has maximum length of 90 km and width of 65 km. During the study, equipments such as balance (analog and digital), crucible, oven, bomb calorimeter, manual beehive briquette mould, carbonizer, mortal and chopping knives were utilized.

Biomass Collection and Processing

The water hyacinth biomass matter was manually collected from Lake Tana specifically from Gorgora, which is one of the highly infected areas (Figure 1). Other agricultural residues which are abundant in rural communities were also collected from nearby farmlands for comparison. The collected biomass was cleaned to avoid foreign materials prior drying. The raw materials were sun dried for 7 days. The dried raw materials were chopped with chopping knives.

The moisture content of the sample before and after compaction was determined by using oven drying methods. The initial weight of the sample was determined, and placed in an oven set at 105ºC for 24hours. The samples were removed from the oven and allowed to cool before weight determination.

Figure 1: Water hyacinth biomass

Carbonization Process

For the carbonization a portable cylindrical structure with an opening at the top for loading the dry biomass and sealed at the bottom was used. The drum has 12 tubular hollow extensions at the side in symmetrical arrangement in three stages but staggered to regulate the air for generating the required thermal energy for biomass to char conversion.

Figure 2: Carbonization process

The collected biomass was loosely loaded into the kiln. After loading the biomass into the kiln, the top of the kiln was closed with metal lid attached to a conical chimney. The kiln was ignited in the firing portion with little amount of biomass and the doors were closed tightly to start the pyrolysis process (Figure 2).

At the start of carbonization process, the air was supplied via temporarily uncovered large opening from the top and opening on the kiln lateral walls. The kiln chimney also served as a removal of smoke from the kiln. Kiln temperature was controlled by regulating the air supply. The air supply was regulated by closing the air- port opening by commencing from the bottom zone to the upper most zone of the drum step by step. When glowing of biomass was observed through ports, the first pair of ports at the bottom of kiln was sealed. This stepwise procedure was followed until all air ports sealed, at which time carbonization is generally completed (~2hrs).When the temperature was reduced to the surrounding temperature, the kiln was opened and to remove the char. The resultant char powder has been used for preparation of briquettes.

Briquette Production Process

The char which was produced in the drum was crushed into smaller particles for filling into the mould. This was done by locally made mortal, which was found the easiest and cost effective way to grind the charcoal and produce powder. Finally, the carbon powder sieved using an ordinary grain flour sieve to separate the larger carbon particles for better densification in making fuel briquettes.

Clay soil was used as binding agent because it was easily available and cheapest. Carbonized char powder was mixed with soft wet soil (4:1 ratio) until a uniform mixture was obtained. The char and wet clay soil mixture has been made into briquettes by loading the mixture directly into the briquetting mould which was fabricated for this study using locally available materials at mechanical welding shop of Bahir Dar University and the wet material was shaped under low pressure in simple block press or extrusion press. After the briquettes were dried in sun light for 7 days, characterization was done.

Determination of Physico-Chemical Properties of Briquette

Physical Properties Determination

The physical properties of briquettes include thickness, diameter, weight and bulk density of the briquettes were determined using standard testing methods. The bulk density of the briquette was calculated by measuring volume and mass of the sample briquette. Mass measurements were performed with an electronic balance with an accuracy of 0.01 g and the volume of the samples was determined by using water displacement method in accordance with (Tayade, 2009). The average bulk density was calculated by using Equation 1:

Bulk density = $\frac{M}{V}$ ………………………………………………………………………. (1)

Where, M = mass of briquette

V = Volume of briquette

Proximate Analysis of Briquette

The proximate analysis indicates the percentage by weight of moisture content, volatile matter, ash content and fixed carbon in that briquette. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The proximate analysis which involved the determination of volatile matter, ash content, fixed carbon were determined based on the ASTM (1983) D3172, D3175 and D3177 standards respectively.

Percentage of Moisture Content (PMC)

Moisture content is one of the main parameters that determine briquette quality. A lower moisture content of briquettes implies a higher calorific value. The percentage of moisture content (PMC) was found by weighing 2 g of the briquette sample (E) and oven drying it at 105°C until the mass of the sample was constant. The change in weight (D) after 60 min was then used to determine the briquette's PMC using Equation 2:

$$PMC = \frac{D}{E} \times 100 \quad (2)$$

Percentage Volatile Matter (PVM)

The percentage of volatile matter (PVM) was determined by pulverising 2g of the briquette sample in a crucible and placing it in an oven until a constant weight was obtained. The briquettes were then kept in a furnace at a temperature of 550°C for 10 min and weighed after cooling in a desiccator. The PVM was then calculated using Equation 3:

$$PVM = \frac{A-B}{A} \times 100 \quad (3)$$

Where A is the weight of the oven-dried sample and B is the weight of the sample after 10 min in the furnace at 550°C.

Percentage of Ash Content (PAC)

The percentage of ash content (PAC) was also determined by heating 2 g of the briquette sample in the furnace at a temperature of 550°C for 4 h and weighed after cooling in a dessicator to obtain the weight of ash (C). The PAC was determined using Equation 4:

$$PAC = \frac{C}{A} \times 100 \quad (4)$$

The Percentage of Fixed Carbon (PFC)

The percentage of fixed carbon (PFC) was computed by subtracting the sum of PVM, PAC and PMC from 100 as shown in Equation 5:

$$PFC = 100\% - (PVM + PAC + PMC) \quad (5)$$

Combustion Characteristics

Calorific Value (CV)

The heating or calorific value of the samples was determined in the laboratory using a bomb calorimeter in accordance with ASTM D-3286.

Burning Rate (BR)

The burning rate of the briquette was determined according to the method used by Onuegbu et al. (2012). Burning rate was calculated as the ratio of the mass of the fuel burnt in gram (M) to the total time taken in minute (T).

$$BR = \frac{M}{T} \quad (6)$$

Data Analysis

Laboratory and other necessary data were recorded, summarized, and analyzed using SPSS and Microsoft Excel.

Data Quality Control

During collection of the water hyacinth foreign materials like leaves, grass, sand, soil, and wood branches were avoided. After collection, these materials have been allowed to dry and stored in clean and dry area until they were carbonized and pelletized. Then the briquettes had been packed and kept in dry and clean environment and were sent for laboratory analysis. During laboratory analysis we used standard procedure and calibrated instrument.

Result and Discussion

Char yields From Carbonization of Water Hyacinth

The char yield obtained after carbonization of 12 kg biomass was ranged from 3.50 to 4.30 kg. The maximum (35% char yield) was obtained from carbonization of water hyacinth and agricultural residue combination. This is in the range of 30-45%. According to Suguman and Seshadri (2010), 30-45% char powder can be produced through carbonization process. The char yields obtained after carbonization as illustrated in Table 1.

Table 1: Char yields obtained from carbonization of water hyacinth

Biomass	Mass of dried samples(kg)	Time period	Mass of char(kg)	Char yields (%)
Soot part water hyacinth	12.00	1:50	4.00	33.33
Root part water hyacinth	12.00	2: 20	3.50	29.17
Whole water hyacinth	12.00	1:55	3.90	32.50
Water hyacinth with other agri.wastes(4:1ratio)	12.00	2:00	4. 30	35.83

Physical Properties of the Briquette

The briquetting process in this study produced cylindrical briquettes (Figure 3). The average thickness of the briquettes varied from 11.2 cm to 11.9 cm. The average diameter of briquettes varied from 5.8 to 5.9 cm. The average weight of individual briquettes varied from 250 g to 273 g.

Figure 3: Outcome of water hyacinth briquettes

The minimum bulk density was found 507 kg/m3 from briquettes of water hyacinth root while briquettes from combination of water hyacinth and agricultural residue shown the maximum value (691kg/m3) (Table 2). Several researchers have reported that densification would result in bulk densities in the range of 450 to 700 kg/m3 depending upon feedstock and densification condition (Sokhansanj and Turhollow, 2004).

Table 2: Average bulk density of briquettes

Briquettes from	Bulk Density(Kg/M^3)
Shoot part of water hyacinth	663
Root part of water hyacinth	507
Whole water hyacinth plant	648
Combination of water hyacinth with agricultural residue	691

Briquettes Proximate Analysis

The average results obtained from the analysis are summarized and shown in Table 3. The minimum moisture content was 8.68 from carbonization of water hyacinth and agricultural residue combination. This is nearly equal with the same study conducted on carbonized chat briquettes (Tigabu and Nigussie, 2014). The maximum and minimum volatile matter of the briquettes was 48.90 % and 26.54 % respectively. According to Kindie and Nigussie (2013), in terms of quality specification, the low volatile matter implies that the briquettes might not to be easy to ignite but once ignited they will burn smoothly with clean flame without smoke.

Table 3: Proximate analysis of water hyacinth briquette

Briquettes biomass	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
Shoot part of water hyacinth	9.30	45.18	38.40	7.12
Root part of water hyacinth	12.17	26.54	57.31	3.98
Whole water hyacinth plant	10.14	42.85	40.65	6.36
Combination of water hyacinth with agricultural residue	8.68	48.90	29.62	12.80

The briquette produced from shoot part of water hyacinth contained more volatile matter (45.18 %) than the root part and the whole water hyacinth which showed that there were more combustible gasses in the shoot part than other parts of water hyacinth.The briquette sample with the highest volatile matter was observed to have the highest (4402.38 KCal/Kg) gross calorific value (Table 4).

The ash content of briquettes from whole water hyacinth was 40.65 %, which is much higher than 12.4% which was reported by Munjeri et al. (2016) but lower than the maximum ash content of water hyacinth briquettes (74.66 %) reported by Anthony et al. (2014). This difference was might be due to the nature of the binding materials used. The percentage of fixed carbon in whole water hyacinth briquettes was 6.36 %, which is lower than 21.9% reported by Munjeri et al. (2016) but these values are nearly the same with the maximum value (6.91 %) reported by Anthony et al. (2014). This might be due to the difference in binding agent.

Table 4: Combustion efficiency and burning rate of the briquette

Briquettes biomass	Fixed carbon (%)	Calorific value (KCal/Kg)	Burning Rate (g/min)
Shoot part of water hyacinth	7.12	3886.14	1.61
Root part of water hyacinth	3.98	3219.86	1.35
Whole water hyacinth plant	6.36	3727.04	1.55
Combination of water hyacinth with agricultural residues	12.80	4402.38	1.68

The briquettes from combination of water hyacinth with agricultural residues showed highest calorific value when compared with the other briquettes produced in this study. This is an indication that more heat during combustion might be generated from these briquettes. Moreover, the calorific value of briquettes produced from combination of water hyacinth and agricultural residue was 4402.38 Kcal/kg. This value is higher than the minimum calorific values of commercial briquette (4179.8 kcal/kg) (Deutches, 1996).

The calorific value of briquettes produced from whole water hyacinth was 3727.04 Kcal/Kg. This value was lower than charcoal (6592.5 Kcal/Kg) but these values are nearly the same with the value of 3701.30 kcal/kg reported by (Anthony, et al., 2014).

The burning rate value of water hyacinth briquettes was 1.55g/min. This value was lower than the minimum value reported by Davies and Davies (2013) which was 1.63 g/min. This difference could be due to difference in binding agent, which was Phytoplankton Scum as binder in their study. As shown in Table 4, briquettes from the combination of water hyacinth and agricultural residues had high burning rate, 1.68. The implication of this observation is that more fuel might be required for cooking with briquettes produced from combination of water hyacinth and agricultural residues than the other briquettes produced in this study**.**

Conclusion

In this study the production of briquettes from water hyacinth with clay soil as a binding material in 4:1 ratio successfully performed.The results have shown the possibility of utilizing water hyacinth as fuel briquette of good source that support combustion. The result of these analyses confirmed that fuel efficiency of water hyacinth briquettes competed favorably with other biomass briquettes. This study has also shown that combination of water hyacinth with other agricultural residue can produce briquette with a better fuel efficiency. Generally the results of this study clearly demonstrated that converting water hyacinth into briquettes can provide an alternative energy to the people and can be one among the solution for environmental problems.

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Policy Brief: Rising e-waste in Ethiopia: a cause for concern

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Summary

The projected rise in e-waste amount needs prompt reaction through various forms of environmental protection tools to avert effects on the ecosystem. E-waste stream are soon likely to become diverse in kind. Higher e-waste generation mean problems starts to face this new challenge, households with low income which stagger for basic needs are prone to the danger particularly and in general the society which has lower awareness about the consequence of e-waste could continue disposing e-products carelessly that would render significant threats to human and environment.

Conclusion

The study undertaken in the four cities (Addis Ababa, Hawassa, Bahir Dar, Dire Dawa) has given the e-waste status which can indirectly describe the general picture at a country level. Despite the e-waste amount was not know prior to 2011, the projection made from 2012 to 2020 shows the spike in e-waste generation. The rapid population growth, economic growth, income growth, expansion of electronic manufacturing companies, and new emerging life styles would hasten the e-waste generation rate in the years to come. Low public awareness about the impact of e-waste would make the management system difficult. Hence, organized awareness creation program is in due demand. Prompt short and long term e-waste management strategies should be designed to curb the impending risk on the environment and humans.

Introduction

Electronic and Electrical Equipments (EEE) waste, commonly referred as e-waste, is one of the fastest growing segments in the municipal solid waste stream. In 2014, approximately, 41.8 million tons of e-waste was generated worldwide. The quantity included 12.8 million tons of small equipment, 11.8 million tons of large equipment, 7.0 million tons of temperature exchange equipment (freezing and cooling equipment), 6.3 million tons of screens and monitors, 3.0 million tons of small IT and 1.0 million tons of lamps. The amount of worldwide e-waste generation is expected to be 49.8 million tons in 2018 with an annual 4-5 percent growth.

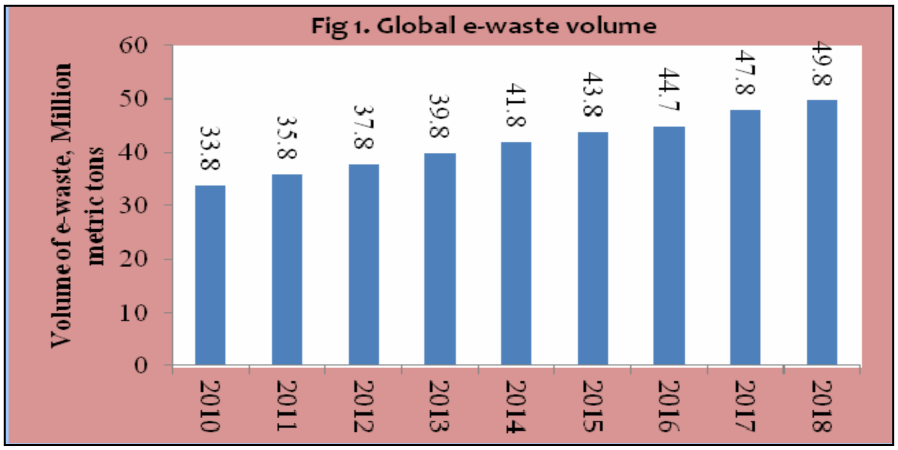

Figure 1: Global e-waste volume

Accordingly, the year 2018, it is predicted that some 6.7 kilograms of e-waste per capita will be produced globally. The majority of e-waste generated around the world are from small electronic equipment. Generally, the amount of global e-waste is expected to grow by 8 per- cent per year (Global e-waste monitor, 2014).

Ethiopia has been reported for its rapid economic growth in the recent past. The country is working to have a transition from agriculture to industry led economy. However, the country has poor waste management facilities which are becoming the concern to the environment and humans. The rate of population growth, and economic growth in the country has height- end the rate of waste generation which worsen the existing problem of waste. In a country with lacking capacity to manage the non-hazardous wastes, the issue of e-waste can be viewed as the fancy element of the discourse.

Nonetheless, the danger associated with e- wastes is incomparably high where critical attention is being sought. E-wastes contain over 1000 various substances many of which are toxic and potentially hazardous to the environment and human health if they are not handled properly (Edwards 2011). Similar to the global scenario, the rate of e-wastes generation is increasing against the absence of waste management facility and lack of awareness in the community. Globally it is recognized that there is a lack of reliable data on the generation, collection, import and export of e-wastes, and management scheme for handling it in general (Edwards 2011).

Analysis

How does e-waste generation look in Ethiopia?

Though Ethiopia had no clue about the status of e- waste generated for the past decades, the study conducted in 2011 by Pesticide Action Nexus (PAN) in four cities (Addis Ababa, Dire Dawa, Bahirdar, Hawassa) has disclosed "where we are" and "where we go". The study assessed the amount of e-waste generated and the current e-waste management practices. Though the values shown in Figure 2 are low, the rate of e-waste generation projected for these cities indicated that significant change in quantity of this waste stream would happen. Compared to other African countries such as Ghana and Nigeria, there are no indications that massive recycling. Although there are some indications that e-waste is disposed-off in an uncontrolled manner, the majority of obsolete e-products is currently stored in government premises, offices or households awaiting future solutions. As government bodies as well as other types of offices (banks, businesses, NGOs) have until recently been the dominant consumers of electrical and electronic equipment, they are currently the most important source of e-waste in the country.

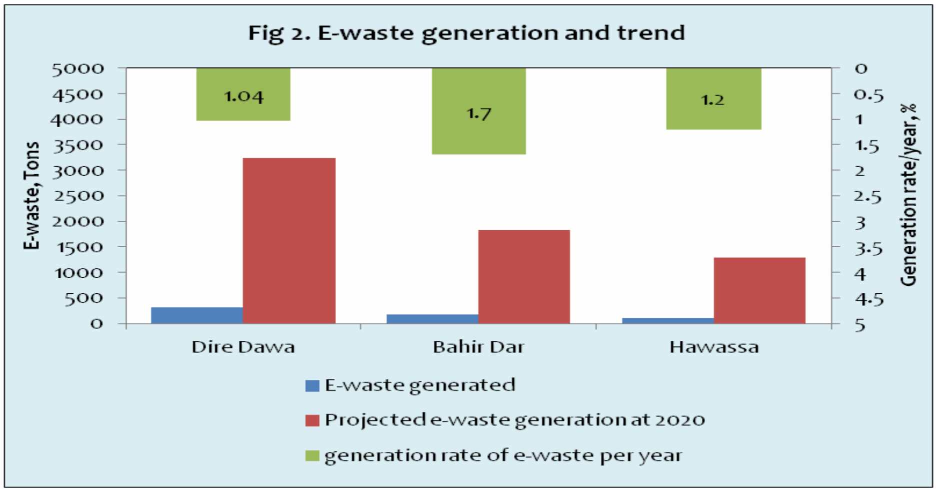

Figure 2: E-waste generation and trend

Furthermore, it can be asserted that e-waste is mostly generated in urban areas and not in rural settlements. One exception from the urban- rural disparity in the use of e-products is battery powered devices such as torch-lights and radio/ cassette players. It has been reported that more than 300 million dry cell batteries are consumed in Ethiopia annually (UNIDO 2010).

So how e-waste will rise in recent years?

Ethiopia is one of the fastest growing economies in Africa so that consumption and disposal patterns will rapidly change in the near future. Once devices such as computers, mobile phones and TVs are not regarded as luxury goods any more, the willingness to store obsolete devices will also decrease. In addition, urban centers – and in particular Addis Ababa – are already host to active informal collection and scrap metal businesses, which typically also take over e-waste recycling once sufficient quantities are available.

The rapid pace of globalization has also rendered an easy access to penetrate markets in developing countries. Consequently, the rapid penetration of electrical and electronic equipment in the Ethiopian society will soon alter this picture to a more heterogeneous e-waste situation, particularly with regard to mobile phones in number, and computers and their accessories in volume and weight. It is known that many households not connected to an electricity supply make use of low-price non- rechargeable standard batteries. These batteries often have short lifetimes and contain heavy metals such as lead and/or cadmium. In addition, efforts to promote decentralized rural electricity supplies often use solar panel installations coupled with lead-acid battery storage systems. Once obsolete, these systems (and in particular the lead-acid batteries) are of high environmental and health concern.

What is the expected path for e-waste in developing countries?

The growing quantity of waste from the electronics industry is beginning to reach disastrous proportions. This is due to the lack of protective measures and the inadequate way of dismantling and processing in order to ex- tract valuable components. This can lead to severe health and environmental hazards. Public-health problems and environmental degradation caused by recycling of old computer equipment could skyrocket in the next two decades. Within six to eight years, developing countries will be disposing of more old computers than the developed world, suggests a study published in Environmental Science and Technology. And by 2030, these nations will be disposing of two to three times as many computers as the developed world for recycling is completely shut off, the developing world will still have to cope with a massive amount of domestic electronic waste.

The problem comes from efforts to reclaim precious metals from circuit boards and wires using "very primitive" methods. To obtain copper, for example, informal 'backyard' recyclers in the developing world simply burn off the insulation, producing a host of toxic chemicals from the burning plastic. And to obtain gold and other metals from circuit boards, they simply treat them with of nitric acid and cyanide. There's no proper way to dispose of the waste acid and cyanide, which ends up being dumped into local water or soils (Tadesse 2010).

What will be the impact on the environment and humans?

Electronics and Electrical Equipments (EEE) are made of a multitude of components, some containing toxic substances that have an adverse impact on human health and the environment if not handled properly. Often, these hazards arise due to the improper recycling and disposal processes used. It can have serious repercussions for those in proximity to places where e-waste is recycled or burnt. Several electronics contain highly toxic chemicals like lead, cadmium, mercury, beryllium, BFR, polyvinyl chloride and phosphor compounds (Sinha 2007). These chemicals exerts toxic effects on various systems in the body such as the central and peripheral nervous systems, the hemopoietic system (anemia), the genitourinary system (capable of causing damage to all parts of nephron) and the re- productive systems (male and female) (Harrington et al., 2003). Moreover, most chemicals are bio-accumulated in different living organisms found at different level of the food chain. Example; when inorganic mercury spreads out in the water, it is transformed into methylated mercury, which bio-accumulates in living organisms and concentrates through the food chain, particularly by fish. Consequently, the stored mercury or other kind of toxic metals will be transferred to the higher food chain such as to human (Hu, et al., 2001; Harrington, et al, 2003).

What can policy-makers do about this?

As long as Ethiopia is signatory to Basel convention, environmental issues and trade associated with e-waste at local, trans-boundary and international levels have to be checked and strengthened with functional strategy and directives. In order to manage the import of low grade electronic appliances with short life time, integrated strategy has to be designed between MEFCC, Ministry of Industry, Trade, Transport, Science and Technology, Electricity, Water and Irrigation, and Custom authority. This would help to minimize the rate of e-waste generation if the imported electronics and electrical materials are good quality in terms of functioning time.

For instance, in Addis Ababa with local name "Ched Tera" is renowned with recycling of various used materials for which huge amount of electronic materials used. This kind of observation is also exist in different part of the country regardless of the magnitude. It is impossible to stop the generation e-wastes at all, the better approach might be establishing national e-wastes recycling industry either by the government or the private sector as happened in Kenya. In return, the environmental qualities and human health would be maintained sustainably.

The awareness gap in a society was also re- ported above 90% where it requires attention to create holistic e-waste management nation- ally from the generation source to the final fate of the waste. Though the study is limited to the cities aforementioned, the ground truth for other part of the country would not be different. Consequently, national level awareness programs can be designed using various approaches.

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Chapter Eight: Abstracs Presented in the Workshop

(Full write up of the abstracts is already published or is in press by other publishers)

Ethnobotany of *Moringa stenopetala*: A case study from Derashe and Konso ethnic communities in Southern Ethiopia

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Abstract

Moringa stenopetala is an important cabbage tree, cultivated and managed for various purposes in the southern part of Ethiopia. The study was conducted to document Ethnobotnical knowledge on moringa related to cultivation, conservation and management of the resources. The study was conducted in Konso and Derashe district that are found in Segen Peoples Zone of the Southern Nations and Nationalities Peoples Regions (SNNPR). The districts were selected purposively because they are known for their age-old management of moringa. Data were collected using focus group discussion and household survey. A total of 180 households were surveyed using a semi-structured questionnaire. A focus group discussion were also conducted involving elderly people, youths, men and women and experts. Descriptive statistics were used to elaborate the results. Result showed that Moringa is an important components of the daily dish of the studied communities and also used for medicinal purposes. Moreover, it is also used for medicinal purposes. Local communities propagate moringa using seed and cuttings, and is also practiced by farmers. As the species can be easily propagated via seeds and cutting, this is a good opportunity in the future for expanding moringa plantation at similar agro ecologies of the country. The studied communities mainly plant the species at homestead . Never the less, they also plant Moringa on the crop fields, but trees need to be pruned every year so as not be a shelter for birds especially in maize and sorghum growing areas. The study recommends research should be done to investigate the optimum cutting height and season for better survival and growth of seedlings. Moreover, traditional use as medicine both for livestock and humans should be further verified by research for further utilization of the information in antibacterial study and then further utilization in the drug development industry in the future.

Controlling Water Hyacinth in Lake Tana Using Biological Control

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(Full write up of the abstracts is already published by other publishers)

Abstract

Eichhornia crassipes is one of the most dangerous aquatic weeds for Lake Tana. To minimize its invasion on aquatic body biological, chemical and physical control methods can be used. Biological control based on the use of natural enemies of the weed to discourage its development was the best option. Plant pathogenic associated with naturally infected Faba bean by fungus was conducted at three wereda's (Amba Gyorgese, Dabat and Debarke) around Gondar at 20 Peasant association , the collection were done from fungus infected Faba bean leaves and roots by isolated using PDA medium. Highest disease incidence per plant was recorded in water hyacinth plants in green house and pond .Disease severity were recording using (Freeman and Charudattan, 1984) rating scale in green house. In ponds disease severity were recording using Modified Naseema etal (2001) by inoculated with Rhizoctonia solani spp. Aspergillus flavus, Tricothcium roseum ,Fusarium spp and Aspergillus niger isolated from necrotic , brown or yellow Faba bean leafs and root. Those fungus were released on September ,2016 to open pond that hold healthy water hyacinth at 16 m2 and water hyacinth was started severely attacked on November, 2016 but in September 2016 the fungus remains latent in the water hyacinth leaf because of the weather condition was cold and the average temperature below 23 oc in the experiment site that far 60 km from Lake Tana , its disease incidence was 55 % at 23 oc and humidity 39 % in November 2016 , in December 2016 its disease incidence was 58.4 % at humidity 31 % and 23 oc .Some species of Fungi found in Faba bean leaf and root can eradicate the healthy water hyacinth at above 26oc and at less than 25% Humidity.

Effects of Environmental Factors and Anthropogenic Disturbances on Plant Diversity and Communities in Five Montane Forest Patches of Awi Zone, Northwest Ethiopia

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(Full write up of the abstracts is already published by other publishers)

Abstract

Environmental factors and disturbances are the two major drivers that shape plant diversity, distribution, composition and structure in montane forests. A clear understanding of influence of environmental factors and disturbances on species composition and community formation has important implication for restoration of forest patches. Thus, the objective of the study was to determine and describe effects of environmental factors and disturbances on plant diversity and communities in Awi Zone, Northwest Ethiopia. Data of plant species, environmental factors (elevation, slope, aspect) and disturbances (harvesting and grazing) had been collected in quadrant plots (trees >5cm dbh, 20mx20m), shrubs ($25m^2$) and herbs ($1m^2$). All statistical data were analyzed in R environment. Cluster analysis using Euclidean distance with ward method and ordination using detrending and redundancy analysis was performed to classify plant communities and identification of community–environment relationship respectively. Indicator species analysis was tested by Monte Carlo permutation at $p<0.05$ to identify species with statistically significant associations in the communities. Five diversity indices were also calculated to analyze variation of species diversity. Disturbance impact factor was derived from relative stem densities of harvested woody species and associated forest canopy opening. The result showed that five forest patches contained considerable number of plant species (153 species) belonging to 65 families. A cluster analysis, coupled with indicator species (16.37 to 94.24% value in the group) revealed four plant community types, which can designated as Lepidotrichilia volkensii - Erythrococea trichogyne, Albizia gummifera -Justicia schimperiana, Bersama abyssinica-Pavetta abyssinica and Rytigynia neglecta -Maytenus undata community. The A. gummifera-Justicia schimperiana community occurred relatively in lower altitude (1988–2176m). Ordination analysis confirmed that population of woody species were significantly structured by elevation ($p<0.001$), harvesting and grazing intensities ($p<0.05$) and their interaction ($p<0.001$). The regression analysis showed that species diversity had declined from lower ($H'=$ 2.63) to higher elevation ($H'= 2.23$) and intermediate slope ($H'=2.65$) to steep slope ($H'=2.45$) at $p<0.05$ but species richness increased towards higher elevation. The maximum species diversity ($H'=2.48$) attained on moderately disturbed and community forest ($H'=2.63$) patches. The species turnover or Beta diversity (βw) had changed from least ($\beta w= 2.87$) to moderate ($\beta w= 2.49$) disturbed forest patches but more explanatory in relation to latitude. In conclusion, environmental factors and disturbances played significant variation of plant composition, diversities and communities. Therefore, restoration intervention like area exclosures and community-based conservation should be best strategies to maintain sustainability of forest patches. Specifically, future research should assess indigenous uses of plant species and their carbon stocks in the forest patches.

The Effect of Provenances and Seed Pre-sowing Treatment on Germination Rate of *Juniperus procera* Hochst ex Endl

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(Full write up of the abstracts is in press by other publishers)

Abstract

Juniperus procera (Hochst. ex endl.) is an important indigenous tree in Ethiopia. However, it is an endangered species found in the IUCN red. The current study focuses on the effects of pre-sowing treatment and provenances on germination of J. procera seeds. Cones of the tree were collected from *Adaba and Wof -Washa forest. Germination of seed was tested by using cold water for 12hrs, hot water for 24 hrs, sulfuric acid (98%) for 5 min., 10 min., and 15 min., scarified by rough sand paper and control both in laboratory and nursery. The experiment was laid out in CRD under both conditions. Different germination parameter were determined and data were subject to ANOVA and independent t-test. Under laboratory condition, statistically higher mean germination was recorded for untreated seeds (Adaba 60.75%; Wof- Washa 35%) and seeds treated with sand paper (Adaba 56%, Wof- Washa 32%) followed by seeds socked in cold water (Adaba 42.25%; Wof- Washa16%). Under nursery condition, statistically higher mean germination was recorded for seeds soaked with cold water for 12 hrs (Adaba 80%; Wof- Washa 24%), untreated seeds (Adaba 60%; Wof- Washa 38%) and seeds treated with sand paper (Adaba 57%, Wof- Washa 17%). Under this study, it is observed that germination of J. procera seed depends on the site of collection, i.e. the provenances and the media. Similar trends were observed in both laboratory and nursery in comparing seed sources by the parameters, Adaba is greater than Wof-Washa which is endowed with higher seedling vigor and speed. Higher germination (80%) was recorded while soaked seeds in cold water were sown in the nursery where there is high light intensity and temperature, on pure sand media than sowing seeds in the laboratory (at room temperature) by using the treatments. Thus seedling producers are advised to consider provenance and sow J. procera seeds under nursery conditions.*

"Fungi and Plantation Forests" Diversity of Pathogenic Fungi on Plantation Forests of North and North West Ethiopia

Wendu Admasu
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Abstract

Forest plantations in Ethiopia constitute mainly exotic genera of Eucalyptus, Cupressus, Casuarina, Pinus, and native Juniperus species. These plantation species are suffering from attack by disease causing agents at varying degrees, particularly Amhara region is among regions with plantation forests that have in recent years been subjected to attack by diseases in Ethiopia. Plantation trees in commercial stands, farm lands and woodlots were surveyed for diseases symptoms in 20 selected areas of Amhara and Tigray from May to June 2016. Leaf blight, leaf spot, tip blight and stem canker were the most common symptoms appeared during the survey period with leaf spot and steam canker the most prevalent. Tree samples showing clear disease symptoms were collected, surface sterilized, cultured and morphologically characterized for pathogen identification. A total of 42 isolate of fungi colonies were identified from samples collected of 20 localities. Morphological characterization of fungal isolates reveals, six fungal genera belonging to Alternaria, Diplodia, Pestalotiopsis, Curvularia, Phoma and Penicillum were the cause for the observed disease symptoms. Among the isolates 14 (33.3%) were Alternaria species, 15(37.7%) were Phoma species, and the remaining 13 isolates were Diplodia 3(7.2%), Pestalotiopsis 7(16.7%), Curvularia 2(4.7%) and Penicillum 1(2.4%). Based on the findings of the study, Phoma lingam, Phoma glomerata, Alternaria alternata, genera of Curvularia, Pestalotiopsis, Penicillum and Diplodia were found to be the cause for diseases of the tree plantations. Phoma and Alternaria species were the most prevalent isolates, showing majority of symptoms observed on plantations were due to their co-infection. The pathogenicity test result of the research also confirmed fungal isolates were the cause for the diseases symptoms observed. The findings of this research enables to study and design appropriate diseases management options among Cultural management, Biological management and Chemical management approaches or their combination for the future prevention and control of the diseases specially when there is prolonged environmental stress in the country.

First Report of *Lasiodiplodia theobromaeca* Using Needle Blight and Stem Canker Diseases on *Araucaria heterophylla* in Ethiopia

Wendu Admasu
Central Ethiopia Environment and Forest Research Center

Abstract

Canker and needle blight of Araucaria heterophylla (Norfolk Island pine) trees were observed during surveysconducted inAddis Ababa and Adama cites (Ethiopia)from November to December 2016.The main objective of this study was to investigate fungal pathogens that cause diseases on Araucaria heterophylla trees.Six localitieswith Araucaria heterophylla plantings were purposively surveyed for diseases symptoms. Samples from symptomatic parts of treeswere collected, surface sterilized, cultured on PDA and morphologically identified for genus and species. A total of 36isolates of fungi were identified fromsix localities.Based on macro-andmicroscopic morphological featuresof the colonies, the fungalisolates were found to be the genus Diplodia and species Lasiodiplodia theobromae(Pat.) Griffon and Maubl.(syn. Botryodiplodia theobromae), the anamorph of Botryosphaeria rhodina(Berk and Curtis)Arx. The pathogenicity test showedthat the isolates ofLasiodiplodiatheobromae, caused stem canker and needle blight onAraucaria heterophylla. This finding is important in the study of management options for future prevention and control of the diseases in the country.

Eucalyptus globulus (*E. globulus*) Leaf Spot and Stem Canker Diseases due to *Phoma* spps in North and North West Ethiopia

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Abstract

Eucalyptus globulus species are among the exotic plantation speices used in Ethiopia. Plantation of these species covering one-third of the total plantation area of the country mainly to meet the demand for construction and fuel energy resources and showed a good adaptation and growth. The success of growth and development of E. globulus plantations is currently influenced by fungal pathogens causing leaf spot and stem canker diseases. The main objective of this study was to investigate the diversity and distribution of fungal species associated with plantations causing leaf spot and stem canker diseases, so that management options to be studied for effective control and prevention of the diseases. Twelve plantation sites were purposivly sampled and surveyed in Amhara and Tigray regions of Ethiopia from May to June 2016 for disease symptoms. Samples with clear diseases symptoms were collected cut to desired size, surface sterilized and inoculated on the potato dextrose agar media to isolate the caustative agent. Twenty pure cultures that have similar colony growth were selected and morphologically characterized to genus and species level for identification. The collected data were summarized, ranked and expressed using simple descriptive statistics of SAS Version 9.0 procedures. Based on the results morphological characters ,among the isolates 60% of the isolates were found to be with pink and dark green to grey mycilia containing long chains or solitary, unicellular or multicellular, alternarioid chlamydospores. The morphological characteristic were consistent with genus Phoma and species Phoma glomerata. The rest of isolates were with milky conidia, two oil droplets inside, oozing in characteristic shape from dark pyinida and without chlamydospores,which is the morphological features of genus Phoma,species Phoma lingam The mean colony diameters of the isolates ranged from 7 to 8cm and 7.3 to 8cm for Phoma lingam and Phoma glomerata respectively. There is no significance difference in mean colony diameter among the isolates. The result of this study demonstrated that Phoma glomerata and Phoma lingam were the cause for leaf spot and stem canker diseases of E. globulus tree plantations in high lands of Ethiopia. It is therfore important to study the management options for control and prevention of the diseases in the country.