Package of Technologies and Information

Ethiopian Environment and Forest Research Institute (EEFRI)
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PACKAGE OF PRACTICES FROM RESEARCH OUTPUTS

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Regional Environment, Forest and Climate Change Bureaus/Authorities

Tree farmers

Forest products processing enterprises

Wood based industries

Volume I

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Preface

Ethiopia has formulated shorter-term Growth and Transformation Plans (GTP II) and longer-term Climate Resilient Green Economy (CRGE) strategy to propel the country to middle class economy status by 2025 following low carbon and resilient green development pathways. Forest and environment sectors have immense potential to contribute to this ambitious target by sustaining the on-going economic development, creating green jobs and fostering climate change adaptation and mitigation potential. To this end, the country has been undertaking various activities to sustainably manage and utilize its forest resources, including the plan to increase its forest cover from 15.5% to 20%, doubling forest sector contribution from 4% to 8% in five years (2016 – 2020). Moreover, the government pledged to rehabilitate 15 million ha of degraded landscapes by 2025 as part of the Bonn Challenge, and this plan was increased to 22 million at the 2014 UN Climate Summit in New York (MEFCC, 2017). At the same time, the country has given greater attention to manage environmental pollution and degradation due to the recent unprecedented scale of agricultural expansion, industrialization, and urbanization. Ethiopia's commitment to follow a low-pollution, low-emissions and resilient pathway will enable its people to lead healthy and productive lives.

The realization of these ambitious national targets is contingent on provision of technologies, knowledge, and information generated from rigorous research endeavors. To achieve these goals, the Ethiopian Environment and Forest Research Institute (EEFRI) has generated various technologies and information in forestry, environment and climate change fields, which are useful for productivity enhancement, income generation, and creation of employment opportunities, poverty alleviation, and realization of climate resilient green economy. Here are lists of technologies and information generated by EEFRI since its establishment in December 2014. The complete package of these technologies and information are presented for wider dissemination.

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October, 2018

Message from the Deputy Director General, EEFRI

Ethiopia's economy is growing in noticeable rate; however, it is broadly based on rain fed agriculture where this sector's average share from 1980's to 2014 in the GDP was about 51%. For the same period, the share for other sectors viz., industry, manufacturing and service were 11.0, 4.9 and 38.1%, respectively. Growth rates for the last three decades showed the lowest for agriculture (3.8) as compared to industry (6.9), manufacturing (5.1) and service (7.1).

Cereal average productivity is at a standstill at 2.2 tons per hectare, which have been ascribed to the low level of agricultural technology in use viz. poor farming practice, soil erosion, nutrient loss, soil "sickness", low input supply, low product value addition and marketing. The low productivity per unit area also holds true for the forestry sector in Ethiopia. Until recently, forestry has never been accounted to have any contribution to the GDP (currently about 4%). Remaining under continuous deforestation, degradation and loss for agricultural expansion, free access to livestock grazing, unlimited resource extraction exacerbated by lack of appropriate institution for management and law enforcement, the sector has been badly ignored.

Considering the importance of the environment management and forest sector development for better agricultural productivity, ecosystem services and climate change adaptation and mitigation, the Federal government proclaimed the establishment of the then Ministry of Environment, Forest and Climate Change in 2013. Subsequently, Ethiopian Environment and Forest Research Institute (EEFRI) was established in December 2014 to support the Ministry with extendible environment and forestry research outputs in the form of packaged technologies and information to the sectors development.

EEFRI, recognizing the need for extendible forestry and environment management technologies and information under local circumstances has presented its first volume of extracts from research outputs. It is with the understanding of the urgent need to provide package of practices and users manuals as transfer of technology and information to improving forest management, promoting investments in the wood-based industries both in private and public sectors and creating a favorable and safe industrial environment enabling economic development as well as climate change adaptation and mitigation. The present volume contains about ten packages of technologies and twenty-seven packages of information extracts as well as five manuals based on EEFRI's research on the ground. We have indicated the responsible researchers for contact in view of extending the practices with potential users. The packaged practices and users manuals transferred will certainly benefit extension workers, tree farmers in private and association, public forest and wood based enterprises, small scale wood workshops, environment and forest management departments of the federal and regional governments and policy makers.

I congratulate and compliment the efforts of EEFRI researchers who in very short period of time have prepared these packages from their partly and fully completed research outputs under very constrained research infrastructure and logistic supply.

I also extend my thanks to all research directors engaged in continuous back and forth exchange of the write up with staff associated with the research outputs for improvement till this final form.

My gratitude also goes to the support staff who contributed in facilitating the research with smooth financial and procurement activities as well as human resource allocation and management.

Finally, the reviewers listed are acknowledged for their enormous professional inputs and corrections put forward to make the contents easily understandable and readable to users.

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Pakage of Technologies

1. The potential of *Jatropha curucas* husk for briquette production

Responsible researchers: Weldemedhin Merete, Berhane Kidane, Abeje Eshete, and Amsalu Tolessa

Brief description of the technology

The world energy demand is mainly dependent on fossil fuel utilization which is contributing to accumulation of greenhouse gases, those creating conditions for happening of climate change (Eijck *et al*., 2006). Owing to this dilemma, the world focuses on searching of renewable sources of energy from locally available biomass resources. When efficiently carbonized, these are environment friendly and less carbon emitting. Therefore, this study was undertaken to determine suitability of waste biomass (Husk from *Jatropha curucas*) for briquette production and also to assess the energy quality of briquettes produced using different available binding agents.

The *Jatropha* husk are obtained from *Jatropha* milling located in Amhara Regional State, Bati Woreda and the binding material is prepared from caly soil, banana peel, potato peel, mixture of banana peel and clay soil binder, mixture of potato peel and clay soil binder. First, the required amounts of husk are allowed to dry under the sun for removing the moisture before carbonization. Then after, husk is carbonized by using kiln Carbonizer (one that converts a carbon-containing biomass to carbon by partial burning under oxygen scarce environment), then grinded into char powders and finally the grinded char powder of Jatropha husk is mixed with binder in ratio of 3:1 and briquetted by briquette press machine.

The quality of briquettes produced using Jatropha husk binded with mixture of banana peel and clay soil is higher in terms of heating value (>6000Cal/g) and lower in ash (29.44±2.68 %) and fixed carbon content (41.67±1.65%) relative to the other binders. On the other hand 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. Thus, we encourage the use of Jatropha husk for briquette production as it can be an alternative to firewood for household cheap energy demands.

Suitability

Briquettes from Jatropha husk biomass are better substitutes to raw biomass and charcoal, as these have improved combustion performance and energy efficiency. Briquettes from this source are idetified suitable for cooking and heating where cooking fuels are not easily available. The briquettes provide several advantages as compared to conventional wood fuel as they reduce fuel consumption and fuel wood dependency; have uniformity in size and quality, minimum indoor air pollution, less fly ash; are easier and clean to handle, pack, transport and store.

Requirements:

To implement briquetting technology the pre-requisites are:

a. Feedstock
   - Jatropha Husk, banana peel and preferably clay soil
b. Safety Materials
   - Gloves
   - Safety shoes
   - Lab coats,
   - Safety working clothe
c. Materials for production of Briquette
   - Carbonizer (for husk)
   - Carbonized husk miller
   - Shovel/scoop
   - Handcart
   - Mixer (husk and binder)
   - Briquette machine
   - Jar

Moreover, training of producers and efficient biomass stove are also important.

Practice*:*

To make briquettes from Jatropha husk, the husk is collected, allowed to dry on the sun for removing the moisture before carbonization. Jatropha husk is carbonized using carbonizer in the oxygen scarce environment at a temperature of 500°C to 600°C, then grinded into char powders and mixed with binder (banana peel with clay soil) at the ratio of 3:1 and finally briquetted by briquette press machine to obtain briquettes which dry in the sun for two days and then the briquettes are ready for use.

Figure 1 Briquette made from Jatropha husk with a mixture of banana peel and caly soil

Management*:*

- Keep the biomasses and briquettes in a dry and clean environment.
- Protect yourself from toxic gasses which are formed during carbonization.
- Clean the instruments after completing your activity

Comparative advantage/yield

Advantages of briquette technology use in Ethiopia:

Provide an alternative solid biomass fuel to wood fuel and charcoal for domestic cooking from waste materials, create employment opportunity for youth, create a chain of income generation ventures from production to consumption, reduce environmental pollution especially in the urban and peri-urban areas & conserve trees and vegetation

Cost effectiveness

No financial analysis has been done.

Risk and uncertainty

There are a number of challenges and barriers that risk the advancement of the sector.

- Product certification or standardization of briquettes
- Lack of consistency in quality
- Government regulations,
- Finance, transportation cost and higher moisture content of raw materials may require longer drying time which increases production cost

End users

- Industries
- Boilers,

- Distilleries,
- Bakeries
- Restaurants
- Biomass power stations
- University cafeterias and hotels
- Individuals

2. The Potential of *Prosopis Juliflora* for Briquette Production

Responsible researchers: Weldemedhin Merete, Sewale Wondimneh, Abeje Eshete and Berhane Kidane

Brief description of the technology

In Ethiopia traditional biomass is the major source of energy (more than 92%) of the national energy consumption. This practice of raw biomass use for energy has been causing different environmental and socioeconomic impacts. Traditional biomass being used as the primary source of energy in all sectors, there is a need for the development of alternative biomass energy technologies. Charcoal has been produced from *Prosopis juliflora* tree stem commonly with a larger diameter as alternative method to control its invasive nature (Wakie *et al*. 2016). Other parts of this species such as branches, twigs and leaves are not used for charcoal production; more often, they are left to decompose in open field due to their smaller diameter, low density and loose properties as well as the inconvenience to use in traditional stoves. Therefore, research has been done to assess the possibility of briquette production from branches, twigs and leaves of *P. juliflora*; and characterize their energy quality.

The biomasses are collected, dried and carbonized separately in the oxygen scarce environment by using carbonizing kiln; then grinded and mixed with binder at 3:1 ratio. Finally, the mixtures are poured into the briquette press machine to make briquettes.

The result shows that the calorific value of briquettes from *P. juliflora* branches, twigs and leaves is 5666.51±173.97, 5281.41±74.88 and 4463.37±70.69 Cal/g, respectively. The higher calorific value gives a good opportunity for the diversification of energy source from *P. juliflora* for local communities in domestic cooking. In addition, it can also be considered as a means to reduce the expansion of the tree species.

Suitability

Briquette from *P. juliflora* biomass is better substitute to raw biomass and charcoal and found suitable for cooking and heating. The briquette provides several advantages as compared to conventional wood fuel: i) it reduces fuel consumption and fuel wood dependency; ii) have uniformity in size and quality, iii) minimum indoor air pollution with less fly ash; iv) easier and clean to handle, pack, transport and store.

Requirement

For the production of briquette from *P. juliflora*, the materials required are:

- Glove, safety goggle, dress coat and safety shoes
- Sieve
- Biomass (branches, twigs and leaves of *P. juliflora*)
- Briquetting machine (including feed hopper, separator, hammer mill, dryer, briquetting press, briquette cooling line, briquette packing system, kiln/drum)
- Binding materials (clay soil and water in the ratio of 1:2)

Practice

Biomasses from *P. juliflora* are collected and sorted into branches, twigs and leaves. The collected biomass especially branches and twigs are chopped to a length of 10 cm by using axes to obtain homogeneous size for the carbonization process. Before carbonization the biomass is exposed to direct sunlight for drying. Later, branches, twigs and leaves are separately carbonized using kiln in an oxygen scarce environment in between 500 ^{o}C to 600 ^{o}C. Biomass carbonization refers to a process in which biomass are decomposed by using heat in the absence of oxygen.

Afterwards, the carbonized biomasses are grinded into fine particles and mixed with binder at a ratio of 3 to 1 *i.e.* three kilograms of carbonized biomass is mixed with one kilogram of binder prepared from clay soil and water in the ratio of 1:2 (Merete et al., 2014). Finally, this mixture is fed into the briquette press machine to make briquettes. The excess amount of moisture bound in the briquettes is removed by exposing them to direct sunlight and then are allowed to dry further under oven and ready for use.

Steps to manufacturing briquettes

- Biomass collection
- Drying
- Carbonization
- Preparation of Char powder
- Binder preparation & Mixing
- Briquette production
- Drying

Figure 2 Briquette made from *Prosopis juliflora* biomass

- Keep the biomasses and briquettes in a dry and clean environment.
- Keep yourself from toxic gasses which are formed during carbonization.
- Clean your instruments after you complete your activity

Comparative advantage/yield

Advantages of briquette from *P. juliflora* are: i) environment friendlyness due to low volatile matter such as low sulfur content, ii) minor release of sulfur oxides, iii) produces less residue or waste while burning briquettes, iv) the increment in density of the briquettes and their fitness for utilization and v) creates employment opportunity for youth and women.

Cost effectiveness

Cost analyses have not been conducted on the production of briquettes.

End users

- Industries
- Boilers,
- Distilleries,
- Bakeries
- Restaurants
- Drying and also in power stations
- In educational institutions and hotels as well as by individuals

3. Effective lumber seasoning technologies and uses of *Pinus tecunumanii* tree species

Responsible researchers: Getachew Desalegn, Gemechu Kaba, Anteneh Tesfaye, Saifu Amanuel, Tsegaye Wubshet and Tesfanesh Ababu

Brief description of the technology

Proper lumber seasoning (drying) technologies remove moisture and highly minimize/ avoid moisture associated problems from lumber. The moisture (often ≥ fiber saturation point, 30%) removal or seasoning is done through natural and artificial methods such as kiln, solar and other seasoning techniques. Increasing efficiency of utilization of forest products through value addition and maximization of uses of wood and wood–based products will be possible by determining the different characteristics and quality of each species. Thus, research has been undertaken on economically lesser known timber species *Pinus tecunumanii* that is not yet known by the development, processing and construction sectors, manufacturers and end users in the lumber market of Ethiopia.

Pinus tecunumanii (Synonym: *Pinus patula ssp tecunumanii*) was introduced to Ethiopia and planted in 1986 by Central Ethiopia Environment and Forest Research Center at Bonga (Keja) experimental site (Mebrate Miheretu et al., 2004). *P. tecunumanii* is a tree species with a single, straight bole and slender trunk; fast growing; high yielding and potential lumber species but still under-developed and under-utilized species in the country. Investigation was conducted on seasoning and density characteristics of *P. tecunumanii* lumber with general objective of generating appropriate seasoning technologies and potential uses.

Sample trees of *P. tecunumanii* were harvested at the age of 30 years. Representative sample trees of merchantable log size were selected and harvested having 40.8 m mean height, 42.8 cm mean breast height diameter (dbh) and total volume 13.4 m^3. 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 light density (300 - 450 kg/m^3) and very rapid air and kiln seasoning timber species.

The kiln seasoning technology delivers good quality of seasoned wood within a short period of time with high cost. In cities like Addis Ababa, where land values are very-high, kiln

seasoning is a better technology choice. Therefore, kiln seasoning technology of wood is generally preferable than the air seasoning for *P. tecunumanii*.

Suitability

- The air seasoning (under shed seasoning) technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.
- Comparatively the kiln seasoning (Chamber) technology is expensive that could be affordable and recommended to medium and large-scale forest products processing industries, construction sectors and marketing enterprises.
- Seasoned wood of *P. tecunumanii* is acceptable for sawn lumber, light and general structural uses and flooring. Other studies on this species has also recommended its suitability for vehicles, food containers, box and crate manufacture, shingles, furniture, cheap joinery, framing, pallets, broom sticks, poles, turnery, fuel wood and kindling for fires, veneer/plywood, particleboard, pulp and paper.

Requirements

- Sawmill
- Processing machines for sample preparation
- Sensitive balances
- Air drying shed/yard as stated in section Air seasoning method
- Dry kiln machine with all accessories as stated in section Air seasoning method
- Skilled kiln operator
- Electric power (for kiln seasoning)
- Drying/micro-oven machine and moisture meter
- Relative humidity and wood equilibrium moisture content charts
- Seasoning process control room
- Weights made as concrete slabs//stone for top loading of lumber stacks
- Stacking stickers with a uniform cross-section (2.5*2.5 cm, thickness and width)

Practice

i. Harvesting of trees

- Trees to be harvested should be matured with mean DBH of 30 cm.
- Felled trees should be bucked into log lengths (preferred 3-5 m) but it depends on the depth/capacity of the particular dry kilns in operation.

ii. Log sawing and moisture content sample preparation

- The logs should be kept green (> 30% MC) and avoid direct sunlight so as to prevent excessive end splits and checks.
- The logs are sawn through and through into a uniform length of 3 m and thickness of 3 cm mixed flat and radial boards
- 10-12 representative boards are selected and converted into samples with a dimension of 100 cm in length, 3 cm thickness and width equal to log diameter.

iii. Stacking sawn boards for air and kiln seasoning

- Boards are transported to the air seasoning yard/shed (Figure 3) and/or compartment kiln seasoning chamber (Figure 4) areas.
- Principles of lumber stacking are similar for both air and kiln seasoning technologies.
- Boards are stacked horizontally in vertical alignments at 3 cm spacing between successive boards and separated by well-seasoned, squared and true cross section (2.5x2.5 cm), uniform sized and standard stickers, having a dimension of 2.5x2.5x180 cm (width, thickness and length, respectively).
- Stickers are placed at an equal distance (75 cm) across each layer of lumber and are aligned one on top of the other. This stacking alignment helps to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process.
- Short strips (2.5x2.5x20 cm) are placed up on the long stickers to easily access the control sample boards of each stack (Figure 3 and 4).

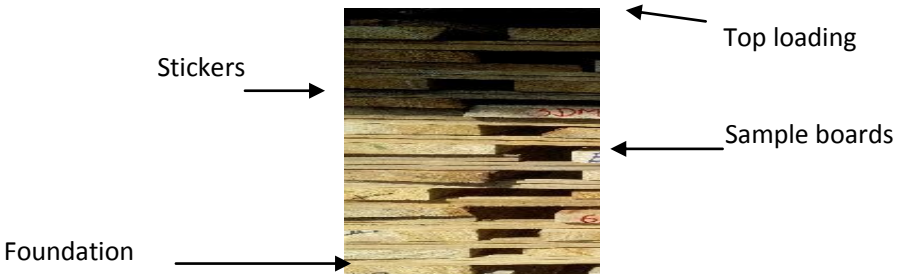

Figure 3 Air seasoning stack with stickers

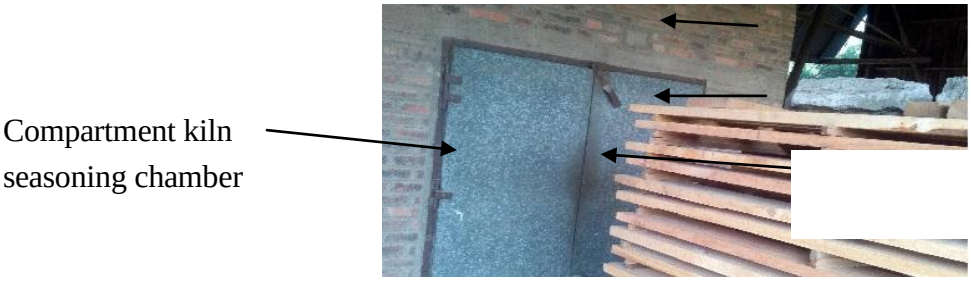

Figure 4 Kiln seasoning stack of *P. tecunumanii* lumber

- In each stack of the air and kiln seasoning, heartwood, sapwood and tangential boards segregated in the stack when clearly differentiated. The heartwood boards, which have less moisture content, are to be placed in the middle, while the sapwood and tangential boards are to be placed along the sides, top and bottom of the stacks.
- The control sample boards are properly distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack (Figure 3 and 4). The number of samples depends on the stack layers.
- The control sample boards will help to determine the progress of seasoning (moisture reduction rate) and the final moisture content.
- Top loading using concrete slabs/heavy stones weighing about 50 Kg/m^2 can be applied on top of the air and kiln seasoning stacks at a spacing of 75 cm as restraint and minimize warping for the seasoning stack as a whole. In case of air seasoning, clamps can also be used.

Air seasoning method

- Stacked boards for air seasoning are placed under shed without direct interference of moisture, rainfall or sunshine.
- The air seasoning shed has on average a temperature of 20-25°c and relative humidity of 60-70%, but highly depends on environmental conditions.
- Boards have to be stacked on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4 m, width, thickness and length, respectively.
- The boards are aligned in a north-south direction where the ends should not be exposed to the direction of the wind.
- The north-south direction alignment of boards is done to facilitate good air circulation and reduce the direct influence of fungi, temperature, wind and relative humidity.
- Initial moisture content of the stack is determined using the moisture samples: - initial weight of all control samples (while green) is determined using oven dry method and

12 sections cut with size having 1.2 cm length and 3 cm thickness from the moisture sample boards. The number of samples depends on purpose and precision of results required.

- Weighing of moisture samples is done at 4 hours interval by minimizing moisture absorption and desorption.
- The process continues until the difference between two successive weights of each specimen is between 0.1-0.2 g, constant and is considered as final oven- dry weight.
- Estimate of the final mean equilibrium moisture (EMC) content of the wood is about 12%, which is EMC for out-door purposes and standard for comparison within and between lumber species.

Kiln seasoning method

- Boards for kiln seasoning are stacked outside of the kiln seasoning chamber on transfer carriage (2.7x1.6x0.30 cm), placed in the kiln and seasoned.
- The conventional type of artificial kiln seasoning chamber can be used. The chamber has to be well insulated (brick wall) with 5-10 m^3 lumber loading capacity.
- It should have controlled air velocity, temperature and humidity that can be adjusted according to internal stresses or observed defects during kiln seasoning progress.
- The kiln should have psychrometers (dry bulb and wet bulb thermometers or temperature sensors) from both ends and has to be equipped with fans to force air circulation, through the chamber and also air outlet.
- The kiln seasoning schedules consists steps/norms involving serious of dry and wet-bulb temperature levels and relative humidity corresponding to various MC levels.
- Kiln schedules are selected based on lumber species type, its initial moisture content and density.
- Kiln seasoning schedule applied for *P. tecunumanii* lumber presented in Table 1 (Kiln seasoning schedule 3 of Ethiopia- hardwood type schedule).
- During the kiln seasoning, steam is injected into the chamber to avoid checking and splitting of the lumber when the moisture content of wood reduced below fiber saturation point.

Table 1. Kiln Schedule 3 of Ethiopia

Initial MC (%)	Temperature (°C)		Relative humidity (%)
	Dry-bulb	Wet-bulb	
>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

- Samples are 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 wood seasoned.
- The process continues until the required final moisture content level (about 12%) is reached.
- Kiln seasoning boards can undergo initial air seasoning (up to fiber saturation point, 30% MC) before stacking and commencing the regular kiln seasoning processes. This is to reduce kiln seasoning charges.

Moisture content determination

- Moisture content (MC) has to be determined for both air and kiln seasoning stacks of the lumber species (Table 2).
- The oven- dry weight method of MC determination (the standard way) has to be applied since it is an indication of the amount of solid substance present.

In both seasoning methods, the MC (%) has to be determined by formula.

$$MC\ (\%) = (IW-OD/OD)*100 = (IW/OD-1)*100 = (W/OD)*100$$

Where, IW= initial weight of wood with water (g), OD = oven dry weight of wood without water (g), W = weight of water alone (IW-OD) (g).

Rate of seasoning determination

- Air and kiln seasoning rates of the species have to be estimated from the MC samples of the species (Table 2).

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).
- The dimensions and weights of 12 green samples of the lumber with approximate dimension of 2x2x3 cm, width, thickness and length, respectively were measured, placed in seasoning oven and seasoned at a temperature of 105°c±3°c until they attained a constant weight (between 0-0.2 g).
- Shrinkage rates of each specimen at tangential, radial, longitudinal direction and volumetric are determined by imperial formulas from green (≥ 30%) to 12% MC and from green to 0 % MC, respectively.

Shrinkage characteristics (%) = [Decrease in dimension (mm)/green (Initial) dimension (mm)]*100.

The shrinkage values (Table 2) will help to determine the allowance limit in the final placement/utilization of lumber for dimensional movement (Shrinkage and swelling) due to environmental changes.

Density determination

The density and/or specific gravity values of the species were determined from the shrinkage samples, procedures and measurements as stated earlier using mathematical formulas. Density determined at different MC and sample volume conditions using formulas:

Basic density= (Sample oven dry weight/Sample green volume)

$$\text{Density at 12\% MC } (\rho 12) = Pw * [1-0.01*(1-KO)*(W-12)]$$

Where, Ko= coefficient of volumetric shrinkage for a range in 1% MC. For approximate calculations the value of Ko= 0.85*10-3*Pw when density is expressed in $Kg/m^3$and Ko= 0.85*Pw when density is expressed in g/cm^3.

P. tecunumanii is light density lumber species. The density values at green and at 12% MC presented in Table 2.

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

Seasoning defects determination

- Initial and after seasoning defects of lumber species including knots, cup, bow, twist, end split, end and surface checks are measured and determined using calliper, ruler and tape meter determined.

Handling of seasoned lumber

- Seasoned boards are properly piled and stored in the air seasoning yard under shed, board on board, without stickers between boards.
- Boards are stored without direct impact of sunshine with no contact to moistening conditions to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack.
- Follow-up of seasoned boards have to be done. This will help when, how and where to utilize the lumber species by controlling seasoning defects, infestation and biodegradation attack.

Management

- Stack lumber properly
- Seasoned boards are properly piled
- Steaming should be applied to increase relative humidity of the kiln as remedy during kiln seasoning for refractory lumber. This is done when the moisture content decreased below the fiber saturation point (< 30%) and serious seasoning defects occurred.

Comparative advantage/yield

- The existing improper and/or no lumber seasoning (unseasoned lumber) has led to excessive loss of quality, low recovery rate in sawing and further processing, loss of productivity, loss of usability and profitability to industries.

- Proper seasoning minimizing the major problems (> 90%) related with wood and its rational utilization and about 75% of the manufacturing problems in furniture industries.
- Kiln seasoning is faster than air due to higher temperature, ventilation and air circulation; inhibits/kills insects and their eggs; minimizes seasoning defects.
- Air seasoning time for sawn boards of *Pinus tecunumanii* 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.

Cost effectiveness

- No Cost effectiveness analysis done

Risk and uncertainty

- Risk is very minimal. When technologies applied by processing industries and kiln operators, risk of fire during kiln seasoning may occur. Thus, care should be taken.
- During and after air seasoning bio-deteriorating agents (borer/beetle, fungi and termite) may attack the lumber. Thus, seasoning time shall be shortened using grooved stickers.
- Follow up of seasoned lumber until selling, shipping and utilizing for the intended purpose is also needed against bio-deteriorating agents attack and seasoning defects.

End users

Beneficiaries include urban communities, Wood Industries, House Constructing Companies and other construction sectors, Investors, Civil Engineers, Vocational Training Colleges, Higher Learning Institutions and other stakeholders.

4. Lumber seasoning technologies and uses of *Trichilia dregeana* tree species grown at Abote Dedessa

Responsible researchers: Getachew Desalegn and Gemechu Kaba.

Brief description of the technology

Proper lumber seasoning (drying) technologies remove moisture and highly minimize/ avoid moisture associated problems from lumber. The moisture (often ≥ fiber saturation point, 30%) removal or seasoning is done through natural and artificial methods such as kiln, solar and other seasoning techniques.

Increasing efficiency of utilization of forest products through value addition and maximization of uses of wood and wood–based products will be possible by determining the different characteristics and quality of each species. Thus, research has been undertaken on economically lesser known timber species *Trichilia dregeana* that is not yet known by the development, processing and construction sectors, manufactures and end users in the lumber market of Ethiopia.

The study indigenous tree species was *Trichilia dregeana* Sond [Family: Meliaceae] that have fast growth, good performance (height, diameter and clear bole), versatile timber and non-timber forest products, socio- economical/ cultural and ecological benefits and services. T. dregeana attains a height of up to 35 m, the tall main stem assuming a relatively straight trunk dividing into large branches and sometimes buttressed habit up to 1.8 m in diameter (Azene et al., 1993; Thirakul, 1993). The sample trees were harvested from Arjo-Jimma/Abote Dedessa site and tests conducted during three consecutive years since 2014. The sample trees had mean height of 15 m and mean breast height diameter at 1.3 m above ground was 60 cm.

Investigation was conducted on seasoning and density characteristics of *T.dregeana* lumber with general objective of generating appropriate seasoning technologies, technical information, potential uses and utilization technologies.

Rate of seasoning: Air seasoning rate of *T. dregeana* lumber was 1.19 %/day. Kiln seasoning rate of *T. dregeana* lumber was 8.94 %/day. Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber. Kiln seasoning was > 7.5 times faster than air seasoning. Controlling of environmental conditions and seasoning defects was less likely during the air seasoning process.

Suitability

- The air seasoning (under shed seasoning) technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.
- Comparatively the kiln seasoning (Chamber) technology is expensive that could be affordable and recommended to medium and large-scale forest products processing industries, construction sectors and marketing enterprises.
- Comparable lumber species: In density values at 12% MC with accuracy of ± 5% were selected with those same method and laboratory. Lumber species *Albizia schimperiana, Eucalyptus delegatensis, Grevillea robusta* and *Podocarpus falcatus* are comparable with *T. dregeana.*
- The wood easily worked making it very suitable for carving. It is used for furniture and household implements, plywood and veneers, furniture, mortars, joinery, cabinetworks and interior decoration, construction and firewood.

Requirements*:*

- Sawmill
- Processing machines for sample preparation
- Sensitive balances
- Air drying shed/yard as stated in section Air seasoning method
- Dry kiln machine with all accessories as stated in section Air seasoning method
- Skilled kiln operator
- Electric power (for kiln seasoning)
- Drying/micro-oven machine and moisture meter
- Relative humidity and wood equilibrium moisture content charts
- Seasoning process control room
- Weights made as concrete slabs//stone for top loading of lumber stacks
- Stacking stickers with a uniform cross-section (2.5*2.5 cm, thickness and width)

Practice

i. Harvesting of trees

- Sample trees of *T. dregeana* were harvested from Abote Dedessa, river Dedessa area on the way Nekemt to Bedele.

- The sample trees of *T. dregeana* had mean height of 15 m and mean breast height diameter at 1.3 m above ground was 210 cm.
- Trees to be harvested should be matured with mean DBH of 30 cm.
- The trees should be harvest based on mean annual increment and management plan of the stand.
- Felled trees should be bucked into log lengths (preferred 3-5 m) but it depends on the depth/capacity of the particular dry kilns in operation.

Figure 5 *Trichilia dregeana* at Jimma-Arjo Dedessa river area February 2014

The logs should be kept green (> 30% MC) and avoid direct sunlight so as to prevent excessive end splits and checks.

- The logs are sawn through and through into a uniform length of 3 m and thickness of 3 cm mixed flat and radial boards but possible to use a thickness more than 3 cm based on the purpose
- 10-12 representative boards are selected and converted into samples with a dimension of 100 cm in length, 3 cm thickness and width equal to log diameter.

ii. Stacking sawn boards for air and kiln seasoning

- Boards are transported to the air seasoning yard/shed (Figure 6) and/or compartment kiln seasoning chamber (Figure 7) areas.
- Principles of lumber stacking are similar for both air and kiln seasoning technologies.
- Boards are stacked horizontally in vertical alignments at 3 cm spacing between successive boards and separated by well-seasoned, squared and true cross section (2.5x2.5 cm), uniform sized and standard stickers, having a dimension of 2.5x2.5x180 cm (width, thickness and length, respectively).
- Stickers are placed at an equal distance (75 cm) across each layer of lumber and are aligned one on top of the other. This stacking alignment helps to separate boards,

facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process.

- **Short strips** (2.5x2.5x20 cm) are placed up on the long stickers to easily access the control sample boards of each stack (Figure 6 and 7).

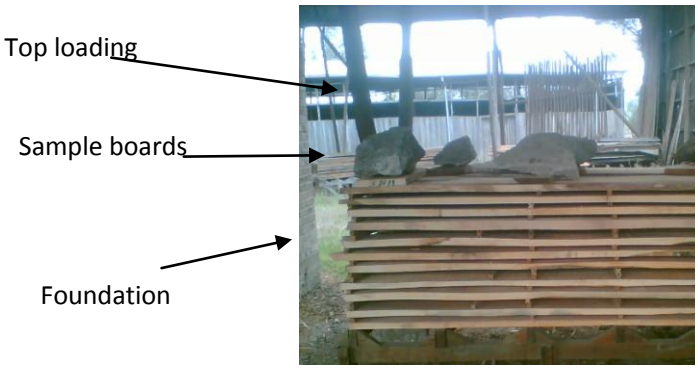

Figure 6 ***Trichilia dregeana*** **lumber air seasoning stack**

Figure 7 ***T. dregeana*** **lumber stack in Kiln seasoning chamber.**

In each stack of the air and kiln seasoning, heartwood, sapwood and tangential boards segregated in the stack when clearly differentiated. The heartwood boards, which have less moisture content, are to be placed in the middle, while the sapwood and tangential boards are to be placed along the sides, top and bottom of the stacks.

- The ends of boards are made equal in both directions. The control sample boards are properly distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack (Figure 6 and 7). The number of samples depends on the stack layers.
- The control sample boards will help to determine the progress of seasoning (moisture

reduction rate) and the final moisture content.

- Top loading using concrete slabs/heavy stones weighing about 50 kg/m^2 can be applied on top of the air and kiln seasoning stacks at a spacing of 75 cm as restraint and minimize warping for the seasoning stack as a whole. In case of air seasoning, clamps can also be used.

Air seasoning method

- Stacked boards for air seasoning are placed under shed without direct interference of moisture, rainfall or sunshine.
- The air seasoning shed has in average a temperature of 20-25°c and relative humidity of 60-70%, but highly depends on environmental conditions.
- Boards have to be stacked on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4m, width, thickness and length, respectively.
- The boards are aligned in a north-south direction where the ends should not be exposed to the direction of the wind.
- The north-south direction alignment of boards is done to facilitate good air circulation and reduce the direct influence of fungi, temperature, wind and relative humidity.
- Initial moisture content of the stack is determined using the moisture samples: - initial weight of all control samples (while green) is determined using oven dry method and 12 sections cut with size having 1.2 cm length and 3 cm thickness from the moisture sample boards. The number of samples depends on purpose and precision of results required.
- Weighing of moisture samples is done at 4 hours interval by minimizing moisture absorption and desorption.
- The process continues until the difference between two successive weights of each specimen is between 0.1-0.2 g, constant and is considered as final oven- dry weight.
- Estimate of the final mean equilibrium moisture (EMC) content of the wood is about 12%, which is EMC for out-door purposes and standard for comparison within and between lumber species.

Kiln seasoning method

- Boards for kiln seasoning are stacked outside of the kiln seasoning chamber on transfer carriage (2.7x1.6x0.30 cm), placed in the kiln and seasoned.
- The conventional type of artificial kiln seasoning chamber can be used. The chamber

has to be well insulated (brick wall) with 5-10 m^3 lumber loading capacity.

- It should have controlled air velocity, temperature and humidity that can be adjusted according to internal stresses or observed defects during kiln seasoning progress.
- The kiln should have psychrometers (dry bulb and wet bulb thermometers or temperature sensors) from both ends and has to be equipped with fans to force air circulation, through the chamber and also air outlet.
- The kiln seasoning schedules consists steps/norms involving serious of dry and wet-bulb temperature levels and relative humidity corresponding to various MC levels.
- Kiln schedules are selected based on lumber species type, its initial moisture content and density.
- Kiln seasoning schedule applied for *T. dregeana* lumber presented in Table 3 (Kiln seasoning schedule 8 of Ethiopia- hardwood type schedule).
- During the kiln seasoning, steam is injected into the chamber to avoid checking and splitting of the lumber when the moisture content of wood reduced below fiber saturation point.
- Samples are 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 wood seasoned.
- The process continues until the required final moisture content level (about 12%) is reached.
- Kiln seasoning boards can undergo initial air seasoning (up to fiber saturation point, 30% MC) before stacking and commencing the regular kiln seasoning processes. This is to reduce kiln seasoning charges.

Moisture content determination

- Moisture content (MC) has to be determined for both air and kiln seasoning stacks of the lumber species (Table 3).
- The oven- dry weight method of MC determination (the standard way) has to be applied since it is an indication of the amount of solid substance present.
- In both seasoning methods, the MC (%) has to be determined by formula.

$$MC\ (\%) = (IW-OD/OD)*100 = (IW/OD-1)*100 = (W/OD)*100$$

Where, IW= initial weight of wood with water (g), OD = oven dry weight of wood without water (g), W = weight of water alone (IW-OD) (g).

Rate of seasoning determination

- Air and kiln seasoning rates of the species have to be estimated from the MC samples of the species (Table 3).

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).
- The dimensions and weights of 12 green samples of the lumber with approximate dimension of 2x2x3 cm, width, thickness and length, respectively were measured, placed in seasoning oven and seasoned at a temperature of 105°c±3°c until they attained a constant weight (between 0-0.2 g)
- Shrinkage rates of each specimen at tangential, radial, longitudinal direction and volumetric are determined by imperial formulas from green (≥ 30%) to 12% MC and from green to 0 % MC, respectively.

Shrinkage characteristics (%) = [Decrease in dimension (mm)/green (Initial) dimension (mm)]*100.

The shrinkage values (Table 3) will help to determine the allowance limit in the final placement/utilization of lumber for dimensional movement (Shrinkage and swelling) due to environmental changes.

Density determination

The density and/or specific gravity values of the species were determined from the shrinkage samples, procedures and measurements as stated earlier using mathematical formulas. Density determined at different MC and sample volume conditions using formulas:

Basic density= (Sample oven dry weight/Sample green volume)

Density at 12% MC (ρ12) = Pw* [1-0.01*(1-KO)*(W-12)]

Where, Ko= coefficient of volumetric shrinkage for a range in 1% MC. For approximate calculations the value of Ko= 0.85*10-3*Pw when density is expressed in $Kg/m^3$and Ko= 0.85*Pw when density is expressed in g/cm^3.

Table 3 Seasoning and density characteristics of T. dregeana lumber species.

Air seasoning stacks MC (%) and rate of seasoning(%/day)			Kiln seasoning stacks MC (%) and rate of seasoning (%/day)			Density classification at 12% MC*			
Initial MC of air seasoning stacks	Final air Seasoning MC	No. of days in air and rate seasoning	Initial MC of kiln seasoning stacks	Final kiln seasoning MC	No. of days in kiln and rate seasoning	Green /Initial	Basic density	At 12% MC	Density value (Kg/m3)at 12% MC classification
65.8	11.21	46 (1.19 %/day)	65.61	12	6 (8.94 %/day)	940	500	530	*Light*

Seasoning defects determination

- Initial and after seasoning defects of lumber species including knots, cup, bow, twist, end split, end and surface checks are measured and determined using calliper, ruler and tape meter determined.

Handling of seasoned lumber

- Seasoned boards are properly piled and stored in the air seasoning yard under shed, board on board, without stickers between boards.
- Boards are stored without direct impact of sunshine with no contact to moistening conditions to avoid/minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack.
- Follow-up of seasoned boards have to be done. This will help when, how and where to utilize the lumber species by controlling seasoning defects, infestation and biodegradation attack.

Management

- Stack lumber properly using standard size and be seasoned and top loading.
- Seasoned boards are properly piled

Comparative advantage/yield

- The existing improper and/or no lumber seasoning (unseasoned lumber) has led to excessive loss of quality, low recovery rate in sawing and further processing, loss of productivity and profitability to industries.

- Proper seasoning minimizing the major problems (> 90%) related with wood and its rational utilization and about 75% of the manufacturing problems in furniture industries.
- Kiln seasoning is faster than air due to higher temperature, ventilation and air circulation; inhibits/ kills insects and their eggs; minimizes seasoning defects
- Air seasoning rate o*f T. dregeana* lumber was 1.19 %/day.
- Kiln seasoning rate of *T. dregeana* lumber was 8.94 %/day.
- Kiln seasoning technology was better than natural air seasoning in terms of seasoning rate and quality (low shrinkage and seasoning defects) of seasoned lumber.
- Kiln seasoning was > 7.5 times faster than air seasoning. Controlling of environmental conditions and seasoning defects was less likely during the air seasoning process.

Cost effectiveness

- No cost effectiveness analysis done.

Risk and uncertainty

- Risk is very minimal. When technologies applied by processing industries and kiln operators, risk of fire during kiln seasoning may occur. Thus, care should be taken.
- During and after air seasoning bio-deteriorating agents (borer/beetle, fungi and termite) may attack the lumber. Thus, seasoning time shall be shortened using grooved stickers.
- Follow up of seasoned lumber until selling, shipping and utilizing for the intended purpose is also needed against bio-deteriorating agents attack and seasoning defects.

End users

Urban communities, Wood Industries, House Constructing Companies and other construction sectors, Investors, Civil Engineers, Vocational Training Colleges, Higher Learning Institutions and other stakeholders.

5. Seasoning technologies and uses of *Gmelina arborea* lumber tree species

Responsible researchers: Getachew Desalegn, Anteneh Tesfaye, Gemechu Kaba and Saifu Amanuel

Brief description of the technology

Proper lumber seasoning (drying) technologies remove moisture and highly minimize/ avoid moisture associated problems from lumber. The moisture (often ≥ fiber saturation point, 30%) removal or seasoning is done through natural and artificial methods such as kiln, solar and other seasoning techniques.

Increasing efficiency of utilization of forest products through value addition and maximization of uses of wood and wood–based products will be possible by determining the different characteristics and quality of each species. Thus, research has been undertaken on economically lesser known timber species Gmelina arborea that is not yet known by the development, processing and construction sectors, manufactures and end users in the lumber market of Ethiopia.

Gmelina arborea Roxb. [Family: Verbenaceae] was introduced to Ethiopia and planted in 1983 by Central Ethiopia Environment and Forest Research Center at Bonga (Keja) experimental site *G. arborea* is deciduous medium-sized tree up to (30–40) m tall; bole cylindrical, frequently bent, up to (80–140) cm in diameter. The species is still under developed and underutilized species in the country. For seasoning study mean height of trees harvested was 21 m, while mean breast height diameter (dbh) at 1.3 m was 36 cm. It showed good adaptability and good height and diameter growth performance at these sites. Investigation was conducted on seasoning and density characteristics of *Gmelina arbora* with general objective of generating technical information on appropriate utilization technologies and assesses potential uses.

The result showed that air seasoning of *G. arborea* sawn boards took long drying time (210 days), while kiln seasoning took short time (13.5 days) to reach to about 12% MC. Air seasoning rate of *G. arborea* was 7.37%/day, whereas kiln seasoning rate was 0.61%/day. Thus, kiln technology has better advantage than air seasoning in terms of shortening the seasoning time.

The air seasoning technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises. However, kiln

seasoning delivers good quality of seasoned wood within a short period of time with high cost. In cities like Addis Ababa, where land values are sky-high, kiln seasoning is a better technology choice. Therefore, kiln seasoning technology of wood is generally preferable than the air seasoning for *G. arborea*. The technologies are suitable to forest products/wood processing industries, construction sectors and marketing enterprises.

Suitability

- The air seasoning (under shed seasoning) technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.
- Comparatively the kiln seasoning (Chamber) technology is expensive that could be affordable and recommended to medium and large-scale forest products processing industries, construction sectors and marketing enterprises.
- 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. Additionally, the wood has been used in light flooring, musical instruments, matches, particle board, as a mine timber, in vehicle bodies and ships. It is suitable for telephone posts when treated with preservatives.

Requirements

- Sawmill
- Processing machines for sample preparation
- Sensitive balances
- Air drying shed/yard as stated in section Air seasoning method
- Dry kiln machine with all accessories as stated in section Air seasoning method
- Skilled kiln operator
- Electric power (for kiln seasoning)
- Drying/micro-oven machine and moisture meter
- Relative humidity and wood equilibrium moisture content charts
- Seasoning process control room
- Weights made as concrete slabs//stone for top loading of lumber stacks
- Stacking stickers with a uniform cross-section (2.5*2.5 cm, thickness and width)

Practice

i. Harvesting of trees

- Trees to be harvested should be matured with DBH of about 30 cm.
- Felled trees should be bucked into log lengths corresponding to the depth/capacity of the particular dry kilns in operation.

ii. Log sawing and moisture content sample preparation

- The logs should be kept green (> 30% MC) and avoid direct sunlight so as to prevent excessive end splits and checks.
- The logs are sawn through and through into a uniform length of 3 m and thickness of 3 cm mixed flat and radial boards
- 10-12 representative boards are selected and converted into samples with a dimension of 100 cm in length, 3 cm thickness and width equal to log diameter.

iii. Stacking sawn boards for air and kiln seasoning

- Boards are transported to the seasoning yard/shed (Figure 8) and/or compartment kiln seasoning chamber areas.
- Boards are stacked horizontally in vertical alignments at 3 cm spacing between successive boards and separated by well-seasoned, square and true cross section (2.5x2.5 cm), uniform sized and standard stickers, having a dimension of 2.5x2.5x180 cm (width, thickness and length, respectively).
- Stickers are placed at an equal distance across each layer of lumber and are aligned one on top of the other. This stacking alignment helps to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process
- Short strips (2.5x2.5x20 cm) are placed up on the long stickers to easily access the control sample boards of each stack (Figure 8).

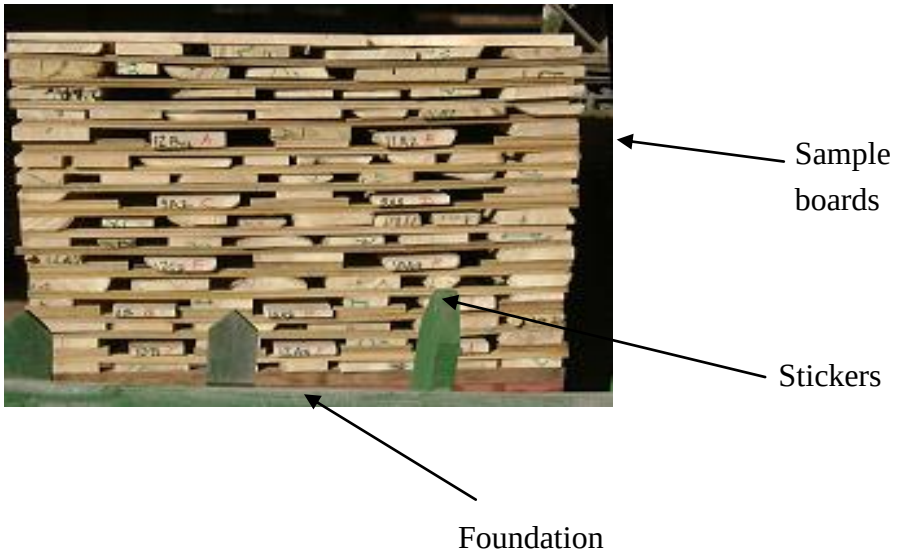

Figure 8 Seasoning stack of *G. arborea* lumber.

- Top loading using concrete slabs/heavy stones weighing about 50 kg/m^2 can be applied on top of the air and kiln seasoning stacks at a spacing of 75 cm as restraint and minimize warping for the seasoning stack as a whole. In case of air seasoning, clamps can also be used.
- In each stack of the air and kiln seasoning, heartwood, sapwood and tangential boards segregated in the stack when clearly differentiated. The heartwood boards, which have less moisture content, are to be placed in the middle, while the sapwood and tangential boards are to be placed along the sides, top and bottom of the stacks.
- The ends of boards are made equal in both directions. The control sample boards are properly distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack (Figure 8). The number of samples depends on the stack layers.
- The control sample boards will help to determine the progress of seasoning (moisture reduction rate) and the final moisture content.

Air seasoning method

- Stacked boards for air seasoning are placed under shed without direct interference of moisture, rainfall or sunshine.
- The air seasoning shed has in average a temperature of 20-25°c and relative humidity of 60-70%, but highly depends on environmental conditions.
- Boards have to be stacked on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4 m.
- The boards are aligned in a north-south direction where the ends should not be

exposed to the direction of the wind.

- The north-south direction alignment of boards is done to facilitate good air circulation and reduce the direct influence of fungi, temperature, wind and relative humidity.
- Initial moisture content of the stack is determined using the moisture samples: - initial weight of all control samples (while green) is determined using oven dry method and 24 sections cut with size having 1.2 cm length and 3 cm thickness from the moisture sample boards. The number of samples depends on purpose (determine quality of wood) and precision of results required.
- Weighing of moisture samples is done at 4 hours interval by minimizing moisture absorption and desorption.
- The process continues until the difference between two successive weights of each specimen is between 0.1-0.2 g, constant and is considered as the final oven- dry weight.
- Estimate of the final equilibrium moisture (EMC) content of the wood is about 12%, which is EMC for out-door purposes and standard for comparison within and between lumber species.

Kiln seasoning method

- Boards for kiln seasoning are stacked outside of the kiln on transfer carriage (2.7x1.6x0.30 cm), placed in the kiln-seasoning chamber and seasoned.
- The conventional type of artificial kiln seasoning chamber can be used. The chamber has to be well insulated (brick wall) with 5-10 m^3 lumber loading capacity.
- It should have controlled air velocity, temperature and humidity that can be adjusted according to internal stresses or observed defects.
- The kiln should have psychrometers (dry bulb and wet bulb thermometers or temperature sensors) from both ends and has to be equipped with fans to force air circulation, through the chamber and also air outlet.
- The kiln seasoning schedules consists steps/norms involving serious of dry and wet-bulb temperature levels and relative humidity corresponding to various MC levels.
- Kiln schedules are selected based on lumber species type, its initial moisture content and density.
- In this case, seasoning schedules presented in Table 4 is applied (Kiln seasoning schedule 3 of Ethiopia- hardwood type schedule).
- During the kiln seasoning, steam is injected into the chamber to avoid checking and

splitting of the lumber when the moisture content of wood reduced below fiber saturation point.

- Samples are 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 wood seasoned.
- The process continues until the required final moisture content level (about 12%) is reached.

Table 4. Kiln Schedule 3 of Ethiopia

Initial MC (%)	Temperature (°C)		Relative humidity (%)
	Dry-bulb	Wet-bulb	
>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

- Kiln seasoning boards can undergo initial air seasoning (up to fiber saturation point, 30% MC) before stacking and commencing the regular kiln seasoning processes. This is to reduce kiln seasoning charges.

Moisture content determination

- Moisture content (MC) has to be determined for both air and kiln seasoning stacks of the lumber species.
- The oven- dry weight method of MC determination (the standard way) has to be applied since it is an indication of the amount of solid substance present.
- In both seasoning methods, the MC (%) has to be determined by formula.

MC (%) = (IW-OD/OD)*100 = (IW/OD-1)*100 = (W/OD)*100

Where, IW= initial weight of wood with water (g), OD = oven dry weight of wood without water (g), W = weight of water alone (IW-OD) (g).

Rate of seasoning determination

Air and kiln seasoning rates of the species have to be estimated from the MC samples of the species.

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).
- The dimensions and weights of 12 samples of the lumber with green approximate dimension of 2x2x3 cm were measured, place in seasoning oven and seasoned at a temperature of 105°c±30C until they attained a constant weight (between 0-0.2 g) .
- Shrinkage rates of each specimen at tangential, radial, longitudinal direction and volumetric are determined by imperial formulas from green (≥ 30%) to 12% MC and from green to 0 % MC, respectively.

Shrinkage characteristics (%) = (Decrease in dimension (mm)/green (Initial) dimension (mm))*100

G. arborea is light density lumber species. The density values at green and at 12% MC presented in Table 5.

Table 5. Lumber seasoning and density characteristics (kg/m^3) of *G. arborea* 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
132	12.99	3.63	1.58	Nil	5.11	940	420

Density determination

The density and/or specific gravity values of the species were determined from the shrinkage samples, procedures and measurements as stated earlier using mathematical formulas. Density determined at different MC and sample volume conditions using formulas: Basic density= (Sample oven dry weight/Sample green volume)

Density at 12% MC (ρ12) = Pw* (1-0.01*(1-KO)*(W-12))

Where, Ko= coefficient of volumetric shrinkage for a range in 1% MC. For approximate calculations the value of Ko= 0.85*10-3*Pw when density is expressed in kg/m^3 and Ko = 0.85*Pw when density is expressed in g/cm^3.

Seasoning defects determination

- Initial and after seasoning defects of lumber species including knots, cup, bow, twist, end split, end and surface checks are measured and determined using calliper, ruler and tape meter determined.

Handling of seasoned lumber

- Seasoned boards are properly piled and stored in the air seasoning yard under shed, board on board, without stickers between boards.
- Boards are stored without direct impact of sunshine with no contact to moistening conditions to minimize dimensional movement (shrinkage and swelling), seasoning defects, infestation and biodegradation attack.
- Follow-up of seasoned boards have to be done. This will help when, how and where to utilize the lumber species by controlling seasoning defects, infestation and biodegradation attack.

Management

- Stack lumber properly
- Seasoned boards are properly piled

Comparative advantage/yield

- The existing improper and/or no lumber seasoning (unseasoned lumber) has led to excessive loss of quality, low recovery rate in sawing and further processing, loss of productivity, loss of usability and profitability to industries.
- Proper seasoning minimizing the major problems (> 90%) related with wood and its rational utilization and about 75% of the manufacturing problems in furniture industries
- Kiln seasoning is faster than air due to higher temperature, ventilation and air circulation; inhibits/kills insects and their eggs; minimizes seasoning defects.
- Air seasoning of *G. arborea* sawn boards took long drying time (210 days), while kiln seasoning took short time (13.5 days) to reach to about 12% MC.

- Air seasoning rate of *G. arborea* was 7.37%/day, whereas kiln seasoning rate was 0.61%/day. Thus, kiln technology has better advantage than air seasoning in terms of shortening seasoning time.

Cost effectiveness

- No cost effectiveness analysis done**.**

Risk and uncertainty

- Risk is very minimal. When technologies applied by processing industries and kiln operators, risk of fire during kiln seasoning may occur. Thus, care should be taken.
- During and after air seasoning bio-deteriorating agents (borer/beetle, fungi and termite) may attack the lumber. Thus, seasoning time shall be shortened using grooved stickers.
- Follow up of seasoned lumber until selling, shipping and utilizing for the intended purpose is also needed against bio-deteriorating agents attack and seasoning defects.

End users

Beneficiaries include urban communities, Wood Industries, House Constructing Companies and other construction sectors, Investors, Civil Engineers, Vocational Training Colleges, Higher Learning Institutions and other stakeholders.

6. Appropriate pot size and soil mix for effective seedling production and field establishment in arid and semi-arid areas

Responsible researchers: Binyam Abera, Abayneh Derero, Samson Waktole, and Getaw Yilma

Brief description of the technology

Arid and semi-arid areas are moisture deficient which require appropriate technology for seedling production and field establishment. Using bare root seedlings and small pot sizes with limited resources and space for growth have not yielded good results as far as seedling production and field establishment is concerned. Faster and better growth of seedlings can be attained with bigger pot sizes and proper soil mixes as compared to the smaller pots with improper soil mixes that are common in several tree nurseries.

The appropriate pot size and soil mix for growing tree seedlings in arid and semi-arid area was determined by an experiment conducted in a tree nursery. The experiment was conducted in three different levels of pot sizes (8 cm, 10 cm and 15 cm diameter) and proper soil mixes which were employed using substrates from local soil, manure and sand; in ratios of 3:2:1 for mix-1, 3:2:0 for mix-2 and 2:1:1 for mix-3 (the local nursery practice).

The results showed that seedlings raised in large pots had significantly greater height and root collar diameter than those raised in the other two container types, and substrate differences did not reveal significant differences. *Ziziphus spina-christi* and *Acacia nilotica* seedlings raised in large pots with either soil mixtures had significantly greater growth than *Dobera glabra* and *Acacia tortilis* grown in large pots with either of soil mixtures. According to the results of the experiment, the tree species *Acacia nilotica*, *Acacia tortilis* and *Ziziphus spina-christi* can attain a mean height of 45 to 60 cm in four months. Moreover, they attain thicker stems, which is a very important attribute of seedlings to be planted in semi-arid areas. The high-quality seedlings could establish very well and grow in the field much better. Especially, seedlings to be planted in dry areas need to overcome moisture related stresses, and hence thicker seedlings are preferred. Such seedling quality is in big contrast to the small pots grown seedlings, which were shorter and thinner. Small potted seedlings grown in the nursery may be kept to attain good height for planting, but they may not get as thick as those grown in bigger pots and have a well-developed root mass. Therefore, bigger pot sizes that are between 14 to 16 cm diameters and about 15 cm height should be used to get better

quality seedlings. Use of bigger pot sizes could have a wider implication in the success of afforestation and reforestation programs at the national level.

Figure 9. Partial view of the layout of the experiment showing different pot size and soil mix treatments

Suitability

This technology is suitable for growing tree seedlings in arid and semi-arid areas which critically lack sufficient moisture for early field establishment and growth of seedlings. The Rift Valley region and other lowland areas that receive a mean annual rainfall of 400 to 700 mm can benefit from this technology.

Requirements

For this technology to be successful, the use of appropriate nursery practices and good field planting and post planting management are essential (see the practice section below).

Practice

- Prepare good soil mix with local soil and other materials such as sand, forest soil, manure and compost to improve soil structure and soil fertility. The ratio of the soil mixture will vary with the soil type (sandy, clay, loam) and its fertility status. Either of the soil mix ratios used in this experiment can be applied.
- Moisten and then press the mixture into the pots to a depth of about 10 cm height. Fill the top part more loosely with the mixture and press down lightly to avoid compaction and to facilitate easy root penetration.
- Arrange and align the filled pots in the nursery beds prepared for placing pots.
- Sow seed directly into the pots. To get good and fast germination, apply appropriate seed pre-sowing treatment. In addition, the soil should always be kept moist for good germination.

- Transplant the seedlings (if seeds were sown on a seed bed) to the pots when they have about two to three normal leaves or when they are about 2 cm tall.
- Cover the pots (or the seed bed) with grass or other material to protect them from direct sunlight and drying.
- Water the seedlings in the morning and in the evening. The soil should not be too dry or too wet, and the soil moisture must be monitored regularly.
- Construct shade from locally available material such as wood and grass to protect seedlings from direct sunlight for weeks.
- Remove weeds regularly as weeds could compete the seedlings for nutrients, water, and light.
- Prune roots with a sharp pruning scissors, a sharp knife or wire when the roots protrude outside of the pot and penetrate the surface of the nursery bed. Water the seedlings properly before pruning the roots.
- When the seedling reaches planting size (about 50 cm), expose them to harsh conditions (direct sunlight, less frequent watering) so that they can withstand the harsher condition in planting sites.

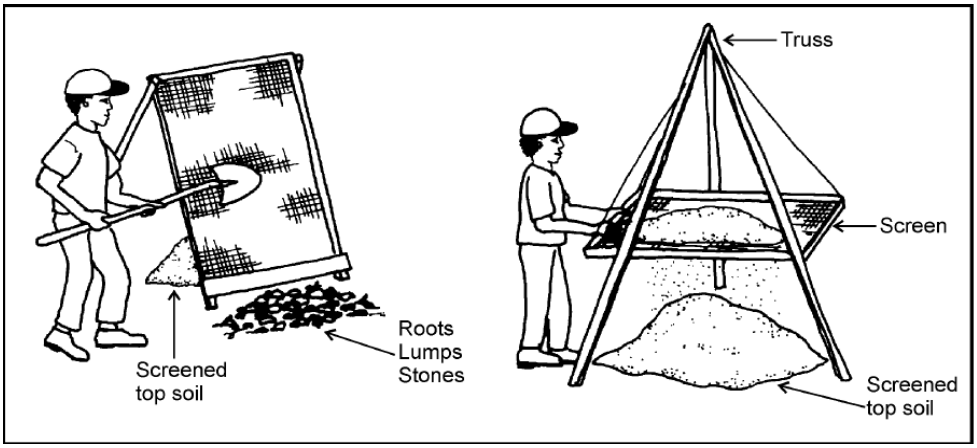

Figure 10 Soil mix preparation

Management

Appropriate nursery management, field planting and post planting management specifically designed for moisture stressed areas need to be implemented for the success of the technology.

Figure 11 Nursery activities

Comparative advantage/Yield

Better quality seedlings (taller and thicker seedlings with good root mass) can be produced in shorter period and growing high quality seedlings can improve success in tree establishment and growth. The cost of seedling production in bigger pots can be off-set by the return obtained from successful establishment of plantations.

Cost effectiveness

- The use of the technology may mean higher initial investment per a seedling compared to growing seedlings in smaller pots.
- The wide application of the technology may result in grand shift from massive planting with high risk of failure in plantation to planting of fewer seedlings with high potential for success in plantations.

Risk and uncertainty

This technology can guarantee high seedling quality, growth and good economic return; however, risks of failure from diseases, mismanagement as well as inappropriate nursery practices can entail greater loss in terms of seedling production and economic return.

Purpose

The purpose of the technology is to improve the tree seedling production in quality and quantity that translates to success in afforestation and reforestation.

End users

Farmers, pastoralists, investors, extension, forest enterprises, schools, universities

Reliability of the technology

This technology package is based on original research work conducted at EEFRI. It was initially published by Binyam Abera, Abayneh Derero, Samson Waktole and Getaw Yilma (2018): Effect of pot size and growing media on seedling vigour of four indigenous tree species under semi-arid climatic conditions. *Forests, Trees and Livelihoods* 27(1): 61-67.

7. Vegetative propagation and nursery life span of *Populus tremuloides* in Ethiopia

Responsible researchers: Diriba Nigussie and Tesfaye Humnessa

Brief description of the Technology

The effort to adapt the current changing climate and meet escalating demand for fuel and construction wood could be achieved with an introduction, evaluation and management of economical and fast-growing tree species in Ethiopia. Production of planting material to establish fast growing tree species such as *Populus* is one of the means of fulfilling the demand for construction and industrial wood products.

Populus tremuloides is a deciduous tree native to cooler areas of North America, one of several species referred to by the common name aspen. It is commonly called as white poplar. The trees have tall trunks, up to 25 meters tall, with smooth pale bark, scarred with black marks. The species often propagates through its roots to form large clonal groves originating from a shared root system. *Populus tremuloides* wood is used mostly as raw material for pulp, paper and match industries and also it is used for construction material and fuel wood. *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). Production of planting material and testing methods of establishment of *populus tremuloides*is a means of laying out baseline information for its large-scale promotion to achieve the demand for construction and industrial wood products.

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 (CEE-FRC). 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 *Populus 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 (see figure 13). 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 *Populus 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.

Figure 12 Vegetative Propagation of Populus

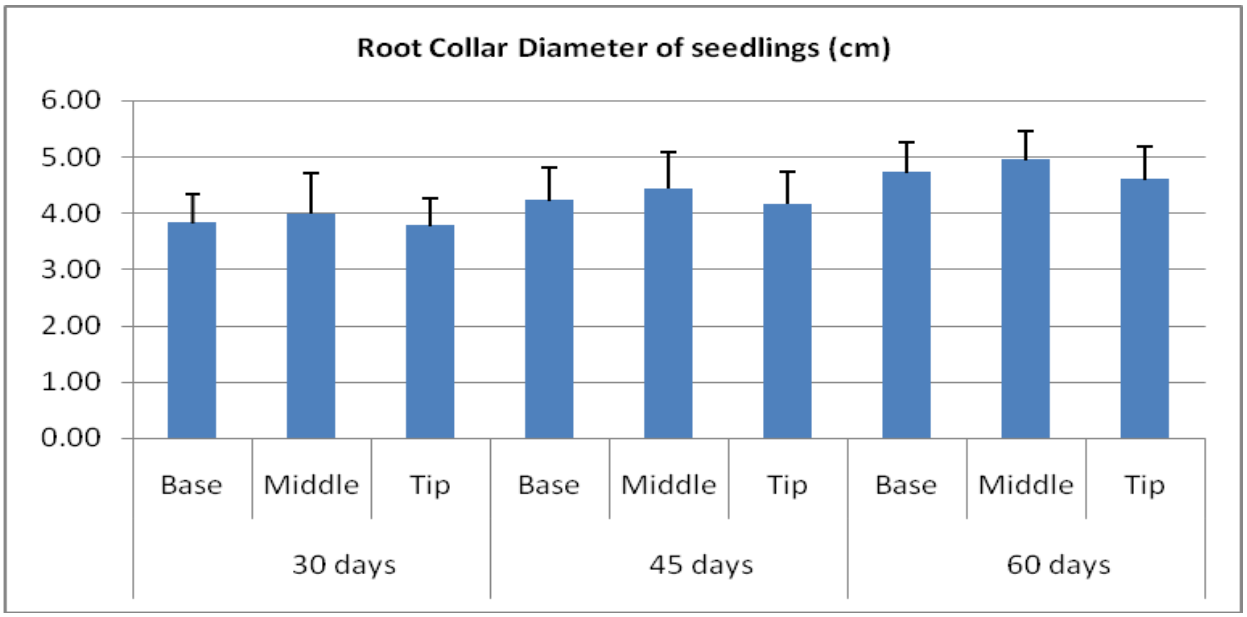

Figure 13 Root collar diameter (cm) of populus shoots per cutting

Suitability

This technology is suitable for producing vegetative propagated seedlings and is well fitted to frost-free areas with adequate rainfall or irrigation. The seedlings require deep sandy loam to clay loams with high moisture holding capacity and well drained fertile soil with adequate soil moisture for growth.

Requirement

For this technology to be successful, the use of appropriate nursery practices and good field planting and post planting management are essential (see the practice section).

Practice

- Identify healthy mother trees of *Populus tremuloides*and mark to collect branches.
- Collect a one year healthy and vigorous branches from selected mother trees with active lateral buds (Figure 14b)
- If the site of branch collection is far away from the nursery site:
- Pack the collected branches using ice berg or local material (sack filled with moisten sand) and seal it to transport to the targeted nursery site (Figure 14d)
- Continuously water the sealed sack to supply more or less fresh branches
- Remove immature and damaged part of collected branches and cut at every 12-18 cm lengths with at least 2-3 buds per cuttings, (make a sloping cut at the upper part to exposure to rain fall and sunlight) Figure 14c.
- Leave a 1cm free stem above the last bud at upper part of the cutting (Figure 14e**)**
- Once the cuttings are prepared, soak them in tap water for 1-2 days to increase the moisture content of the cuttings and to reduce propagator inhibiting substances (Figure 14f).
- Then, plant the moistened cutting in the polythene bags filled with appropriate soil composite for propagation (70% local soil, 15% sand and 15% organic fertilizer).
- Set the pots under the shade (green house) and water regularly for a month, after one month the seedlings should be shifted to an open place in nursery, (Figure 14 h &i)

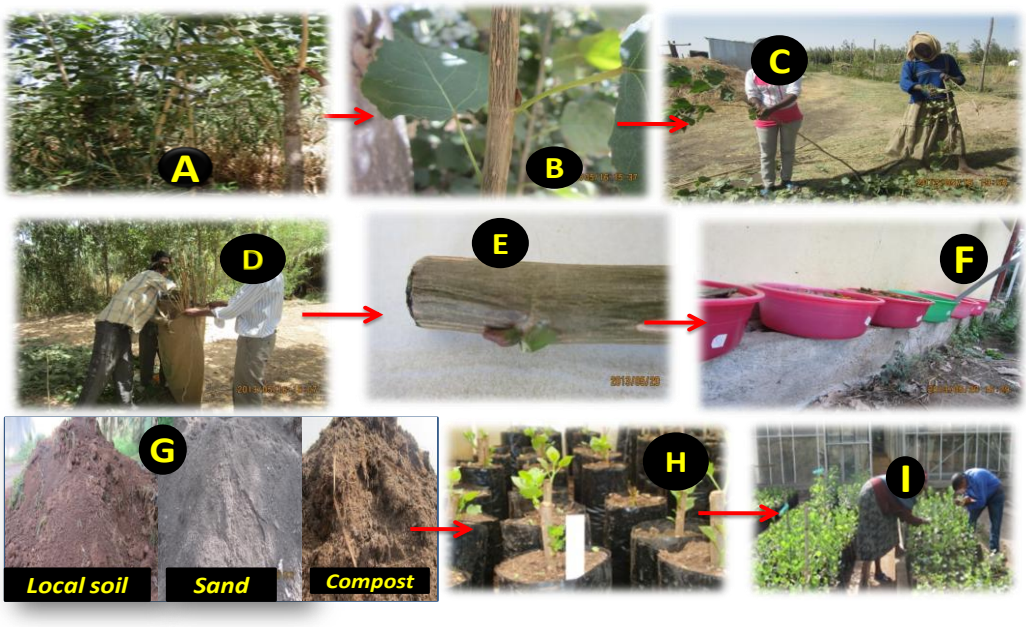

Figure 14 Procedures in the preparation of Populustremuloides planting material

Management

Appropriate nursery management, field planting and post planting management operations need to be implemented for the success of the technology.

Comparative advantage/yield

It is possible to produce plantable size of *Populus tremuloides* seedling from cutting from one to two months requiring little resource (without sophisticated equipment or chemicals). This may encourage an investor or stakeholder including small scale farmers to engage in production of seedling either for sale or to establish *populus* plantation that could be a raw material for pulp, paper and match industries.

Figure 15 Populus intercropped with cereals and its wood products (India)

Cost effectiveness

It is possible to produce plantable size of *Populustremuloides* seedling from cutting from one to two months requiring little resource (without sophisticated equipment or chemicals).

Risk and uncertainty

This technology can guarantee high seedling quality, growth and good economic return; however, risks of failure from diseases, mismanagement as well as inappropriate nursery practices can entail greater loss in terms of seedling production and economic return.

Purpose

The purpose of the technology is to improve the tree seedling production in quality and quantity that translates to success in afforestation and reforestation.

End user

This technology can be used by government and non-governmental organization, investor or stakeholders including small scale farmers engaged in seedling production either for sale or to establish *Populus tremuloides* plantation that could be a raw material for pulp, paper and match industries.

8. *Lantana camara* and *Senna siamea* green manures for enhanced soil fertility and maize yield

Responsible researchers: Wondwosen Gebretsadik and Lisanework Nigatu

Brief description of the technology

In Ethiopia, the use of commercial mineral fertilizers for crop production has been restricted to few farmers who can afford to purchase mineral fertilizers. The majority of the small holder farmers, on the other hand, are lacking the financial resources to purchase sufficient inorganic fertilizers. In order to improve soil fertility and increase crop yield per unit of farm land, organic resources, particularly use of green manure, are often proposed as alternatives to commercial mineral fertilizers. In this regard, the species *Lantana camara* and *Senna siamea* have been known to improve soil fertility and organic content of the farm lands when applied as green manure.

To this end, an experiment was initiated to investigate the effect of *Lantana camara* and *Senna siamea* green manure and inorganic fertilizer on maize crop yield and soil fertility of the farmland at Tullo district, West Hararge. The purpose of the experiment was to compare maize yields and soil nutrients availability resulting from applications of green manures of *Lantana camara* (Lantana), *Senna siamea* (Senna) and the recommended fertilizer.

The average maize yield of traditional practice is 3000-3700kg/ha and with recommended fertilizer 3800-4000kg/ha. According to the result of the experiment, using green manure of Senna and Lantana at 5 tons/ha rate can give a yield of 5000 - 5100kg/ha and 4200 - 4250kg/ha respectively. Compared to the traditional practice and the recommended fertilizer rate, the relative advantage of obtaining better yield is apparent. Use of green manure in farming plots has the potential to replace inorganic fertilizers for better maize crop productivity. Therefore, as there is an immense and abundant biomass resource of these species, it will be important to use these resources as green leafy manures in plots of small holder farmers who may not economically afford to use solely commercial fertilizer.

Suitability

This technology is applicable in similar agro ecological conditions where *Lantana camara* and *Senna siamea* are abundantly available and maize is grown. It is suitable to small holder farmers who may not economically afford to use solely commercial fertilizer.

Requirement

For this technology to be successful, a good supply of Lantana and Senna biomass for green manure is required.

Practice

- Collect green biomass /manures consisting of leaves and tender shoots from nearby areas where Lantana and Senna are available.
- Chop the leaves and tender shoots making them ready to apply as a green manure.
- Apply green manures from Senna and Lantana to cropping area at rates of 5 tons per hectare respectively before planting and incorporate into the soil.
- Maize (hybrid: Pioneer) should be sown at the spacing of 0.30m by 0.75m.
- Weeding and other standard agronomic practices need to be applied.

Management

Appropriate agronomic practices specifically designed for maize production need to be applied and proper application of green manures at recommended rate: 5 tons/ha rate for both Senna and Lantana is needed.

Comparative advantage/yield

Crop lands treated with Senna and lantana green manure had higher organic matter, total nitrogen and available phosphorus concentration compared to untreated farm lands. The average maize yield of traditional practice is 3000-3700kg/ha. The use of green manure from *Senna* and *Lantana* will give a yield of 5000-5100 kg/ha and 4200-4250 kg/ha respectively. Use of green manure in farming plots can replace use of inorganic fertilizers to improve maize crop productivity.

Cost effectiveness

As compared to the yield from traditional practice (3000-3700kg/ha) and fertilizer application (3800-4000kg/ha) the use of green manures has a better yield increment with minimum cost for green manure.

Risk and uncertainty

This technology assures high productivity of maize production if it is applied as per the recommended green manure application rates and if there is adequate moisture and abundant biomass resources of Lantana and Senna. Lantana and Senna should not be newly planted and expanded as they are invasive species and the practice should be restricted to using the already existing resources.

Purpose

The purpose of this technology is to introduce a productive use of invasive tree species and to provide small holder farmers who are lacking the financial resources to purchase sufficient inorganic fertilizers with an alternative organic fertilizer for maize production.

End user

Small holder farmers who may not economically afford to use solely commercial fertilizer, agricultural extension workers.

9. Production of Briquette from Water Hyacinth

Responsible researchers: Getu Derbew, Addisu Kebede and Mohamed Berhanu

Brief description of the technology

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. This alien species has been observed in Ethiopia for the past three decades on different water bodies. However, the magnitude of the invasion was not reported as risky until it is impacting Lake Tana. To manage the problem, the regional authority has been mobilizing the public and removed to clean huge amount of water hyacinth from the water body. However, the collected biomass is piled near the lake which render the re-entry of the seed into the lake. Consequently, this research undertaking was designed by realizing this problem. Therefore, the aim of this study was to evaluate the energy potential of the water hyacinth biomass and convert into briquette. 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. 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 experimented that water hyacinth biomass can be converted into briquettes. From dry 15 kg water hyacinth biomass, nearly 4.8 kg of char was obtained. Upon mixing the biomass with agricultural residues, the amount of char obtained increase to 5.4 kg. The combustion and physical characteristics of water hyacinth briquettes demonstrated that it can be used as an alternative energy source. Eventually, the finding of this research underlines that in applying integrated management for water hyacinth, considering briquette production from this biomass is economically important and environmentally sound.

Suitability

Dealing on how to manage the biomass collected and piled is a critical question where this technology tries to give one alternative solution. Specially, the local community harvesting the water hyacinth has been suffering with energy shortage and the area is also highly deforested one and in wood scarcity. Though this aquatic weed can be converted into different useful substances, focusing on energy aspect is area and condition specific. In

general, converting the water hyacinth biomass into briquette charcoal is the best alternative to make the effort exerted by the community comprehensive.

Pre-requirement

This technology is a very simple and can be practiced by any segment of the community regardless of the education level. The required preconditions and materials are the following:

- Water hyacinth biomass/additional agricultural waste if there is/
- Clay soil for binding
- Carbonizer/ temporarily this can be done by metal barrels/
- Mold/ can be made from any available material locally/

Harvesting devices and transportation to the target area.

Practice

- Collection of Water hyacinth biomass. (additionally, if there is agricultural residues, collection is important)
- The pure biomass is screened from other components prior to drying
- The water hyacinth biomass is dried for 7days using sunlight.
- The dried biomass is chopped using knives
- The biomass is loaded into the kiln and the mouth of the kiln is closed using metal lid attached to a conical chimney. Then the biomass is ignited with little amount of starter and the biomass inlet is tightly closed to start the pyrolysis process.

At the start of carbonization process, air is supplied via temporarily uncovered large opening from the top and opening on the kiln lateral walls. The kiln chimney also serves as a wayout of smoke from the kiln. Kiln temperature is controlled by regulating the air supply. The air supply is 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 glow of biomass is observed through ports, the first pair of ports at the bottom of kiln is sealed. This stepwise procedure is followed until all air ports sealed, and carbonization generally completes in ~2hrs time.

- When the temperature drops to the surrounding temperature, the kiln can be opened and char removal takes place. Then the resultant char powder is ready for preparation of briquettes.
- The char which is produced in the drum then crushed into smaller particles using locally made mortal, which is the easiest and cost-effective way to grind the charcoal

and produce powder. Finally, the carbon powder is 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 is easily available and cheapest. Carbonized char powder was mixed with soft wet soil (4:1 ratio) until a uniform mixture is obtained. The char and wet clay soil mixture then added into the briquetting mold and the wet mix was shaped under low pressure in simple block press or extrusion press. The briquettes were then dried in sun light for 7 days. Finally, combustion was made with no practical challenge and a single briquette was observed to burn from one to two hours.

Figure 16. Briquette making devices and the process of briquetting

In making this technology practical, the following points need careful attention:

- Appropriate drying time of the weed biomass so as to save and energy during carbonization process.
- Complete pyrolysis time is required to avoid smoke during burning of the briquette
- During mixing process of the char with the binder, adequate amount of binder is required to have physically stable briquette.
- After molding enough time is required to dry in order to make easier to transport.

- Comparative advantage/yield*:*

- The technology doesn't emit any dangerous gaseous chemical for human health in comparison with wood-based charcoal.

- It would have positive impact on the lake ecosystem by continuous removal of the weed from the lake surface. Practically, it would also have positive effect on the forest resource.
- Since the biomass is soft with low lignin content the pyrolysis and carbonization timing are small.

From dry 15 kg water hyacinth biomass, 4.8 kg char can be collected. When the water hyacinth biomass mixed with agricultural residues (crop residues), from 15 kg mixed (random mix) biomass nearly 5.37 kg char is obtained.

Cost effectiveness

There was no economic analysis performed to show relative economic comparison. However, the cost of this technology depends on the free human labor invested to collect, convert the biomass into briquette. And the materials required for making mold and carbonizer which is able to be made from thrown material. In case if someone is interested to have new mold or carbonize, the price is determined based on the type and size of this equipment. With all consideration this technology can be considered as cost effective.

Risk and uncertainty:

The probable associate risk with this technology is:

- Inconsistent source of the biomass, particularly if compete eradication become practical. However, no success story has reported to eradicate water hyacinth completely.
- Incomplete pyrolysis that render smoke and reduced burning time.
- Unable to meet the required amount of binder that affect the briquette physical stability.

Purpose

- The Amhara Regional Environmental Authority has been leading repeated public campaign to remove the weed manually. However, the collected biomass is piled near to the lake and not transferred to another place. Consequently, the effort took by the authority become incomplete due to the re-entry of the water hyacinth seed into the lake. The current management of the weed is hand picking and from practical experience of others, the future management of the weed is similar but the removal becomes mechanical(machine). In both context the biomass is collected and removed so that further step is required for complete management of the problem.

- Eventually, the final target of this technology is to make the weed management process integrated and comprehensive by converting the biomass collected into briquette. As a result of this, the effort applied to confront the problem will get better momentum so that sustainable management can be realized.

End user

This technology can be used by numerous bodies depending on their interest. However, the following users can be listed as potential users:

- Regional environmental protection bureaus can use it as means of job creation for youths.
- Local communities (*particularly*, farmers) can produce briquette charcoal with little training.
- Micro-enterprises can use the technology and improve the livelihood of themselves.
  Policy making organs can consume this technology as a source of information and devise a strategy to manage water hyacinth sustainability.

10. Four exotic bamboo species as alternatives for indigenous bamboos of Ethiopia

Responsible researchers: Yigardu M., Asabeneh A., Yared K., Abera G., Mistre A., Mehari A. , and Berhane K.

Brief description of the technology:

Bamboos are eminently renewable resources; under the right conditions, they display prodigious rates of growth. They grow fast and mature early. They are perennial grass belonging to the Poaceae (Gramineae) family and Bambusoideae subfamily. They comprise more than 1500 species that are widely distributed in the tropical, subtropical and temperate regions of all continents except Antarctica. Ethiopia possesses two very important indigenous bamboo species (*Yushania alpina* or African alpine bamboo and *Oxytenanthera abyssinica* or lowland bamboo) that have numerous traditional and industrial applications. As their names indicate, the two indigenous bamboo species are found limited in highland and lowland areas; *Yushania alpina* is found in highland areas of altitude 2400-3500 masl and *Oxytenanthera abyssinica* in lowland areas of altitude 500-1800 masl.

With the objective of selecting bamboos for mid altitude areas and so as to augment diversity of bamboos in the country, ten bamboo species have been introduced in 2008 (the 1st entries) by the then East Africa Bamboo Project (Ministry of Agriculture). Six of the species namely *Dendrocalamus hamiltonii, Dendrocalamus asper, Dendrocalamus membranaceus, Bambusa vulgaris var. green, Bambussa Balco, and Guadua amplexifolia* were evaluated for their adaptability and growth performance in different sites in Ethiopia. This technology package is produced based on the performance of these species in Southwestern Ethiopia (Jimma), Northwestern Ethiopia (Chagni) and Central Ethiopia (Gambo and Wondogenet) areas. Generally, the testing sites have an altitudinal range 1700-2450 masl, annual rain fall 1250-1726 mm, minimum temperature 11.3-26.2 ^{o}C, maximum temperature 20- 28.6 ^{o}C and well-drained soils.

A simple randomized complete block design was used in establishing the experiments. The propaguoles used were seedlings. Parameters such as number of culm, culm height, diameter at breast height (DBH), root collar diameter, number of annual shoot sprouts per clump, shoot sprout height, and biomass were measured. SPSS was used for analyzing and presenting the data.

At the age of four years after establishment, *Dendrocalamus hamiltonii* attained an average height of 10.6 meter and average culm diameter at breast height of 3.4 cm with an average dry weight of 82.16 kg/clump at Jimma. The dry weight estimate of the species four years after establishment at Chagnii was 103.5 kg/clump (65 t/ha). It can be assumed that the clump attains more biomass as it gets matured. This species has big size and enormous number of leaves that constitute about 20% of the total biomass of the clump. The number of culms per clump at Gambo (Southern Ethiopia) four years after establishment was 34. From the five-species planted at Gambo, *D. hamiltonii* showed the highest record in culm height (5.4 cm) followed by *D. asper (*3.5 cm) and *B. vulgaris* (2.5 cm).

The average number of culms per clump of *Dendrocalamus membranaceus* 4 years after establishment from seedling at Jimma was 42 and the average height at the same age was 7 m. It has an average total dry weight of 76 kg and 45 kg per clump at Jimma and Chagnii, respectively, 4 years after establishment. This species showed good performance in other sites. *D. membranaceus* and *B. vulgaris var. green* had showed the highest number of shoot sprouts per clump at Gambo.

Bambusa vulgaris var. green has 66 culms/clump and 22 new shoots per clump 4 years after establishment at Jimma. The average total dry weight was estimated at 90 kg per clump at Chagnii and 76 kg per clump at Jimma 4 years after establishment. *D.asper* showed the highest total biomass accumulation which was 131 kg/clump (82 ton/ha) followed by *D. hamiltonii (*104 kg/clump or 65 t/ha) at Chagni.

Further performance evaluation made at Tepi, Hirna and Wondogenet showed that these species perform were in these sites. At Tepi, *D. hamiltonii* (height 3.1 m, RCD=28.1.mm), *D. membranaceus (*height 3.04 m, RCD=24.6 mm) and *B. vulgaris var. green* (height 2.5 m, RCD=16 mm) showed prodigious growth one year after planting. These species also performed well at Hirna and Wondogenet. Assessments made on insect pest and disease occurrence on these species did not show any risk that hamper further promotion of these species.

The results indicated that *D. hamiltonii, D. asper, D. membranaceus* and *B. vulgaris var. green are* good species for cultivation in the sites of the study and areas that have similar soil and climatic conditions Ethiopia. The species can be planted for the different uses of their culm and leaves. Their culm can be used substituting wood in different applications in woodworking, furniture and paper and pulp industries, house construction, fencing, fuel, household utensils, handicrafts etc. The young shoots of these species are also reported to be used for human food and are part of the world bamboo shoot market and/or traditional

cuisine. The proximate composition of these species revealed that their leaves are rich in organic matter and crude protein contents hence can be used for livestock feed. A study on determining the effect of feeding *D. hamiltonii* leaf, i.e. about 20 % of the total biomass of the plant, on Arsi Bale sheep confirmed that animals supplemented with 67% bamboo leaf hay of this species and 33% concentrate mix of other sources had higher final body weight than others supplemented with less *D. hamiltonii* leaf and more concentrate mix of other source, thus this species is biologically recommended for fattening sheep.

Suitability:

D. hamiltonii, D. asper, D. membranaceus and *B. vulgaris* var. green showed good growth performance and adaptability at Jimma, Chagni and Gambo site conditions. On the other hand, *D. hamiltonii, D. membranaceus* and *B. vulgaris var. green* also demonstrated superior growth and adaptability at Tepi, Hirna and Wondogenet testing sites. Specific elevation and climatic conditions of the specific testing sites are as follows:

Table 6 Geographic location, edaphic and climatic conditions of the testing sites

S. No.	Name of testing site	Administrative location where the testing site is found			Lat-Long	Alt. (m)	Climate (Average value)		
		District	Zone	Region			An.RF (mm)	Max. Temp. (oC)	Min.Temp. (oC)
1	Jimma	Mana	Jimma	Oromiya	70°6'N, 36°00' E	1753	1530	26.2	11.3
2	Chagni	Guangua	Awi	Amhara		1700	1725	28.6	13.2
3	Gambo	Arsi-Negele	East Shoa	Oromiya	07°20' N,38°49 E	2450	1250	15	20
4	Wondogenet	Wondogenet	Sidama	SNNP	7°19'N, 38°38'E	1920	1372	26.2	11.5
5	Tepi	Yeki	Sheka	SNNP	7°3'N, 35°18'E	1200	1678	30	15
6	Hirna	Tullo	W.Haraghe	Oromiya	9°13'N, 41°06'E	1763	920	20	15

Pre-requirement*:*

The pre-requirement for the implementation of this technology:

- Propagation and multiplication of planting materials (seedlings) if the establishment is planned with seedlings and/or securing one to two-year-old bamboo plants for preparing rhizome-based planting materials that will be done by severing them from the rhizome system
- Propagation and multiplication of planting materials (seedlings) requires nurseries with the basic nursery materials (forest soil/compost, agricultural soil, sand, plastic bags or polyethylene tubes, etc) and facilities (water, propagation bed, shade house or green house)
- Trained human resources for propagation and field management.
- Available and prepared land for planting

Practice:

To implement this technology:

- Prepare propagation material (offsets or seedlings) before the planting season.
- Prepare planting site for planting in the field:
  - ✓ Clear the land from all weeds and unwanted vegetations,
  - ✓ Waterlogged areas are not re commended for bamboo planting, so select areas that have good drainage,

- ✓ Use spacing of 7x7 m, it provides sufficient space for intercropping and allows greater ease of movements for maintenance and harvesting activities,
- ✓ For river banks and gully stabilizations use spacing of 5 x 5 m,
- ✓ Dig planting hole with a diameter of 1 m and a depth of 60 cm or twice the size of the clump.
- ✓ Use offsets or nursery raised plants (seedlings) for planting. Seedlings are better for large plantations due to the associated cost of establishment and difficulties to get offsets.

- Select plants that have well-developed roots and rhizomes for better survival,
- Handel the seedling or offsets appropriately during transporting into the field,
- Water the seedling before transportation,
- Transport offsets or seedling with due care and in rainy time,
  - ✓ Plant the seedling during the start of the rainy season.

Field Management

- After planting, check the survival of the seedling regularly and replace dead seedlings and offsets in the first year of weeding,
- Fence the plantation to protect it from browsing and damage by animals such as goats, cows, and deer,
- Weed regularly, use a radius of 60 cm around the seedlings,
- Mulch the planted seedling by using grass or other locally available material,
- Loos the soil around the plant twice a year to improve soil aeration twice,
- Thinnthe clump to provide space for the emergence of the new shoots,
- If rotting culms observed, dig around the stump and remove the rotted culm,
- Note and report symptoms of disease or fungal infections,

Harvesting and post harvest management

- Harvest culms only during the dry season. It makes them less susceptible to attack by borers due to the lower starch content during the dry season,
- Use X-shaped or Horse-shoe shaped harvesting design as the species are clumping types.
- Use very sharp tools during harvesting, try to avoid cutting the young shoots if the clump allows harvesting from the interior or if it is suitable for harvesting from the inside,

- Harvest at 15 cm to 30 cm from the ground or just above the first node from the ground level,
- Do not clear-cut or harvest unless it has been verified that a disease severely infects the stumps.
  After harvesting enrich the soil by incorporating the leaf biomass into the soil around the clump

Comparative advantage/yield*:*

The technology provides new species that can grow on an area that the indigenous species is not grown.

- It helps to increase the diversity of bamboo species and thereby guarantee sustainable supply of raw materials for different bamboo applications especially during mass flowering of a bamboo species in an area
- Improves resilience of bamboo uses in cases of disease and other insect attacks.
  - ✓ Helps to enhance the productivity of bamboo species

Cost effectiveness:

The technology is applicable and affordable to end users as it is low cost and needs less time to and resource to manage. But, the use of offsets for large plantation may not be practical for smallholders, because of its high establishment cost and the associated consequences on planting material sources. Therefore, alternative propagation techniques like tissue culture are important.

Risk and uncertainty:

Extreme drought after planting might affect the performances as well as the management of this technology.

Package of Informaion

1. Rubber Latex Yield from *Hevea brasiliensis* Clones Grown Under the Agro-climate of South-West Ethiopia

Responsible researchers: Dagnew Yebeyen, Berehanu Segebo, Tatek Dejene (PhD), and Abera A. Bayesa,

Brief description of the information*:*

Hevea brasiliensis is the primarily commercial source of natural rubber in the world. Ten existing *H. brasiliensis* clones were evaluated for their latex yield in Bebeka area, South-west Ethiopia. The clones included PB86, RRIC100, RRIC101, RRIC102, RRIC121, PB2859, GT1, Malawi, Tulikobo and Mixed. For the purpose of the present study, ten trees were randomly selected from each clonal plantation. Then, latex yield was recorded per tree per tapping.

The result showed that the highest average latex yield was obtained from Mixed and RRIC101 clones with the value of 89.60 and 88.97 ml/t/t, respectively. Thus, both clones were recommended for further commercial plantation in the study area and areas with similar agro-ecological context. Moreover, the two clones (RRIC 102 and RRIC 121) gave comparable yield and can also be considered as alternative clones for promotion.

Introduction

Rubber is a valuable commodity in today's economy. Among commercially useful rubber-producing species, *Hevea brasiliensis* is the primarily commercial source of natural rubber in the world. Attempt was made to introduce and test the adaptability of this species in Ethiopia. Currently, about 12 clones of *H. brasiliensis* found as a plantation in the South-west Ethiopia. These clones are considered as the key to the improvement of rubber tree in the country through tree breeding programs. Therefore, the characterization and evaluation of the existing clones is considered to be important aspects for further multiplication and expansion of *H. brasiliensis* plantation over the country. However, the information regarding the yield potential of each introduced clones is yet not characterized and evaluated. Thus, in this study it is tried to characterize the latex yield potential of existing clones and select high yielding clones for further expansion of plantations of *H. brasiliensis*.

Brief methodology

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 1862.9mm. It has 154 evenly distributed rainy days throughout the year. Annual sunshine hours are not less than 2,000.

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.

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). Then, the latex yield was estimated per year of each clone.

Major findings and its importance

- Rubber clones, Mixed and RRIC101 are superior in latex yield and promising planting materials in future rubber production. An average of 89.60 and 88.97 ml/t/t were recorded from the clones, respectively. Two clones (RRIC 102 and RRIC 121) also gave better yield and can also be considered as alternative clones for promotion.

Key Policy Recommendations

- Rubber development and production should be based on high yielding clones. Moreover, further expansion of rubber plantation on the promising clones should be done in similar agro-ecological zones of the country. Farmers and out-growers should also be supported by provision of high yielding rubber clones and training on cultivation and production of rubber.

Potential users of the information

- National Rubber Nucleus Project of Chemical Industry Corporation of Ethiopia
- Investors involved with rubber plantation and production
- Farmers and out-growers

Reliability of information

The study was conducted in collaboration with the National Rubber Nucleus Project of Chemical Industry Corporation of Ethiopia. Data was collected by EEFRI researchers and the staff members of the project.

2. Nutritive Value of Four Introduced Bamboo Species for Livestock Feed at Pawe and Jimma Areas of Ethiopia

Responsible researchers: Fikremariam Haile, Dagnew Y. Burru; Yigardu M. Mengesha and Eyob G. Zemenfeskidus

Brief description of the information

Nowadays, livestock population decreased, at least in north western Ethiopia, as compared to the previous five years, mainly because of feed shortage and prevalence of diseases. Feed shortage, particularly in dry season is the primary problem. This in turn increased the utilization of the two indigenous bamboo species (*Oxytenanthera abyssinica* and) as animal feed, since it is drought resistant and evergreen plant throughout the dry season, it is providing green forage to ruminants. Thus, bamboo leaf is recommended as an important feed resource which is cheap, easily accessible and with good nutritive value for livestock in the bamboo growing areas of Ethiopia. Besides the two indigenous bamboo species, many bamboo species were introduced in Ethiopia since 2007. Therefore, this study was conducted to evaluate the nutritional value of *Dendrocalamus hamiltonii (DH), Dendrocalamus membranaceus (DM), Bambussa vulgaris (BV)* and *Guadua amplexifolia (GA)* species, grown under on-stations at Pawe and Jimma.

Moisture Content, Ash Content, Organic Matter, Nitrogen Content, Crude Protein, Dry Matter, Acid Detergent Fiber, Neutral Detergent Fiber, Acid Detergent Lignin, Cellulose and Hemi-cellulose were determined. The result showed difference between study sites for N, CP and ADF contents. However, there was no difference among the different bamboo species for most of the tested parameters except for NDF, Cellulose and Hemi-cellulose contents. The result also showed that leaves of the introduced bamboo species have good organic matter (82.98 - 87.94 %) and crude protein (26.35 - 30.97 %) and can be used for animal feed substitution especially in dry seasons where there is a scarcity of fodder.

Introduction

Bamboo played a primary role in providing forage to livestock especially during the extended dry season. Feeding bamboo to ruminants is a long-time tradition in Ethiopia. Thus, bamboo leaf is recommended as an important feed resource which is cheap, easily accessible and with good nutritive value for livestock in the bamboo growing areas of Ethiopia (Denbeshu, 2010; Mekuriaw et al. 2011). However, studies on the quality and nutritive values of introduced bamboo species leaves is limited. Thus, this study examined the nutritive value of four introduced bamboo species namely *Dendrocalamus hamiltonii, Dendrocalamus membranaceus, Bamusa vulgaris* and *Guadua amplexifolia*.

Brief methodology

Bamboo leaf samples of *Dendrocalamus hamiltonii (DH), Dendrocalamus membranaceus (DM), Bambussa vulgaris (BV)* and *Guadua amplexifolia (GA)* were collected. The bamboo leaves dried in open air until all the leaves were dried uniformly. Dried leaves were hand-crushed and further grinded using mortar and pestle to pass through 2 mm mesh. Then, the samples were analyzed for their nutritional content (ash, dry matter and organic matter, total nitrogen and crude protein, neutral detergent fiber, acid detergent fiber, acid detergent lignin, cellulose and hemi-cellulose contents).

Major findings and its importance

- The proximate composition of the four introduced bamboo species reveals that their leaves are rich in organic matter and crude protein contents (Table 7).
- They have also lower moisture, neutral detergent fiber and acid detergent fiber contents.
- Their average protein content is a source of amino-acid while their low moisture content is an index of their great permanence due to less microbial susceptibility and long shelf-life of their meal.
- *Dendrocalamus membranaceus* and *Dendrocalamus hamiltonii* had higher crude protein contents as compared to other tested species.
- The introduced bamboo species grown in humid areas also had better crude protein content.

Table 7 Proximate chemical composition of introduced bamboo species leaf samples from Jimma and Pawe areas of Ethiopia

Treatment	Parameter %										
	MC	**DM**	**Ash**	**OM**	**N**	**CP**	**NDF**	**ADF**	**ADL**	**HC**	**Cell**
Species											
B. vulgaris	4.17	95.83	17.02	82.98	4.48	28	72	42.67	6.33	33	32
D. hamiltonii	4.58	95.42	14.64	85.07	4.77	29.8	71	43.67	7.00	29.3	36.35
D. membranaceus	4.67	95.33	12.00	87.94	4.95	30.97	71.67	38.67	6.67	27.3	31.34
G. amplexifolia	4.92	95.08	14.36	85.64	4.23	26.35	69.67	38.67	7.33	31	31.34

- Lack of fodder in Ethiopia, for longer periods of the year especially at the dry seasons, poses a huge threat to animal feed security and also make animals unproductive. Therefore, inclusion of introduced bamboo species leaf in animal diet can increase essential nutrients and decrease the fiber content especially in dry seasons where there is a scarcity of fodder.

Key Policy Recommendations

- The nutritive value of the introduced bamboo species is promising in terms of their fodder values. Thus, promotion of the species in their potential areas and their use as supplementary livestock feed is important.

Potential users of the information

- Entrepreneurs involved in dairy and meat production
- Farmers, semi-pastoralists and pastoralists

Reliability of information

The nutritional analysis of the bamboo leave samples was done at accredited Debrezeit Agricultural Research Center laboratory and by EEFRI and EIAR researchers.

3. Traditional use and management of *Moringa stenopetala* by Derashe and Konso ethnic communities in Southern Ethiopia

Berhane Kidane, Zewdu Yilma and Abeje Eshete

Brief description of the Information

Moringa stenopetala is an important cabbage tree, cultivated and managed for various purposes in the southern part of Ethiopia. The study was conducted in Konso and Derashe district that are found in Segen People's Zone of the Southern Nations, Nationalities and People's Region (SNNPR).

M. stenopetala is used as an important component of the daily dish of the studied communities and also used for medicinal purposes. Farmers in Derashe and Konso propagate moringa using either seeds for direct sowing in the field and raising seedlings and also using cuttings. This has been for long the usual practice by the study communities in southern Ethiopia. Easily propagating of the species via seeds and cutting is a good opportunity in the future expanding moringa plant at similar agro ecologies of the country. The studied communities majorly prefer to plant the species around homestead for further promotion without serious barrier in home-gardens. Many also plant Moringa on crop fields in close association with cereal crops, however the trees have to be pruned every year so as to deny shelter for migratory cereal grain destroying birds especially in maize and sorghum growing areas.

Introduction

Moringa stenopetala (Baker f.), hereafter referred as Moringa belongs to a member of a single genus family called Moringacea and is indigenous to Ethiopia (Mohammed, 2013; www.Konso-Organic.org). It is called a cabbage tree and is a deciduous plant cultivated in the southern part of Ethiopia. The species is well known as "Haleko" or "Shiferaw" in Ethiopia (Orwa et al., 2009). The plant is also believed to be native to Northern Kenya and Eastern Somalia (www.Konso-Organic.org). It is distributed in the lowland ecology of the southern part of Ethiopia, between 1,100 and 1,600 m altitude (Mekonnen and Gessese, 1998).

Moringa has gained more popularity in recent days due to its multiple uses and benefits. It is used as an alternative to vegetables to overcome malnutrition and also used as a metabolic conditioner to aid against endemic diseases in developing countries. The leaves and fruit pods are edible, providing a highly nutritious food for both humans and animals.

Despite the availability of some ethnobotnical knowledge in Ethiopia, studies that particularly contribute to its cultivation, conservation and management of moringa are still scarce. Therefore, the purpose of this

study was to describe the Ethnobotanical knowledge related to its management in Konso and Derashe communities.

Brief methodology

Two districts Dherashe and Konso were selected purposively because they are known for their long years tradition of growing moringa. From each district three Kebeles were purposively selected based on higher moringa distribution on their farm land and planting experience. Checklists were prepared and used for focus group discussion, where at least 10 Key informants composed of different gender and age groups from each district in selected Kebeles were participated in the focus group discussions. A total of 180 and 90 households from each district were selected based on random sampling technique.

Major findings and its importance

Propagation of moringa is either by seed or cuttings and practiced by the local communities. Propagation by seed is possible through raising of seedlings at nurseries or direct sowing in soil. Depending up on the altitude, seedling will reach plantable size within two to four months in the nursery. Therefore, any nursery activity has to be performed considering the time required for the nursery period before out planting. If cuttings are used for propagation purposes, cuttings with a size of >50 cm and < 1.50 cm are used. Relative ease of propagation and fast-growing nature of the species build a good opportunity for promotion of the species both in the study area and also in similar agroecological zones of the country.

The most important environmental factor for moringa cultivation is well drained soil (sandy to sandy loam), mean annual rainfall > 600mm or irrigation supply and warm weather at altitude below 1600 masl. Moringa can gown in areas with less than 800 masl but has to be supported by irrigation for optimum production. Moringa planted in crop fields of maize and sorghum has to be regularly and annually pruned so as to deny roosting over the branches by grain feeding birds.

Figure 17. Moringa pruning height to avoid bird roosting and leaf biomass harveting on crop fields

Almost all plant parts of Moringa is used for the treatments of different human and livestock diseases by the local communities. The hot soup made from Moringa leaf is used for the treatment of human cough, tonsillitis and flu. It is also used for the treatment of bloated stomach and "Asthma". The green leaf sap fluid of moringa is used for the treatment of eye disease. It is usually applied and used when the diseased eye is red and has burning sensation. The root of the plant chewed and the fluid is swallowed to serve for the treatment of stomach ache. It is also believed that the plant is used for the treatment of diabetics. The root of Moringa plant is used for the treatment of venome from snake bite. For this treatment the root is chewed and the liquid (juice) is swallowed immediately after snake bite. The information on the use of moringa for medicinal purpose can also be used by different pharmaceutical factories after identification of the major ingredient that contributes to the treatment of specific type of ailments.

Key Policy Recommendations

Land in potential areas should be available by the government to encourage investment on moringa. Incentives in the first two years is important in order to encourage people that have interest to invest on the development of this resources.

Potential users of the information:

- Rural and urban communities
- Food processing industries, soft drink factories
- Farmaceutical industries
- Investors involved in plantation
- Development practitioners
- Policy makers

Reliability of the information:

This ethnobotany study is original work conducted by EEFRI researchers in SNNPR

4. Quality of Gum-arabic from *Acacia senegal* found in Different Localities of Ethiopia

Dagnew Yebeyen and Fikeremariam Haile

Brief description of the Information*:*

Owing to 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. To this end and get in to the market, gum arabic for commerce must conform to certain chemical specifications. In–depth physicochemical screening is needed to learn more about between–site, between–tree and seasonal variations in gum quality.

The study was conducted to investigate the effect of growing location on physico-chemical properties of gum arabic obtained from *Acacia senegal* populations found in Ethiopian (Abederafi, Yabello, Awash and Filtu areas). Laboratory analyses were employed to determine the physico-chemical characteristics which included: moisture content (MC), ash content (Ash), pH, relative viscosity (RV), Nitrogen (N), Crude Protein (CP) and mineral contents.

The analysis indicated that there is difference in ash, pH, RV, Iron, Calcium, Sodium, Cupper, Potassium, Nitrogen and Crude Protein contents of the gum arabic samples between the study sites. The percentage MC of the gum arabic samples were 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.

Introduction

One of the most recognized Non-Timber Forest 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*. The use of gums has declined today as compared to the early years 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. One factor observed to influence the quality of gum arabic is botanical origin. Quality of gum arabic differs between and within species. Gums from different species exhibit characteristics that are intrinsically different. Even within the same species, different varieties produce gum with different characteristics. 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. Moreover, compared to other producer countries, very little studies have so far been done on the physicochemical characteristics of gum arabic of Ethiopian origin.

Brief methodology

The study was conducted in the *Abederafi*, *Yabello*, *Awash* and *Filtu* areas of Ethiopia. Representative *A. senegal* gum samples were collected from different regions of Ethiopia so as to include different populations of the tree. The samples were then air dried for fourteen days and ground using pestle and mortar for physico-chemical analyses. 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 was following known standard procedures.

Major findings and its importance

- Gum arabic samples from *A. senegal* trees of the study areas meet most of the specifications given by the 'Joint Expert Committee for Food Additives for Gum Arabic' (Table 8).
- Viscosity and Ash contents of gum samples brought from *Abederafi* site were different from gum arabic samples brought from the rest of the study areas and the international standards.
- The gum arabic from the study areas 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.

Table 8 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	4.04	0.49	3.11	2.5	4.4	116.55	28.22	192.12	0.86	901.84	1.16	1333.6
Abederafi	12.64	16.98	0.513	3.21	0.9	4.88	226.66	273.54	130.87	1.7	445.04	145.2	1723.2
Awash	13.27	0.32	0.313	1.943	4.2	4.64	139.13	34.36	178.2	1.32	1355.9	288.33	1578.7
Filtu	13.41	4.04	0.497	3.11	3.9	4.97	161.84	42.61	55.7	0.6	1233.6	252.2	1850.4

Key Policy Recommendations

- We found that quality of gum arabic from most of the *Acacia senegal* trees of the country are comparable to best gum arabic qualities of the world like Kordofan. Therefore, promotion works of the gum arabic products form *A. senegal* species should be strengthen.

Potential users of the information

- Natural gum Enterprise of Ethiopia
- Investors involved with gum and resin production and export
- Farmers and pastoralists occupied by gum production
- Pharmaceutical and beverage industries which utilizes gum arabic as a raw material

Reliability of information

The physico-chemical analysis of the gum samples was done at accredited laboratories of the Deberezeiet Agricultural Research Center and Addis Ababa University by EEFRI researchers and respective professional from the laboratories.

5. The Contribution of Agroforestry for Food Security

Responsible researchers: Demelash Alem, Sewale Wondimneh, Sintayehu Eshetu, and Wondossen G/Tsadik.

Brief description of the Information

Agro-forestry is recognized as a land-use system which is capable of yielding both wood and food while at the same time conserving and rehabilitating ecosystems. In general, agroforestry practices have significant contribution in providing goods and services for livelihood and food security improvement of the local community.

A study was conducted to know the contribution of agroforestry practices (AFPs) for food security in selected districts of north western Ethiopia using questionnaire survey. The study revealed that almost all of the respondents (96%) are engaged in agro-forestry practices and AFP is contributing significantly to food security of the community in the study districts. The majority of the respondents (about 79%) practiced home gardening which makes it the dominant AFP followed by planting trees on farmland. There are different uses and services provided by these AFPs and famers allocate significant amount of land for AFPs. More than half of the respondents (60%) stated that they have been supporting their livelihood by selling agro-forestry products.

According to the respondents, the proportion and amount of fruit trees planted in farm lands is generally limited. Burie and Jabitehnan districts which are mid-altitude areas have better fruit tree and other income generating species than the other study districts in the highland and lowland areas. The contribution of AFP for food security would have been better if more cash generating and fruit trees were included and their proportion increased especially in the highland and lowland areas. Tree/fruit species which produce products/services during July to October, the critical food shortage periods for the majority of the respondents are important. Apple, mango, avocado orange, coffee and banana in order of importance are major fruits and cash crops being produced by the local community.

The type and intensity of management being applied to the AFPs are found to be unsatisfactory. More than half of the respondents agreed that AFPs have positive effect on crops, soil, and environment. 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 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 lack of knowledge on species choice and management technologies.

Introduction

In Ethiopia, 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 including Ethiopia, outlooks that are more integrated have begun to emerge. One of these is agroforestry (Agrodoc, 1996). Agroforestry is a collective name for land-usesystems 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 capacity of trees to maintain or improve soils is shown by the high fertility status and closed nutrient cycling under different agroforestry practices.

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 ownway 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 agroecologies 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. The present study was conducted to document the contributions of selected AFPs for food security in selected districts of north western Ethiopia and to indicate future research direction to optimize the potential merits of these activities.

Figure 18 Alley cropping as one of AFPs

Brief Methodology

The 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. Sample districts were selected from each selected zone and from each agroecology of the region. Accordingly, *Ebnat, Farta, Guagusa, Gozamen, Jabitehnan* and *Burie* districts were selected. From these districts, 8 Kebeles (*Balarb, Awuzet, Gassay, Shinkurta, Giraram, Chertekel, Mankusa and Adelagata*") which have traditional AFP were selected. Within each *kebele* sample sub-kebeles "*gots*" were selected for data collection.

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. A total of 201 respondents were selected to administer the questionnaire.

Major findings and Justification of its Importance

Type of AFP in the study areas

The dominant AFPs practiced in the study area are home garden followed by planting trees on farmland. However, the diversity and number of fruit trees per household is very limited. Number of trees planted

by the farmers differs among districts and different agro-ecologies. The highest number of trees per household was recorded in mid altitude (Woyinadega) areas while the lowest was recorded in other two agroecologies. The three most dominant fruits trees being planted by the local community are apple, mango, avocado, orange, coffee and banana.

Preferred tree species for various uses and services

The most commonly planted trees species across all agroecologies and study districts is *Cordia african*a followed by *E. globulus* and *Sesbania sesban*. The different trees/shrub species preferred by respondents are indicated in the table below:

Table 9 List of tree species in agroforestry application and their potential use by farmers

Tree/shrub species	Uses and services
Sesbania sesban	Fodder, soil fertility maintenance
Chamacytus palmensis,	Fodder, soil fertility maintenance
Rhamnus prinoides,	Income generation
Coffee	Income generation
Cordia africana	Wood for furniture, income generation, medicinal use
E. globulus	Construction, fuel wood, and income generation
E. camaldulensis	Construction, fuel wood, and income generation
Croton macrostachyus	Soil fertility maintenance
Vernonia amygdalina	Medicinal use

.

Seedling production practice by the local farmers

The study revealed that only about ***39%*** of the respondents raise seedlings of multipurpose tree and shrubs on their private nursery. Therefore, the majority of the respondents depend on other sources for seedling supply. Tree seedling production and marketing is becoming one of the income generating activity in some districts of the region. More than 50% of the respondents who are involved in raising tree seedlings produce seedlings both for private use and for sale. Respondents also raised constraints in seedling raising including water shortage, land shortage, lack of technical knowledge, and lack of seeds.

Management practices on AFPs

About 93.5% of the respondents replied that they manage agro-forestry practices. However, the type and intensity of management varied with the type of AFPs. Cultivating, watering, pollarding, manuring and weeding in order of importance were the major types of management on home gardens. While pollarding, fencing and lopping are practiced on farmlands.

Contribution of AFPs for household nutrition, family income and food security

The study revealed that AFPs are contributing a lot to food security for about 71 percent of respondents. It was only 21% of the respondents who replied that AFP has little contribution to household food nutrition. In general, it was found out that there is a need to diversify species composition of AFPs and increase the proportion of food fruit trees in agro-forestry components. About **72**% of the respondents agreed that AFP increased farm income. The amount of income generated from AFPs ranged from 100 to 50000 ETB, per household per year while the average is 6000 ETB per household per year.

Effect of AFPs on crops and pasture

About 64% of the respondents replied that AFPs affect crops positively and about 56% of the respondents mentioned that AFP affect pasture positively.

Contribution of AFPs to soil and water conservation, soil fertility management, and modifying local condition

More than half of the respondents agreed that AFPs significantly contribute to soil and water conservation and about 90% of the respondents agreed that AFPs increase soil fertility. Concerning effect of AFPs on environment, about 90% of the respondents replied that AFP has positive effect on the environment and improved local condition. This indicates that farmers are aware of the role of AFP on the environment.

Role of AFPs in saving time needed for collecting fuel wood

About 85% of the respondents replied that AFP saved time required for collecting fuel wood. Since women and youth are mainly responsible in collecting fuel wood, AFPs will have great contribution in reducing women and youth workload, thereby contributing better access to education and producing healthy society and community. However, species diversification is very important in achieving the desired objective.

Major constraints in promoting agroforestry practices

The major constraints mentioned by the farmers in managing AFPs are water shortage, lack of planting materials especially fruit tree seedlings, labor, land shortage, wildlife damage and lack of skill and technical knowledge.

Recommendations

- The inclusion of fruit and other economical trees into the existing AFPs is detrimental in improving the contribution of AFPS for income generation and livelihood improvement. It is necessary to screen multipurpose tree species for different AFP.
- Skill and technical knowledge in managing AFPs will significantly improve the productivity of AFPs. Therefore, technical support and extension services need to be provided to this end. Model AFPs have to be established to demonstrate good management of AFPS so that the local people will learn from.
- Water shortage has to be solved through different approaches such as constructing water harvesting structures, pond construction, river diversion or any other water source. It is necessary to stop or reduce free grazing through integrated livestock production, management and forage production.

Potential users of the information

Farmers, extension experts, higher learning and research institutions, investors, tree growers, policy makers.

Reliability of information

This information is based on research conducted by EEFRI researchers and it is a direct result of data collected from farmers.

6. Priority shade/support trees for spice production

Responsible researcher: Wondwosen Gebretsadik

Brief description of the Information

Next to coffee, spices are economically and socially important in south western part of Ethiopia where they are a source of income for smallholders. Forest spices grow in wild form in the natural forests in Bench Maji, Kaffa and Sheka zones of SNNPR along with coffee. Spice crops are well adapted to the hot–humid and lowland agro-ecologies of southwestern part of Ethiopia. On the average, the crops were observed to perform best in areas with altitudes ranging between 500-1500 m.a.s.l, annual rainfall of 1200-7000mm and mean annual temperature of 20-35 ^{0}C. Farmers in these areas are used to collect these spices as NTFPs (Non-Timber Forest Products) for income generation. Spice crops need shade and support for them to properly grow and be productive. Farmers use different trees/shrubs as shade or support for spice crops.

A study was initiated to investigate farmers perception with respect to the types of tree species used as shade and/or support for spice production and to assess the economic and environmental contributions of these shade trees in spice agro forestry systems. A total of 53 tree species were identified as shade and support trees for spice production in the study area: Bench Maji, Kefa and Sheka zone in SNNPR. *Millettia ferruginea* (54%) is found to be the most prominent and the first prioritized tree species as shade tree for spice production followed by *Albizia gummifera* (49%), *Erythrina brucei (43%),* and *Ficus sur (38%).*

Eighty two percent of the shade tree species for spice production were indigenous which are used to be retained around home gardens and crop fields. Evergreen tree species were superiorly ranked compared to deciduous tree species since theformer retain leaves and provide better shade in dry season. However, tree species like *Millettia ferruginea and albizia gummifera or schemperina* shade their leaves and increase nutrient input. The survey found out that men (92%) household members were mainly responsible for harvesting spice. Among the households, 100% have their own land and 95% of them have trees as farm forest on their land as shade tree for spice production. About 99% of the respondents said that shade trees have a positive contribution for spice production.

Introduction

South western part of Ethiopia is one of the few areas commonly known with high forest cover of natural forest resources which consist of a number of forest tree species, spices, coffee and tea production. These forests serve important environmental functions in land stabilization, erosion control, regulation of climate and hydrologic flows. These resources have also considerable economic benefits. A study conducted in 2004 revealed that 90% of the households in Bench Maji, Kaffa and Sheka zones were engaged in harvesting and production of non-timber forest products (NTFPs) including wild and semi-wild forest coffee, forest honey, and wild forest spices.

Almost all of the spice crops are found well adapted to the hot–humid and lowland agro-ecologies of southwestern part of Ethiopia. Next to coffee, spices are economically and socially important since they are a source of income for smallholders. They are the means to generate foreign currency and provide ample opportunities for employment and industrial development. This study was initiated to identify the type of tree species used as shade and/or support for spice production and to assess the economic and environmental contributions of shade trees-spice agro forestry system.

Brief methodology

The study was conducted in south west Ethiopia in Bench Maji, Kefa and Sheka zone in SNNPR. Three potential districts from Bench Maji zone and one district from Kafa and Sheka zone was selected. One potential sub district from each three districts of Benchmaji zone (Menitgolg, Shay bench and Debub bench) and three potential sub districts (Kuti, Dishi and Boba Gecha) were selected from Dacha district of Kaffa zone and also three spice productive sub- district (Uwa, Gada and Beto) were selected from Masha sub district of Sheka zone. Fifteen farm households per Kebele and 10 investors or commercial farmers in the study area were selected and interviewed based on a questionnaire focusing on the major potential and constraints of spice shade and/or support trees in the area.

Major findings and Justification of its Importance

- Out of 53 tree species that were identified as shade and support trees for spice production, *Millettia ferruginea is* found to be the most prominent and the first prioritized tree species as shade tree for spice production followed by *Albizia gummifera*, *Erythrina brucei*, and *Ficus sur* respectively.
- Eighty two percent of shade tree species for spice production were found to be indigenous tree species which are retained around home gardens and crop fields.

- Evergreen tree species were superiorly ranked compared to deciduous tree species since theformer retain leaves and provide better shade in dry season.
- Tree species like *Millettia ferruginea and albizia gummifera or schemperina* shade their leaves and increase nutrient input.
- The survey found out that men (92%) household members were mainly responsible for harvesting spice.
- Among the households, 100% have their own land and 95% of them have trees as farm forest on their land as shade tree for spice production.
- About 99% of the respondents said that shade trees have a positive contribution for spice production.
- Among the respondents, 6% preferred exotic tree species for spice production. However, 11% said both indigenous and exotic tree species were used as shade and support for spice production. Most of the farmers preferred natural forest rather than plantation for spice production.
- Among the respondents, 54% preferred ever green tree species, whereas 26% selected deciduous and 20% preferred both ever green and deciduous tree species for shade for production of *Aframomum angustifolium* (korerima), *Elletaria cardamomum* (hell) and *Piper capense* (timiz)**.**
- In general, 42% of the respondents preferred trees that have the ability to increase soil fertility and sparse crown while 20.8% have chosen shade and support trees that have the ability to maintain soil fertility and those that can be used for construction and having sparse crown.

Recommendations

- The identified priority shade and support tree species need to be artificially propagated and their seedlings need to be distributed to small holder farmers for spices production.
- Large scale spice producers need to artificially propagate and use the identified and prioritized shade/support trees for effective spice production.

Potential users of the information

Farmers, investors, extension experts, practitioners of spice production, Assessment of Biomass and Soil Carbon Stocks of Agroforestry Systems and Adjacent Cultivated Land, in Cheha District, Gurage Zone, Ethiopian higher learning and research institutions, , tree growers, policy makers.

Reliability of information

This information is based on research conducted by EEFRI researchers and it is a direct result of data collected from farmers.

7. Socioeconomic determinants that affect investment on degraded lands

Responsible researchers: Biruk Birhan, Fekadu Dule, Wondimagegn Amanuel, and Solomon Mulat

Brief description of the Information

In Ethiopia serious land degradation problems usually lead to the deterioration of soil fertility and productivity which adversely affect agricultural production which further contributed to the slowdown of the country's economic development. Despite the different efforts made by different actors to halt land degradation and improve land productivity, farmers' investment on rehabilitation of degraded lands remained limited.

A study with the aim to identify the socio-economic factors that significantly affect investment on degraded lands and to interpret the underlying causes and effects has been conducted in Wulbareg district, Silte zone, SNNPR through questionnaire survey. Resource limitations, absence of technical supports, lack of awareness, conflict between neighboring communities and lack of uniformity of physical and biological soil and water conservation structures are identified as major determinants that affect investment on degraded lands. On the other hand, appropriate species-site matching, better awareness, good site preparation, appropriate planting techniques are identified as reasons behind the success of rehabilitation of degraded lands.

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". The problems of land degradation are most serious in tropical regions, where communities' livelihoods depend on products from land resources (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).

Although there have been several efforts made to reduce land degradation and improve land productivity in Ethiopia, farmers' investments on degraded land remain limited because of various factors. A study was conducted with the aim to identify the socio-economic factors that significantly affect investment on degraded lands and to interpret the underlying causes that affect the investments in Wulbareg district, Silte zone, SNNPR.

Brief methodology

The study was conducted in two peasant associations (PAs) (*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 key informants was conducted to classify wealth status and determine perception of the local community towards investment on rehabilitation of degraded lands. Semi-structured questionnaire was administrated to 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.

Major findings and Justification of its Importance

- Resource limitations, absence of technical supports, lack of awareness, reluctance to invest, conflict between neighboring communities and lack of uniformity on physical and biological soil and water conservation structures determine investment on degraded lands.
- Appropriate species-site matching, awareness, good site preparation, appropriate planting techniques are some of the possible reasons behind the success of rehabilitation of degraded lands
- Most of the time, programs related to rehabilitation of degraded lands are mainly monitored and financed by government bodies. Government supports 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. Other developmental actors such as NGOs, investors, and local communities also monitor and participate in the program.

Recommendations

- As resource limitations and absence of technical supports are the major reasons for the reluctance of farmers to invest on rehabilitation of degraded lands, government should take the leading role in rehabilitation programs.
- Local communities need to be motivated to invest on rehabilitation of degraded lands and capacity building programs through development of community by laws and creation of sense of ownership. Further assistance on seedling provision and materials support is critical.
- The success of some rehabilitation programs and the respective advantages and benefits gained from them are concrete evidences for local communities to further engage themselves in the program and such areas should serve as a field school.

Potential users of the information

Primarily this information is useful for forest sector development agents which directly involve in development of rehabilitation of degraded lands. These include: MEFCC, regional, zonal and district level environment protection and forest development bureaus, higher institutions, research centers, students, farmers, investors, private sector development agents, non-governmental forest development organizations, etc…

Reliability of the information

This information has been extracted from original research work and can be used for research, communication and scale-up purposes.

8. Exclosures for woody vegetation rehabilitation and carbon stock enhancement

Responsible researchers: Ashenafi Manaye

Brief description of the Information

In Ethiopia, exclosures (EXs) have been recognized as promising practices in the restoration of degraded land and providing various ecosystem services. Though, several studies have been done on the socio-economic and ecological importance of EXs, little attention has been given to woody species conservation and climate change mitigation.

Thus, this study was conducted to evaluate the roles of EXs on Woody species diversity and carbon stock potential in Endamekoni district, Northern Ethiopia. Two EXs and their adjacent open grazing lands (OGL, as control) were purposively selected from the district. A total of 60 quadrants (20mx20m) as main plots at 50 m intervals were established in both land uses. In each main plot varying sized subplots were used to collect sapling, seedlings, herbaceous plants and soil respectively.

A total of 52 woody species, belonging to 48 genera and 29 families were recorded in the two studied land uses. Of all woody species 46 and 26 species were recorded in the EXs and OGL, respectively. Abundance, species richness, Shannon diversity index, Simpson diversity index, basal area and stem density were significantly higher in the EXs than adjacent OGLs. The average woody species stem density and basal area of exclosure were 2.6 and 1.6 times higher than that of the adjacent OGL respectively. The mean total carbon stock (biomass plus soil, 0-30cm) was significantly higher in EXs than adjacent OGL. The conversion of the degraded grazing lands to EXs enhanced the SOC, AGB carbon and herbaceous carbon stock by 38, 197 and 200 % respectively. The total above ground biomass carbon stocks were significantly correlated with the species diversity. Finally, this study revealed that EXs on degraded highland contributes to improve woody species diversity and total carbon stock of biomass and soil in Northern Ethiopia. Therefore, Management plan should be developed for sustainable management of the exclosures.

Introduction

Land degradation and its management are major challenges in arid and semiarid environments (Mureithi *et al*., 2014). The arid and semi - arid dry land vegetations of Ethiopia occupying 50 % of the land area, of which Tigray is among the regions, are seriously threatened by land degradation due to deforestation and forest degradation (Birhane*et al*., 2007, Mekuria and Yami, 2013). Combating land degradation is crucial to ensure long termproductivity of these semi-arid environments. Thus, about three decades ago exclosure

was initiated to avert the degraded semi-arid lands of Ethiopia. So far, several studies conducted in Ethiopia have focused on species composition, soil properties and socio-economic importance of exclosures.

However, all of these studies could not adequately represent the diversity in agro ecology, soil, topography and EXs management. Besides, little study was conducted on effectiveness of exclosures in biomass and soil carbon stocks in the study region. Lack of scientific information on carbon sequestration of exclosures undermines the significance of this strategy for emission reduction mechanism in arid and semi-arid regions of the tropics. Therefore, the objective of this study was to determine the effect of EXs on woody species diversity and carbon stocks in the semi-arid climatic region of Endamekoni District, Tigray, Northern Ethiopia.

Brief methodology

Two EXs and their adjacent open grazing lands (OGL, as control) were purposively selected from the district. A total of 60 quadrants (20mx20m) as main plots at 50 m intervals were established in both land uses. In each main plot varying sized subplots were used to collect sapling, seedlings, herbaceous plants and soil respectively.

Major findings and Justification of its Importance

- A total of 49 woody species, belonging to 45 genera and 28 families were recorded in both EXs and adjacent DOGL. Of these, 46 woody species representing 26 families and 44 genera were recorded in the EX., whereas in the adjacent DOGL, 26 woody species representing 18 families and 26 genera were recorded.
- There was also high woody species similarity between the two studied ecosystems. The three most abundant species in the exclosures were Clutiaabyssinica, Beciumgrandiflorum and Dodonaoeaangustifolia. While Myrsineafricana, Clutiaabyssinica and Maytenusundata were the most abundant woody species in the adjacent DOGL.
- The average abundance and species richness in the exclosure were almost twice that of adjacent open grazing lands. *Juniperus procera*, *Acacia abyssinica*, *Acacia decurrens*, *Acacia saligna*, *Erica arborea* and *Dodonaoea angustifolia* were the top six most important woody species in the exclosures.
- The above and belowground woody biomass carbon stocks significantly differed between EXs and adjacent degraded open grazing lands. The above ground biomass carbon stocks accounted for 79 % of the total biomass of EXs and the total biomass carbon stock recorded in EXs was nearly twofolds of the adjacent DOGL. Overall, exclosures enhanced the soil organic carbon stock over

the adjacent open grazing land and EX showed higher ecosystem carbon stock than the adjacent DOGL.

- Generally, Exclosures on previously degraded open free grazed lands of the studied region has enhanced the recovery of woody species diversity, composition, and structure. Besides**,** exclosures assist to recover and maintain native woody species that are otherwise would be threatened from the wild.
- Moreover, the total above and belowground biomass C stocks as well as SOC stock were significantly correlated to woody species abundance and species richness. The total biomass and soil carbon stock significantly increased following the establishment of exclosures, implying that exclosures is potential land use intervention to enhance climate change mitigation and biodiversity conservation roles of degraded lands in the semi-arid region of the tropics. Furthermore, the exclosure serve in climate change mitigation strategies such as REDD+ schemes as it has been put in place in national REDD+ strategy of Ethiopia and by IPCC for boosting climate change mitigation contribution of tropical countries.

Recommendations

- Exclosure shall be promoted as best practices to enhance biodiversity conservation practices and restoration of the degraded land.
- Management plan shall be developed by relevant institutions for sustainable management of exclosures.
- Restoration activities using indigenous species such as *Juniperus procera* and *Acacia abyssinica* shall be promoted in similar agro ecologies of the study site.
- *Hagenia abyssinica*, *Myrica salicifolia* and *Salix mucronata* are the most social and ecologically important indigenous species and need to be expanded.
- Site- and species-specific biomass equations should be developed for accurate estimation of biomass of indigenous and dominant species such as *Juniperus procera, Erica arborea, Acacia decurrens* and *Dodonaoea angustifolia*.

Potential users of the information

The outcomes of this study can contribute for maintaining biodiversity conservation and climate change mitigation. Moreover, it provides inputs for drafting rehabilitation of degraded land and scaling up exclosures in Tigray Region and beyond. In addition; this finding can be additional sources of material for policy makers, researchers, governmental institutions, NGOs and can be used to create awareness among the community in the importance of exclosures in their effort of land rehabilitation.

Reliability of information

This information is extracted from an MSc thesis which is reviewed by supervisors from EEFRI, Hawassa University WGCF &NR .

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

Responsible researcher: Desalegn Getinet

Brief description of the information

Home gardens are the most popular and very common agroforestry practices (AFPs) in many parts of Ethiopia. Cash crops like coffee and khat are involved in some of these multistrata AFS and are among the top three export products in the country.

More recently, AFPs have been challenged by population pressure, shrinking farm size, poverty and a new market situation. The short term economic benefit has driven the multi-strata AFS towards monoculture production such as khat (*Catha edulis*) and eucalyptus species. Reports show 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. This study was therefore, aimed at comparatively evaluating the potential of biomass and soil organic carbon stocks of multi-strata agro forestry systems and Khat (*Catha edulis*) monoculture farming in Raya Azebo Northern Ethiopia. The highest stem density was recorded for the Khat Farm (KF), followed by Coffee Agro forestry (CAF) and Fruit Agro forestry (FAF) 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 KF (23.3 Mg C ha^{-1}). The highest total SOC stock was recorded in CAF and the least in KF.

Introduction

Anthropogenic factors such as use of fossil fuels, deforestation and land use changehave resulted in emission of GHGs. The relative contribution of tropicaldeforestation and forest degradation account for 12 % of the total CO2 emission (van derWerf*et al.*, 2009; FAO, 2014). Forest resources are subjected to extensive deforestationand forest degradation for expansion of agriculture, fuel-wood collection, and illegallogging among others. This has necessitated looking for complementary land use such asagroforestry systems (AFS) for enhancing climate change mitigation roles.

Agroforestry systems at global scale have a potential to sequester carbon over the next 50 years. 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).

However, 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 in the country. 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. 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. 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.

Brief methodology

The study was conducted in Raya Azebo, Northern Ethiopia. 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. Three sub-plots that measured 1 m x 1 m were randomly laid down (nested) within a bigger plot to collect litter samples. All woody species ≥ 2.5 cm in diameter at breast height (dbh) and total height (h) ≥ 1.5 m were measured across the three studied systems. Additionally, for coffee and khat plants, stump diameter at 40 cm above the ground (d40) and basal diameter at height of 10 cm above the ground (d10) were recorded, respectively.

A total of 120 composited soil samples were collected across the three farming systems using a soil auger for determination of SOC, TN, pH and texture analysis. Total aboveground biomass C stocks defined as the sum of tree, coffee, khat and litter biomass C stock, and total belowground biomass C stocks defined as the sum of the C stocks associated with tree, coffee and khat plant stumps and coarse roots. Total biomass C stocks defined as the sum of the total aboveground and belowground biomass C stocks were calculated using standard equations respectively.

Major findings

General stand characteristic

- The highest stem density was recorded for the Khat Farm (KF), followed by Coffee Agro forestry (CAF) and Fruit Agro forestry (FAF) systems.
- The stem density of native woody species accounted for 16 % and 22 % of the total in the Fruit and Coffee basedAgro forestry, respectively. The basal area of native woody species shared 35 % and 49 % of the total in Fruit Agro Forestry and Coffee based Agro Forestry, respectively. This is because basal area is highly influenced by tree diameter than stem density.

Biomass Carbon Stock

- 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 KF (23.3 Mg C ha^{-1}).
- The proportion of total aboveground C to the total C stock was on average 76 % (ranged from 74 to 78) for all the three AFP.
- Woody 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 carbonstocks varied among the three studied systems.
- Litter biomass carbon shared 4.7 %, 5 % and 5 % of the total biomass C stocks in FAF, CAF and KF, respectively.

Soil Organic Carbon Stock

- The soil C stocks 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 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 agro forestry systems to Khat farming would decline SOC stocks by 20 to 21 % at 60 cm depth.

Ecosystem Carbon Stocks for the Studied Systems

- The highest total C stock was recorded in CAF followed by FAF and KF respectively.
- The SOC accounted for 69, 71 and 82 % of the total ecosystem C stocks in CAF, FAF and KF, respectively.

Recommendations

- Maintaining coffee and fruit-coffee based agroforestry practices would better serve to enhance carbon accumulation potential of the agricultural landscapes in the study area than khat farming.
- Promoting the CAFS and FAFS and shade trees in smallholding farmers, will support large sinks of C and help to mitigate climate change.
- Ongoing threats of observed human activities such as Khat expansion and limited tree density in smallholdings will likely diminish biomass carbon pools unless effective policy measures are enforced.

Potential user of the information

- Policy makers
- Forest development sectors
- Educational and research institution.
- Scientific community

Reliability of information

This information has been extracted from original research work.

10. Domestication of high priority indigenous woody plant species in selected pastoral and agro pastoral areas.

Responsible researchers: Abyneh Derero (PhD)

Brief description of the information

The degradation and shrinkage of the traditional pastoral territory and the natural vegetation coupled with climatic change has made pastoral communities food insecure and requiring support with tree domestication technologies including fruit and fodder trees. To this end this study was conducted to identify high priority indigenous woody plant species for domestication in four selected districts of Afar and Somali regions of Ethiopia through structured questionnaire survey.

Ziziphus mauritania, C*ordia sinensis*, *Acacia nilotica*, *Tamarindus indica*, *Berchemia discolor*, *Acacia tortilis* and *Dobera glabra* were prioritized in a descending order by the pastoralists and agropastoralists based on their level of importance to the livelihood of the community. However, *Z. mauritania* and *C. sinensis* were by far the two most preferred species for planting. Though the contribution of the woody species *Salvadora persica*, *Grewia species* and *Ximenia americana* to livelihood were highly valued, they were less preferred for planting by the pastoralists and agro pastoralists.

Introduction

Pastoral and agro pastoral areas are one of the food insecure areas. The degradation and shrinkage of the traditional pastoral territory and the natural vegetation coupled with climatic change manifested by shortage of rainfall and recurrent drought and compounded by limited policy support has made pastoral communities food insecure to the extent of threatening their livelihoods and making them dependent on relief handouts. There is a remarkable seasonal variation in availability and quality of feed sources due to variation in rainfall distribution. When dry season is prolonged or during drought years animals become unproductive. The agro pastoralists engaged in crop production need to be supported with tree domestication technologies since establishment and management of fruit and fodder tree species in the farming system can benefit them with both income and tree products for household consumption.

The objective of the experiment is to identify and prioritize woody plant species for domestication, determine planting scheme preferences, investigate the experiences of the local people on the uses of trees, tree establishment and management and determine the role of woody plant species and their products in household economy.

Brief Methodology

Formal survey was conducted to collect data from the four selected *districts* mainly through questionnaire and focused group discussion (FGD). Key informant interview was also conducted to get more concrete information about people's preferences. The questionnaire was pre-tested for its consistency, logical flow and length and corrected as per the feedback obtained from the test.

Major findings and Justification of its Importance

- The high priority species selected by the pastoralists and agropastoralists for planting in the order of priority were *Ziziphus mauritania*, C*ordia sinensis, Acacia nilotica, Tamarindus indica, Berchemia discolor, Acacia tortilis* and *Dobera glabra*. However, *Z. mauritania* and *C. sinensis* were by far the two most preferred species for planting.
- Though the contribution of the woody species *Salvadora persica, Grewia species* and *Ximenia americana* to livelihood were highly valued, they were less preferred for planting by the pastoralists and agro pastoralists.
- Camel, goat, sheep and cattle browse and feed on the leaves and fruits of the woody species. However, fruits of *Ziziphus mauritania* are feed resource to none of the livestock; fruits and leaves of *Salvadora persica* are not feed resource to cattle; and fruits of *Grewia sp*. are feed resource only to camel but leaves browsed by both camel and sheep.
- Furthermore, it was found from the discussions that the fruits of *Ziziphus mauritania, Cordia sinensis, Dobera glabra, Tamarindus indica* and *Berchemia discolor, Grewia sp, Ximenia americana* are marketed whereas fruits of *Salvadora persica* and all of the fodder resources are not marketed.

Key Policy Recommendations

The survey results of this study identified priority woody plant species for supporting tree domestication in pastoral and agro pastoral areas. It is thus recommended that tree planting scheme in those areas should give due attention to planting the preferred species by the local communities.

Potential users of the information

Pastoralists and agro pastoralists.

Reliability of information

The information is reliably available at CEEFRC as it was conducted as part of tree domestication mega research project.

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

Responsible researchers: Mihert Semere, Mesele Negash,

Brief description of the information

Forest ecosystems and other ecologically and environmentally sustainable land uses act as a sink for CO_2 by storing carbon as biomass. Thus, the present study was aimed to examine biomass and soil carbon stock potentials of home garden and woodlot AFPs, khat and cultivated land in ChehaWereda, Gurage zone, Ethiopia. Appropriate methodologies were applied to come up with potential results to conclude about the total ecosystem carbon stock potential of the studied land use practices. Accordingly, the results showed that the total ecosystem carbon stocks in home garden were significantly higher than woodlot AFP. The SOC stock was significantly different among the studied land uses. The highest SOC stock was recorded in home garden agroforestry system followed by cultivated land and woodlot agroforestry.

Introduction

Land use management is an important option in reducing CO_2 concentration. Agro forestry 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 (Nair, 1993). These have been recognized to sequester carbon and have therefore gained attention from both industrialized and developing countries (IPCC, 2000).

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 largely aimed at assessment of biomass and soil carbon stocks accumulation potentials of AFS and adjacent cultivated land in the selected study area. The study was intended to estimate and compare above and below ground biomass carbon stocks and SOC stocks of home garden, woodlot AFP and cultivated land.

Brief Methodology

A preliminary reconnaissance survey was conducted to identify the study area representative kebeles. Key informants i.e. development agents, elders and district's natural resource experts were consulted to identify dominant agroforestry system. Accordingly, two representative kebeles were selected based on agroforestry dominance, accessibility and available resource and time. This sampling size determination has considered the availability of resources and accessibility. Woody species inventory and soil sampling

has been conducted in a plot size of 20m x 20m laid down in each sample farm following Pearson *et al.* (2005). This sampling was carried out to acquire all possible data which are important for further analysis.

Major findings and Justification of its Importance

- This study shows that AFS have high carbon stock potential compared to cultivated land use systems. The total ecosystem carbon stock ranged between (55 MgC ha^{-1} -140 MgC ha^{-1}). Higher carbon stock in both biomass and SOC was observed in homegarden AFS (100.4Mg ha^{-1}) followed by woodlot AFS (72.9Mg ha^{-1}). Thus, higher biomass carbon stock in homegarden AFS (6.09Mg ha^{-1}) than woodlot AFS (4.74Mg ha^{-1}) were recorded but the difference was not significant. 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. In general, amongst the studied land uses the highest mean ecosystem carbon stock was recorded for homegarden and the least was for woodlot AFS.
- In conclusion this study showed that land use conversion has a significant effect in biomass and SOC stock potential. It also indicates the overall information about carbon stock potential of AFP in this particular study site.
- It also implies, practicing mixed agroforestry systems could support soil fertility and enhance production than mono cropping system. AFS has great potential for 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.

Key Policy Recommendations

- 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.
- Governments should consider agroforestry which could offer an opportunity for sequestering a large amount of carbon, at the same time meeting demand for other household requirements and other socio-economic activities in smallholder farms.
- In addition, the current policy agenda on recognition of agroforestry as climate change mitigation strategies are strengthened by this study.

Potential users of the information

This information can be used by government and non-governmental organization, research, academic institutions and scientific communities. Most importantly this finding will be functional for works in relation with carbon stock estimations to quantify the role of different land use systems with respect to climate change mitigation.

Reliability of the information

The findings of this thesis research work are based on original experimental research by WGCF-NR/ with support of EEFRI.

12. Socio-economic and Environmental Impacts of Community-Based Rehabilitation Programs on Degraded lands: The case of Silte Zone, Southern Ethiopia

Responsible researcher: Biruk Birhan

Brief description of the Information

Even though 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. Thus, 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, Wulbareg district, Silte Zone of southern Ethiopia and assessed and evaluated the socio-economic and environmental impacts of community-based rehabilitation programs on the degraded lands. A total of hundred (100) respondents were randomly selected to assess the impact of community rehabilitation of degraded lands on the farmers' livelihood improvement. The study used descriptive analytical method based on field observations, interviews with key informants, household survey questionnaire, and focus group discussion that was supplemented by data from district office of agriculture.

The study revealed that the household income of the majority (91 %) of respondents was enhanced due to remuneration gained through area exclosure. Meanwhile, 43 % of the respondents agreed that the rehabilitated land created better prospect of employment for the nearby community members. Greater part of the vegetation cover in the exclosed area was substantially enhanced in terms of biodiversity and species density. Fodder availability increased considerably that enabled them to feed their livestock.

Hence, the rehabilitation of degraded land through enclosures is relatively low-cost and reverses land degradation processes by improving the availabilty of livestock fodder, wood-fuel and grass for house construction; and enhancing biodiversity. It has the potential to be scaled up quickly in areas where tree and shrub species have the ability to re-sprout and where rights to resource are secured. Associated advantages include reduction in runoff and soil.

Introduction

In many developing countries land degradation has caused 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.

The practice of rehabilitation of degraded ecosystems is becoming an option to reclaim degraded sites In Ethiopia and as a result the trend of rehabilitation made in different watersheds has improved ecosystem health and land productivity. However, the current rate and status of environmental degradation still calls for more extended and coordinated intervention actions to rehabilitate degraded lands.

Exclosures are among the various land management and rehabilitation strategies practiced to improve species diversity, soil quality and ecosystem productivity. 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.

Efforts are 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 programs. There is lack of information on the survival of millions of planted trees and the socio-economic and ecological importance of these programs. 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.

Brief Methodology

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

Major findings and Justification of its Importance

- Exclosures have considerable contributions to the socioeconomic and ecological systems; as they generate both ecological and socioeconomic benefits.
- Majority of the local communities developed sense of belongingness and developed positive attitude to the performance of exclosures. Such perception is a base mark for future sustainability of the practice.
- Some socioeconomic impacts of exclosures include: increased income for individual households, increased crop production and ability and willingness to use/afford energy saving cocking stoves. Generally, the households' income was enhanced significantly due to remuneration gained through area exclosure.
- Moreover, rehabilitated land created better prospect of employment for the nearby community members and contributed for increment of crop yield production.
- The vegetation cover in the exclosed area was substantially enhanced in terms of species abundance (biodiversity) and density. Side by side fodder availability increased considerably in the exclosed area that enabled them to feed their livestock that the farmers' stern.
- Soil erosion and related devastations around farmers'/household near rehabilitated land were significantly decreased after area exclosure.
- In addition, considerable increment on availability of medicinal shrubs and herbs in the exclosed area increased that support farmers' customary healthcare system.
- In summary community-based rehabilitation programs in degraded lands i.e. restoration through exclosure 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 rehabilitation of degraded land through the deployment of exclosures 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, wood-fuel and grass for house construction; and enhances biodiversity. If all benefits are taken into account, exclosures provide a better return than other agricultural land uses such as intensive cultivation and livestock grazing.

Key Policy Recommendations

- Promoting natural regeneration (assisted and farmer-managed natural regeneration) is 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 secured.
- Collaboration at the local level among scientists and stakeholders, along with community involvement, are keys to the successful application of the ecological restoration program in the study area.
- Previous attempts to improve the rehabilitation and productivity rate of exclosures 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 exclosures.
- Rehabilitation of degraded land activities must be accompanied by technological innovations that will enhance the productivity and rehabilitation rate.

Potential users of the information

Primarily this information is useful for forest sector development agents which are directly involved in development of rehabilitation of degraded lands. These may include: MEFCC, regional, zonal and district level environment protection and forest development bureaus, higher institutions, research centers, students, farmers, investors, private sector development agents, non-governmental forest development organizations, etc…

Reliability of the information

This information has been extracted from original research work by EEFRI researchers.

13. Acacia S.I Seeds Insect Predators in Ethiopia

Responsible reseaecher: Abraham Yirgu

Brief description of the Information

Pre-dispersal seed predation study was conducted on *Vachellia abyssinica* (*syn. Acacia abyssinica*), *Senegalia senegal* (*syn. Acacia senegal*), *Vachellia seyal* (*syn. Acacia seyal*) and *Vachellia tortilis* (*syn. Acacia tortilis*) around Lake Langano and Menagesha forest to identify the associated seed predators and determine their impact on seed germination. Eight seed beetles namely: *Bruchidius albosparsus*, *B. aurivillii*, *B. djemensis*, *B. discoidalis*, *B. sinaitus*, B. silaceus, *B.* sp 411, and *B. simulans* were found associated with seeds of these study species. These predators damaged less than 9% of the seeds on the study species. Infested seeds exhibited lower percent of germination. This study unrecorded lists of pre-dispersal seed predators associated with seeds of *Vachellia* and *Senegalia* species in Ethiopia.

Introduction

The seeds and pods of different *Acacia* s.l. species are prone to the attack of insects (such as beetles (Coleoptera: Chrysomelidae: Bruchinae), plant bugs (Hemiptera), moths and butterflies (Lepidoptera), and phytophagous wasps (Hymenoptera)), rodents, fungal decomposition, species of wild animals and livestock. Of these pests, Bruchinae are the major pests on trees and shrubs of Leguminosae growing in dry and tropical environments. Following damage to the cotyledon, the viability of infested seeds is threatened, although they may not be rendered nonviable.

Although the damage by different seed predators in Ethiopia on the seeds of *Vachellia* and *Senegalia* species is observed, there is insufficient information on the type and rate of seed infestation in different *Acacia* s.l. species. Therefore, the objectives of this study were to: (1) collect and describe seed predators involved in seed damage of *Senegalia senegal* (locally known as *Idado, Sabansa dima, Sapessa*), *Vachellia abyssinica* (locally known as *Lafto*), *V. seyal* (locally known as *Wachu*) and *V. tortilis* (locally known as *Tedecha*); (2) determine the level of damage; and (3) analyze the impact of seed predators on seed germination of these species in Ethiopia.

Methodology

Seed pods that had not yet dehisced were randomly collected from more than 10 healthy and mature trees separated 50 m apart. Pods were obtained by shaking branches of study trees over a canvas sheet that was spread beneath the canopy. These pods were dried in the sun and threshed lightly to release seeds onto the canvas sheet. Seeds that were perforated by beetle larvae were handpicked and kept in plastic vessel

covered with nylon mesh to allow emergence of adult bruchines. Percentage of seed damage and position of adult beetle emergence holes were examined from 250 g seeds. The association between number of holes in the pods and number of damaged seeds were analyzed before the pods threshed and release seeds. Seed germination were determined after different treatments: control (no treatment), healthy seeds that were nicked (cut) at the tip of seeds using scissors to promote germination, beetle damaged seeds with one exit hole at the tip of the seed, beetle damaged seeds with one exit hole at the broader width or bottom part of the seed and beetle damaged seeds with the one exit hole at the bottom part but nicked.

Major findings and its Importance

Seed beetle emergence

The seeds of S. senegal, *V. tortilis*, *V. seyal* and *V. abyssinica* were attacked by different Bruchid *seed* beetle. The level of seed attack on the above species was 9, 7, 6 and 4%, respectively. More number of seeds had single than multiple exit holes. The number of holes observed on the surface of the pods were corresponds with the number of damaged seeds inside the pods. Both number and position of seed perforation affected percent of germination. Accordingly, seeds having more number of perforations at their bottom of the seeds have lower percent of germination, that is the position of developing embryo.

Recommendations

- Seed collectors should visually inspect collected seeds during and after collection,
- Fumigation of infested seed is necessary whenever possible,
- Future study need to assess the distribution, abundance and effects of pre-dispersal seed predators on other *Acacia* s.l. species.

Potential users of the information:

- Seed collectors and distributors, tree growers, researchers and educators

Reliability of the information:

- This work has followed and established methodologies in the study of insect science and published in peer-reviewed Journal.

14. Fungal plant pathogens on the plantation forests in Amhara and Tigray Regions, Ethiopia

Responsible reseaecher: Wendu Admasu

Brief description of the Information

Forest plantations in Ethiopia constitute mainly exotic species of *Eucalyptus, Cupressus, Casuarina, Pinus* and the native *Juniperus* species. The production of these plantation species is currently under great challenges due to disease causing agents. As plantation tree disease is an emerging problem, there is lack of comprehensive information on the nature of the diseases, their symptoms, key pathogens and appropriate management systems in the country. As demands of plantation trees increases for different purpose; knowledges of key pathogens that cause diseases with associated symptom is very important to minimize the loss of plantation trees due to diseases in the country. The findings of this study indicate that leaf blight, leaf spot, tip blight and stem canker were the most common diseases observed on the plantation trees studied in Amhara and Tigray regions. The result of the study shows fungal isolates belonging to *Phoma lingam, P. glomerata* were the cause for stem canker diseases in the stems and branches of *Eucalyptus globulus* and chocolate spot diseases were recorded on the leaves of *Eucalyptus globulus* and *E. camaldulensis* caused by *Alternaria alternata, Curvularia* sp., *Pestalotiopsis* sp., whereas *Penicillium* sp were found causing leaf blight disease in a pattern of co-infection in the leaves of *E. globulus, E. camaldulensis.* In addition, tip blight of *Lasiodiplodia theobromae were* found on *Cupressus lusitanica and Juniperus procera* trees. The study aims to provide base line information on the types of diseases, causal fungal pathogens and associated symptoms during infections so that it can be easily differentiated and timely managed through appropriate integrated management options.

Introduction

Plantation forests are more susceptible to diseases than natural forests. About 70 to 80 percent of tree diseases are caused by fungal pathogens around the world. Ethiopia has an estimated 972,000 ha of land covered by commercial plantations, smallholder eucalypt woodlots and community forests, mainly used for construction and fuel wood. The major plantation tree species includes *Eucalyptus*, *Cupressus*, *Casuarina*, *Pinus* and *Juniperus* species. These species are widely planted in Oromia, Amhara, Tigray and the Southern Nations, Nationalities and People's Regions.

Forest plantations of Ethiopia are at varying degrees of attack by disease causing agents. Some of these diseases include leaf disease on *Eucalyptus spp* and *Cupressus lusitanica*; shoot blight and dieback of *Pine* spp. Ethiopia has limited information on the plantation tree diseases, causal pathogens and their

symptoms. In some cases, there is an extent of confusion in differentiating between disease symptoms and non-infectious disorders caused by climate anomalies, nutrient deficiencies and poor species site match. A study was conducted on twenty selected localities of Amhara and Tigray regions. They were assessed in order to fill the existing information gaps on plantation forest diseases of these regions. Therefore, the objective of this study was to identify type, diversity and distribution of pathogenic fungi associated with plantation forest trees causing diseases in Amhara and Tigray regions of Ethiopia.

Methodology

A survey was carried out in commercial stands, farmland trees and woodlots in selected plantation sites in Tigray and Amhara regions. Sample of symptomatic tissues were collected from leaves, needles, branches and segments of stems. Isolation, characterization and morphological identification of fungi were carried out in artificial growth media from these symptomatic plant parts. Fungal isolates were identified to genus and species level based on macro- and microscopic morphological features of colony of the culture and spore morphology. Pathogenicity test on isolated fungi was done to meet Koch's postulate (proof of pathogenesity) on respective host plant.

Major findings and importance of the information

42 pure cultures of fungi were isolated from study species and were morphologically identified. These isolates belong *Phoma lingam, P. glomerata, Alternaria alternata, Lasiodiplodia theobromae, Curvularia* sp., *Pestalotiopsis* sp. and *Penicillium* sp. These fungal pathogens were assumed to be the most virulent causing massive tree death by infecting leaves, needles, branches and stems especially when there is prolonged environmental stress. Some of the most common diseases were leaf blight, leaf spot, stem canker and tip blights on leaves, needle tips, branches and stems of studied tree species. Leaves were seen associated with brown to black spots, separated or aggregated and often located at the margins with brown to grayer coloration in *Eucalyptus globulus* and *E. camaldulensis* plants. Tip blight symptoms were commonly observed on the needles and branches of *Juniperus procera* and *Cupressus lusitanica* trees. The stems of *Eucalyptus globules* were observed with elongated, grayish, hell brown to dark brown border between discolored tissues lession.

The morphological characterization of isolated fungi revealed that 14 (33.3%) of the fungi belongs to *Alternaria alternata*, 15(37.7%) *Phoma* (*Phoma lingam* and *P. glomerata*), *Lasiodiplodia theobromae* 3(7.2%), 7(16.7%) *Pestalotiopsis* sp., 2(4.7%), *Curvularia* sp., and 1(2.4%) *Penicillium* sp. Of these, *P. glomerata* were proven to cause stem canker diseases on the branches and stems of *E. globules*, whereas *P. lingam*, also known to cause chocolate spot leaf diseases on *E. globulus* and *E. camaldulensis.* Four species namely, *A. alternata*, *Curvularia* sp., *Pestalotiopsis* sp. and *Penicillium* sp, were found to cause

leaf blight disease on leaves of *E. globules* and *E. camaldulensis*. The findings from this study confirmed that fungal plant diseases are among main factors that challenge the successful production of tree plantations in Amhara and Tigray regions. The out puts of this study provide basic preliminary information on types of plant disease that can possibly cause potential damage on plantation trees in the regions and to take appropriate management systems to control and prevent those diseases during an incidence.

Key Policy Recommendations

Training on the basic concepts and management options regarding those diseases. Management options can be one or more combinations of cultural management techniques:

- Using healthy, clean or disease-free planting materials
- Growing resistant varieties
- Providing better care and management
- Maintaining proper field sanitation
- Adjusting suitable sowing and planting dates
- Rouging out diseased plants whenever necessary
- Following plant quarantine regulations
- Using proper fertilizer when necessary to boost host immunity
- Proper watering, when there is prolonged environmental stress

Potential users of the information:

- Researchers, Government extension workers, public and private enterprises, tree farmers

Reliability of the information:

- This work followed established methodologies on tree diseases and published in peer-reviewed international journal of plant pathology

15. Fifty-One Tree Seed Standards

Collaborative work: EEFRI (Tree Seed Technology Coordination Unit), ESA (Ethiopian Standards Agency) and stakeholders; EEFRI was representative of the standards and also initiator of the work.
Implemented by: EEFRI, ESA and other stakeholders

Brief description of the Information

Standardization is the process of implementing and developing technical standards based on the consensus of different parties that include firms, users, interested groups, standards organizations and government agencies. Thus, Tree Seed Technology Coordination Unit (TSTCU) of EEFRI in consultation and together with the Ethiopian Standards Agency (ESA) that is responsible in guaranteeing the qualities and applicability of the standards, hold a consultative meeting among key stake holders (MEFCC, Public Forest Enterprises, Private Seed Enterprises, Regional Bureaus of Forests and Environmental Protection-SNNP, EEFRI, EBI, MoA) on 03 Mach 2017. The consultative meeting established a Technical Committee, namely TC-133, that is dedicated for Tree seed standards, as the need arises. Thus, during the consecutive months of the budget years 2017 and 2018, TC-133 has developed a total of 51 tree seed standards, i.e. 46 new, one tree seed terms and definitions and four re-affirmed tree seed standards (Table 8). The 51 standards were subjected for two approvals (1) approval by the technical committee as a whole, (2) approval by the Ethiopian Standards Council that was held on the 18th of August 2017 and August 2018. The contents of the standards include: Scope, Normative References, Definitions, Requirements, Specific Requirements, Sampling and test, Packaging, storage and handling, Labeling and Bibliography.

Introduction

Unlike the past nearly forty years when the then Forest Research Center was a sole supplier of tree seed, currently many actors are involved in the tree seed supply system in Ethiopia. Currently, private seed enterprises, individual suppliers, regional public seed centers of Forest Enterprises such as the Dimma Seed Processing and Storage Center of the Oromia Forest and Wildlife Enterprise (OFWE) and Bahir Dar Forest Seed Center of Amhara Forest Enterprise (AFE), Hawassa Tree Seed Processing and Distribution Center of the SNNPR's Environment and Forest Protection Authority and the Tree Seed Technology Coordination Unit of the Ethiopian Environment and Forest Research Institute (EEFRI) are engaged in seed collection, processing, testing and distribution. Thus, controlling the quality of seed, by setting specific standards and maximizing safety and quality of seeds thereby support the seed business to

make progress through rising competitive market advantages and contributing towards the efficient implementation of aforestation, reforestation and restoration programs of the country is required. The objective of developing tree seed standards was to contribute towards these requirements in Ethiopia.

Major findings and its Importance

The following fifty-one tree seed standards (Table 10) are developed by TC-133 and approved by the National Standards Council

Table 10 Fifty-one seed standards approved by TC-133 and the National Standards Council in 2017 and 2018 in Ethiopia

S. No.	Designation Number	**Title of the Standard**	Remark
1	ES 6098: 2017	Terms and definitions	New
2	ES 6099: 2017	*Acacia abyssinica Seed-Specification*	New
3	ES 6100: 2017	*Acacia albida Seed-Specification*	New
4	ES 6101: 2017	*Acacia decurrens Seed-Specification*	New
5	ES 6102: 2017	*Albizia lebbeck Seed-Specification*	New
6	ES 6103: 2017	*Acacia nilotica Seed-Specification*	New
7	ES 6104: 2017	*Acacia polyacantha Seed-Specification*	New
8	ES 6105: 2017	*Acacia saligna Seed-Specification*	New
9	ES 6106: 2017	*Acacia senegal Seed-Specification*	New
10	ES 6107: 2017	*Azadirachta indica Seed-Specification*	New
11	ES 6108: 2017	*Casuarina equistifolia Seed-Specification*	New
12	ES 6109: 2017	*Cordia africana Seed-Specification*	New
13	ES 6110: 2017	*Cupressus lusitanica Seed-Specification*	New
14	ES 6111: 2017	*Delonix regia Seed-Specification*	New
15	ES 6112: 2017	*Dovyalis abyssinca Seed-Specification*	New
16	ES 6113: 2017	*Eucalyptus camaldulensis Seed-Specificati*	New
17	ES 6114: 2017	*Eucalyptus globulus Seed-Specification*	New
18	ES 6115: 2017	*Eucalyptus grandis Seed-Specification*	New
19	ES 6116: 2017	*Eucalyptus saligna Seed-Specification*	New
20	ES 6117: 2017	*Grevillea robusta Seed-Specification*	New
21	ES 6118: 2017	*Hagenia abyssinica Seed-Specification*	New
22	ES 6119: 2017	*Jacaranda mimisifolia Seed-Specification*	New
23	ES 6120: 2017	*Juniperus procera Seed-Specification*	New
24	ES 6121: 2017	*Melia azedarach Seed-Specification*	New
25	ES 6122: 2017	*milletia ferruginea Seed-Specification*	New
26	ES 6123: 2017	*Moringa stenopetala Seed-Specification*	New
27	ES 6124: 2017	*Olea africana Seed-Specification*	New
28	ES 6125: 2017	*Pinus patula Seed-Specification*	New
29	ES 6126: 2017	*Pinus radiata Seed-Specification*	New
30	ES 6127: 2017	*Podocarpus gracilior Seed-Specification*	New
31	ES 6128: 2017	*Schinus molle Seed-Specification*	New
32	ES 6227: 2018	*Ekebergia capensis Seed-Specification*	New

33	ES 6227: 2018	*Eucalyptus citriodora Seed-Specification*	New
34	ES 6228: 2018	*Eucalyptus viminalis Seed-Specification*	New
35	ES 6229: 2018	*Prunus africana Seed-Specification*	New
36	ES 6230: 2018	*Tamarindus indica Seed-Specification*	New
37	ES 6231: 2018	*Ziziphus spina-christi Seed-Specification*	New
38	ES 6232: 2018	*Parkinsonia aculeata Seed-Specification*	New
39	ES 6234: 2018	*Acacia seyal Seed-Specification*	New
40	ES 6235: 2018	*Acacia tortilis Seed-Specification*	New
41	ES 6236: 2018	*Balanites aegyiaca Seed-Specification*	New
42	ES 6237: 2018	*Callistemon citrinus Seed-Specification*	New
43	ES 6238: 2018	*Cupressus pyramidalis Seed-Specification*	New
44	ES 6239 : 2018	*Dovyalis caffra Seed-Specification*	New
45	ES 6240: 2018	*Dodonaea angustifolia Seed-Specification*	New
46	ES 6241: 2018	*Spathodea nilotica Seed-Specification*	New
47	ES 6233: 2018	*Acacia melanoxylon Seed-Specification*	New
48	ES 443_2000)	*Leucaena Seed - specification*	Re-afirmed
49	ES 442_2000	*Sesbania Seed - specification*	Re-affirmed
50	ES 444_2000	*Tree lucerne Seed - specification*	Re-affirmed
51		*Pigon pea Seed - specification*	Re-affirmed

Key Policy Recommendations

The 51 tree standards are one of the main tools for maintaining quality seed supply. Thus:

- Seed suppliers should select mother trees, collect and process seeds, conduct quality testing and distribute seeds based on the set standards.
- Seed buyers that are either purchasing through Ethiopian Purchase and Procurement Agency or directly purchasing from seed suppliers should consider seed quality as a prerequisite before proceeding to evaluating seeds from price and other criteria perspectives. This will guarantee production of the required amount and quality of seedlings under nursery conditions for the intended afforestation, reforestation and rehabilitation purposes.
- Regional and federal government offices that are concerned with tree seed procurement and seedling production should ensure if seed collection is conducted from intended seed sources.
- A proclamation or seed regulation that is the basis for implementation of these standards should be ratified and be in place to regulate quality seed provision to seedling producers.
- Certification of Seed Sources is another important intervention that highly supports quality seed supply and enhanced implementation of the standards. Thus, it should be conducted as follow up of these standards.

- As implementing these standards is a new start in Ethiopia, many feed backs may come from seed suppliers and stakeholders that may urge further improvement of the standards. Thus, the standards need to be improved based on the feed backs.

Potential users of the information:

- Public and private forest enterprises, tree seed suppliers, government and nongovernment organizations, research centers, universities, informal seed suppliers

Evidence of originality, publicity

- The standards are developed by using long years laboratory data and field experiences of tree seed lab of Forestry Research and that of regional seed centers. Discussion was made amongst stakeholders and consensus reached. It is defended and finally approved by the National Standards Council.

16. Seed source development, seed collection, handling and distribution

Responsible Researchers: Yigardu Mulatu and Neway Adele

Brief description of the Information:

Seed is the most widely used propagation material for tree planting in Ethiopia. Unlike the last decades, during the past five years, different enterprises and individuals were engaged in the seed supply system. Engagement of these suppliers has resulted in highly increased seed supply, more than 10-fold in the country. The main problem at the moment is the low quality of seeds that are distributed for tree growers. Thus, technically supporting seed supplies through training, availing reference materials is required. Technical manual was developed to fill the technical gaps along the seed supply system. The manual has four chapters. Chapter 1: definition and type of seed sources, establishment of seed sources, seed source registry; Chapter 2: seed biology, i.e. types and definition of seeds, collection and handling, reproductive biology; Chapter 3: seed quality testing, storage, distribution and registry. The manual is published by the Ethiopian Environment and Forest Research Institue. It has 37 pages.

Introduction

Starting from the last five years, the tree seed supply of Ethiopia has increased dramatically, more than 100 tons per year. However, the genetic quality, morphological and physiological capacity of seeds under distribution is generally low. This requires technical backstopping and technical capacity building. This manual is developed based on this understanding.

Key Policy Recommendations

- Theoretical and practical trainings should be given as per the technical issues covered in this manual.
- The manual should be printed in adequate quantity and be addressed to concerned actors at local level.

Potential users of the information:

- GOs such as offices of Environment and Forests, offices of Agriculture and Natural Resources
- Public Forest Enterprises such as Orimiya Forest and Wildlife Enterprise, Amhara Forest Enterprise.
- The private sector including the existing tree seed enterprises.
- Consultancy firms, professional societies, etc.

Evidence of originality, publicity

- The manual is developed by using literature review and practical field experiences. Hence can be applied without any reservation.

17. Safe tree climbing and seed collection

Responsible Researchers: Yigardu Mulatu and Shimelis Tadesse

Brief description of the Information

Seed collection methods depend on the stature of mother trees and nature of the fruit/seed mother trees bear. One of the methods of seed collection from emerging trees is by climbing using climbing equipments, protective tools and safety materials. This manual is developed by adopting the lecture notes of Danish lecturers who had given practical training in 1989 to the then National tree seed Project. The manual has four chapters. Chapter 1: Forest activities that need special safety and tree climbing technuiques; Chapter 2: Modern tree climbing techniques, equipments; Chapter 3: Seed collection techniques while a seed collector is on the tree, and Chapter 4: Knots and splices. The manual has 65 pages.

Introduction

Starting from the last five years, the tree seed supply of Ethiopia has increased dramatically, more than 100 tons per year. However, these increments was achieved by traditional way of climbing the trees putting work men under danger of falling from the tree branches and losing lives. Hence, climbers should be equipped with life saving materials and trained about safe climbing of trees while collecting tree pods and fruits. Therefore, this manual is developed for seed collectors based on this understanding.

Key Policy Recommendations

- Theoretical and Trainings should be given as per the technical issues covered in this manual.
- The manual should be printed in adequate quantity and be addressed to actors at local level.

Potential users of the information:

- GOs such as offices of Environment and Forests, Offices of Agriculture and Natural Resources
- Public Forest Enterprises such as Orimiya Forest and Wildlife Enterprise, Amhara Forest Enterprise.
- The private sector including the existing tree seed enterprises.
- Consultancy firms, professional societies, etc.

Evidence of originality, publicity

The manual is developed by using literature review and practical field experiences. Hence can be applied without any reservation.

18. Biology and Management of Indigenous Bamboo Species of Ethiopia

Responsible Researchers: Yigardu Mulatu, Asabeneh Alemayehu and Zebene Tadesse

Brief description of the Information*:*

Ethiopia possesses two very important indigenous bamboo species (African alpine bamboo or *Yushania alpina* and lowland bamboo or *Oxytenanthera abyssinica*) that have numerous traditional and industrial applications. Area coverage of bamboo forest comprised by the two species is estimated at 1.47 million ha very recently (INBAR, 2017). Technical extension packages and technical knowhow to be followed while managing and developing bamboo forests are hardly available.

Based on this understanding, a book entitled "Biology and Management of Indigenous Bamboo Species of Ethiopia" that comprises both technical aspects, step by step procedures and management guideline was written based on research and practical field experience of three authors. The book has four chapters that are intended to fill the knowledge gap in the biology, ecological aspects and management of both at mature stands and stands after mass flowering. The topics covered under each chapter are as follows: Chapter i: Overview of bamboos in global context; uses and prospects of indigenous bamboo species of Ethiopia; Chapter ii: Biology of indigenous bamboos: taxonomy, morphology, growth and flowering characteristics of indigenous bamboo species; Chapter iii: Ecological aspects of indigenous bamboo species of Ethiopia: distribution and area coverage, topography, soil and climate requirements; Chapter iv: Silvicultural management of bamboo stands of indigenous species: the concept of bamboo silviculture, why productivity of bamboo stands deteriorate?, techniques to maximize productivity of bamboo stands, soil management and stand management of bamboo stands, management of bamboo forests after mass flowering. The book (first edition) was printed in 250 copies and distributed to woredas that grow bamboo in Ethiopia through the MEFFCC affiliated regional offices found in the different regions.

Introduction

Despite bamboo is a very important resource in Ethiopia, research and development support of the sector has been scanty. One of the bottlenecks was lack of reference materials specific to the indigenous bamboo resources of the country. Coordinated research on bamboo resources of the country was started in 2008 while the concept of Business Process Re-engineering (BPR) was introduced in the Ethiopian Institute of Agricultural research (EIAR). This is the time when a mega bamboo project on management and

utilization of indigenous bamboos of Ethiopia is started. The implementation of bamboo mega projects was resulted in enhancing practical and research experiences that helped development of this book.

Key Policy Recommendations

- Bamboo forests of indigenous bamboos should be managed as per the management guidelines given in the book.
- GOs such as Offices of Environment and Forests, Offices of Agriculture and Natural Resources, Forest Enterprises and NGOs engaged in forest and natural resources management should give rigorous trainings, using the book as a reference material, to the regional experts, development agents and farmers.
- The book need to be translated in local languages for more understanding by farmers and development agents of the different bamboo growing areas,

Potential users of the information:

- GOs such as offices of Environment and Forests, Offices of Agriculture and Natural Resources
- Public Forest Enterprises such as Orimiya Forest and Wildlife Enterprise, Amhara Forest Enterprise
- NGOs engaged in forest and natural resources management
- The private sector including the existing bamboo industries and potential investors
- Consultancy firms, professional societies, etc.
- International organizations such as INBAR, World Resources Institute, etc.

Evidence of originality, publicity

- The book is developed by using research-based evidences and field experiences on the two-bamboo species across the different bamboo growing areas of the country.
- This book is the first book, with ISBN: 978-99944-950-6, published by Ethiopian Environment and Forest Research Institute (EEFRI). All rights of EEFRI are reserved, but as EEFRI is promoting scientific management and utilization of forest resources, it urges maximum use of the book as reference material and knowledge upgrading.

19. Bamboo Species Introduced in Ethiopia: Biological, Ecological and Management Aspects

Responsible Researchers: Yigardu Mulatu, Asabeneh Alemayehu and Zebene Tadesse

Brief description of the information

Ethiopia has only two indigenous bamboo species namely *Yushania alpina* and *Oxytenanthera abyssinica*. These two species are restricted in limited agro ecological regions, i.e. in highland areas of altitude 2400-3500 m.a.s.l. and in lowland areas from 500-1800 m.a.s.l. Thus, with the objective of evaluating species that can grow in mid altitudes and diversifying the genetic base of the resource, different bamboo species were introduced in the country since 2007. Some of the species introduced during the first entry (2007) were tested under field conditions in different parts of the country while the species introduced during the second entry (2009) are still at multiplication and field evaluation stage in the country. Providing full account of the already introduced species can have paramount importance in tracking and utilizing them, hence this book is devoted principally on the biological, ecological and management aspects of introduced bamboo species since 2007 in Ethiopia.

This book[1] provides basic information about the introduced species under their original sites and in areas where they are found cultivated including their performance under Ethiopian testing site conditions. It is developed to support foresters and extension agents who are responsible for seedling production from prioritized species, providing training, monitoring and supporting local people. The book has three chapters: chapter i. an overview of bamboos; chapter ii. biological and ecological descriptions of introduced bamboo species; chapter iii. field planting and stands management of introduced bamboo species.

Introduction

Different donor supported projects that have been supervised by INBAR and operating within and together with the Ministry of Agriculture and the then Forestry Research Directorate of the Ethiopian Institute of Agricultural Research have introduced 23 exotic bamboo species in Ethiopia in 2007. This species, as new to Ethiopia, have been multiplied and were under different stages of evaluation for their adaptability and growth performance. However, information on their biology, ecological requirements, management and utilization was limited. Thus, this book is written based on research, especially for the first entry made in 2007, and practical experiences of the authors.

[1] Bamboo Species Introduced in Ethiopia: Biological, Ecological and Management Aspects

Key Policy Recommendations

- Bamboo forests of exotic bamboos should be managed as per the management guidelines given in the book.
- GOs such as Offices of Environment and Forests, Offices of Agriculture and Natural Resources, Forest Enterprises and NGOs engaged in forest and natural resources management should give rigorous trainings, using the book as a reference material, to the regional experts, development agents and farmers.
- The book needs to be translated in local languages for more understanding by farmers and development agents of the different bamboo growing areas.
- Research undergoing under the present Ethiopian Environment and Forest Research Institute (EEFRI) on introduced species should be strengthened and follow through the already started pre-scaling up activities and documentation.

Potential users of the information:

- GOs such as offices of Environment and Forests, offices of Agriculture and natural resources
- Public Forest Enterprises such as Orimiya Forest and Wildlife Enterprise, Amhara Forest Enterprise
- NGOs engaged in forest and natural resources management
- The private sector including the existing bamboo industries and potential investors
- Consultancy firms, professional societies, etc.
- International organizations such as INBAR, World Resources Institute, etc.

Evidence of originality, publicity

- The book is developed by using research-based evidences and field experiences on introduced species across the different bamboo growing areas of the country.
- This book is internationally identified with it ISBN: 978-99944-950-2-3 and published by Ethiopian Environment and Forest Research Institute (EEFRI). All rights of EEFRI are reserved, but as EEFRI is promoting scientific management and utilization of forest resources, it urges maximum use of the book as reference material and knowledge upgrading.

20. Manual on Propagation of Bamboo Species in Ethiopia

Responsible Researchers: Yigardu Mulatu and Asabeneh Alemayehu

Brief description of the Information

One of the problems influencing bamboo cultivation in Ethiopia is often mentioned as lack of practical information on how to propagate bamboo species in the country. Currently, there are two versatile indigenous bamboo species that have been utilized for many applications and many introduced ones that are under evaluation. The Forest Research Directorate of the Ethiopian Institute of Agricultural Research had been conducting field trials and nursery experiments on bamboo propagation under different research centers namely Jimma, Pawe, Holeta, Debrezeit and Forestry Research Centers since 2008. Research information obtained from these experiments and practical experiences helped to develop this manual.

This manual provides basic information about species in the country and is developed to support foresters and extension staff who are responsible for providing training, monitoring and supporting local people on nursery management and bamboo seedling production. It can be used by communities in propagating and managing bamboo nursery in the locality and thereby increase technical skill and knowledge about this important natural resource. Guidelines for cultivating and managing bamboos are offered here to help growers to establish new plantations and manage existing bamboo stands. This manual contains seven chapters. Chapter i. general introduction about bamboo species in Ethiopia. Chapter ii. several aspects of bamboo nurseries. Chapters iii, iv and v are the core part of the manual that describe the different propagation methods in detail for highland, lowland and introduced bamboo species. General information as well as a 'step by step' sequence of activities of each propagation technique is illustrated in these chapters. Chapter six and seven describe field planting of propagated materials and plantation

Introduction

Awareness creation, in a considerable state about the current use and potential applications of bamboo has been created since 2008, when the then East African Bamboo Project started its operation, in Ethiopia. However, among many challenges affecting bamboo promotion in the country, lack of information on propagation techniques of both native and exotic bamboo species

has been considered as one bottleneck. Unlike other plant species, propagating bamboos using seed is not a reliable means. It is mainly because of the rarely happening flowering phase of the species. Thus, propagating bamboo vegetatively is a principal method, but information on rooting and shooting and thereby seedling production of both native and introduced bamboo species in Ethiopia is limited. This manual is developed so as to backstop technical problems of bamboo propagation.

Key Policy Recommendations

- Bamboo forests of indigenous bamboos should be managed as per the management guidelines given in the book.
- GOs such as Offices of Environment and Forests, Offices of Agriculture and natural resources, Forest Enterprises and NGOs engaged in forest and natural resources management should give rigorous trainings, using the book as a reference material, to the regional experts, development agents and farmers.
- The book need to be translated in local languages for more understanding by farmers and development agents of the different bamboo growing areas,

Potential users of the information

- GOs such as offices of Environment and Forests, offices of Agriculture and Natural Resources
- Public Forest Enterprises such as Orimiya Forest and Wildlife Enterprise, Amhara Forest Enterprise
- NGOs engaged in forest and natural resources management
- The private sector including the existing bamboo industries and potential investors
- Consultancy firms, professional societies, etc.
- International organizations such as INBAR, World Resources Institute, etc.

Evidence of originality, publicity

The manual is developed by using research-based evidences and field experiences of both the native and introduced bamboo species across the different bamboo growing areas of the country.

21. Inadequate representation of woody species in soil seed banks of Wof Washa forest calls for ex-situ and in-situ conservation

Responsible person(s): Abiyou Tilahun, Sebsebe Demissew, Teshome Soromessa, Tamrat Bekele and Tesfaye Bekele

Brief description of the information

The soil seed bank (SSB) provides an indication of the regenerative potential of forest ecosystems following disturbances. The diversity characteristics of SSBs and the relationships between SSBs and standing forest vegetation in Wof-Washa forest were investigated. A total of 285 soil samples were collected systematically from three depths and were spread on seed beds in a glasshouse. Emerging seedlings were counted, identified and their similarities among community types and soil seed bank layers of Wof-Washa forest were examined. A total of 76 plant species of which 63 species of herbs 8 species of trees, 3 species of liana and 2 species of shrubs were recovered from soil samples. Thirteen woody species with 67 seedlings were identified from soil seed flora of Wof-Washa forest. Higher number of seedlings per m^2 were obtained from the first layer (2948) followed by middle layer (1494) and lower layer (1107). Specie similarity between the soil seed bank and above ground flora was very low. Woody species were not well represented in the soil seed bank. The finding of this study implies that soil seed bank had very limited contribution in the restoration and regeneration of woody species in forest vegetation. Similarly, it was observed that soil seed banks can't be options to enhance above ground diversity. Thus, restoration and/or rehabilitation of degraded forests shall relay on the sustainable management and conservation of the remnant forest using both in situ and ex situ conservation measures.

Introduction

Forest areas of northern and central Ethiopia are highly fragmented and faced rapid deforestation and degradation due to anthropogenic and environmental factors. Wof - Washa forest comprises biodiversity with high numbers of endemic and rare plant species. The forest systems also harbor a number of wild animals and different bird species. Thus, the conservation of these valuable and highly vulnerable ecosystems could be of high priority and needs due attention.

Soil seed banks play a significant role in primary and secondary plant succession. They determine the composition and structure of existing vegetation and for the restoration of natural vegetation. The spatial and temporal distribution of soil seed banks are influenced by the anthropogenic and environmental factors. Exploring the diversity characteristics of soil seed banks and examining the relationships between soil seed banks and the standing forest vegetation is very crucial for the management of vegetation restoration and rehabilitation of degraded forest resource. This package of information presents soil seed bank diversity, density and their relationship with the standing vegetation and recommends relevant interventions to rehabilitate and/or restore degraded forest resources.

Soil seed bank samples were collected from 95 plots. In each plot, five pits that have a size of 15 x 15 cm with three successive layers (0-3, 3-6, and 6-9 cm), four at each corner and one at the center were dug for soil seed bank samples to form a composite soil sample. A total of 285 soil samples were collected and incubated in a glasshouse. Seedling emergence and direct seed counting methods were employed for counting, identification and isolation of seed bank to determine and compare seed density and species composition in the soil of natural forests. Emerging seedlings were identified using taxonomic keys and authenticated herbarium collections placed in the national herbarium (ETH) at Addis Ababa University and Flora of Ethiopia and Eritrea.

Major findings and its Importance

Soil seed bank species composition

A total of 76 plant species of which 63 species of herbs (83 %), 8 species of trees (10 %), 3 species of liana (4 %) and 2 species of shrubs (3 %) were recovered from soil samples (Table 11). Thirteen woody species with 67 seedlings were identified from soil seed flora of Wof-Washa forest. 63 % 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).

The standing vegetation was mostly represented by herbaceous species of different families. The dominant families of herbaceous species contributed the highest species richness (65 and 83 %) in both above ground and soil seed bank species of Wof-Washa forest, respectively. The least

species richness was for shrub species in the soil seed bank (3%) and liana in above ground vegetation (5 %).

Table 11 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

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. Higher number of seedlings per m^2 were obtained from the first layer (2948) followed by middle layer (1494) and lower layer (1107). The five most abundant species of herbs were *Crasula alsinoides, Nephrophyllum abysssinicum, Oxalis corniculata, Eragrostis schweinfurthii* and *Callitri cheoreophila* and contributed 53 % of the seed densities in the soil seed banks of Wof-Washa forest. *Juniperus procera* and *Discopodium penninervum* were relatively well represented in the litter seed bank in higher density among other tree species with 192 and 36 seeds, respectively.

Relation between standing vegetation and soil seed bank of the forest

A total of 405 species were identified both in the form of standing vegetation and soil seed bank. Of these, 394 were in the standing vegetation and 76 were in the soil seed banks and 65 species were common in both standing vegetation and soil seed bank. Eleven (3 %) and 329 (81 %) species were found only in the soil seed bank and standing vegetation, respectively. Species similarity between the soil seed bank and above ground flora was very low.

Juniperus procera, Maesa lanceolata, Olea europaea subsp. *cuspidata, Ficus sur, Vernonia amygdalina, Urerahy pselodendron, Sparmannia ricinocarpa, Hypericum revolutum, Calpurnia aurea* and *Eucalyptus globulus* were represented both in the above ground vegetation and soil seed banks. *Erica arborea, Myrsine africana, Podocarpus falcatus, Ilex mitis* and *Galiniera*

saxifrage were abundant in the standing vegetation but not represented in the soil seed bank and vice versa for *Callitricheo reophila*, *Centella asiatica* and *Eragrostis racemosa*.

Implication of the findings

The very low soil banks in terms of diversity and density for the woody plant species in the WofWasha forests indicates that soil seed banks of WofaWasha forest have limited contribution to the restoration and regeneration of woody species in forest vegetation and could not be considered as an important means for woody species diversity and recovery.

Key Policy Recommendations

In-situ and *ex-situ* conservation measures should be given high priority for the restoration and/or rehabilitation and for the sustainable management and conservation of the remnant forest.

Potential users of the information:

- Local communities of the three-district bordering the forest (Tarmaber, Ankober and Bassona worena Districts)
- Higher learning Institutions
- Research Institutions
- NGOs
- GOs,
- Government and Private Forest Enterprises

Reliability of the information

We confirm that the information packed are the original works of the specified owners and are true.

22. Plant diversity, Carbon Stocks and Rehabilitation of Montane patch forests in Northwestern Ethiopia

Responsible person(s): Getaneh Gebeyehu, Teshome Soromessa, Tesfaye Bekele, and Demel Teketay

Brief description of the Information:

Intense degradation and deforestation due to agricultural land expansion has been reported to cause declining of forest area and fragmentation for several centuries. Currently, the remaining forest patches are found on the steep slopes and inaccessible areas. The role played by fragmented forests for biodiversity conservation, ecosystem services and potential for rehabilitating the forest is crucial for the preparation of management plan of a forest. Such studies on fragmented montane forest patches remained scant. Therefore, this motivated the initiation of examining the biodiversity, carbon stocks and rehabilitation potential in response to the environmental and disturbance gradients of the five fragmented forest patches. The biodiversity and carbon stocks of the remaining forest patches need to be quantified for implication of mitigation of climate change. We therefore, investigated plant diversity, carbon stocks and rehabilitation potential of montane forests of Awi zone, Northwestern Ethiopia in order to provide evidence-based information for development of management plan of the forest and the rehabilitation and restoration efforts of the area. Eighty plots (400 m^2) were systematically laid out to collect data from vegetation, soil, biomass (i.e carbon stocks) along environmental and disturbance gradients and analysis was performed using analytical methods such as multivariate analysis, biomass equation models and Shannon diversity indexes.

A total of 153 plant species, representing 63 families, were recorded in the five forest patches of which 4% of species were endemic. Thirty-eight species representing 28 families were found to be tree species with stem diameter (DBH) >5 cm. Four community types occurred in the forests. The species–environment relationship showed that the four communities were partitioned mainly by the altitude and disturbances. The population of dominant tree species revealed four types of structures showing healthy regeneration, interruption of regeneration at certain stages, irregular regeneration and parabolic on the intermediate pattern. Relatively high species diversity was found in the intermediate and least disturbance than highly disturbed forests. Species diversity

and evenness declined significantly with an increase in altitude. Forests with high steep slope had significantly lower species diversity than forests with intermediate and flat slopes.

The above ground biomass carbon stocks of tree species in least disturbed forest patches at Bari were found to be higher (269.3 t C ha^{-1}) compared to highly disturbed Kahatsa forest patch (140.8 t C ha^{-1}). Topographic factors, soil variables and anthropogenic disturbances had affected diversity, regeneration and carbon stocks of forests differently. Species diversity and their abundance have a potential to support biodiversity and formation of different plant communities whereas species richness and increasing their size shows enhancement of carbon stocks potential of the forests. Therefore, for effective forest management strategy preventing illegal harvesting (i.e open access), and grazing intensity in the forest is important. Specifically, future focus should include sustainable harvesting instead of open access of woody species, establish area exclosures, design enrichment planting of rare plants in gaps of the disturbed forests and demarcate the boundaries of forest patches so that the reduction of carbon emissions and improve sequestration potential of forest patches is assured.

Introduction

Diverse Environmental conditions, topographic and edaphic variations allow the occurrence of a wide range of forest vegetation ranging from tropical rain and cloud forests to the desert scrubs in Ethiopia. This vegetation plays a vital and diverse role for environmental stabilization through soil protection against erosion, regulation of climate and water flow, protection of watersheds, conservation of biodiversity and serving as carbon sinks. However, these forest resources are facing intense degradation and deforestation because of agricultural land expansion and overgrazing that results in significant loss of forest biodiversity and ecosystem services. However, expansion of agricultural land did not completely remove natural forests. There are still remains of forest patches particularly on the steep slope and inaccessible for agriculture and grazing purpose. Past studies were focusing on quantification of species richness, diversity, plant formation and carbon stocks in protected areas. This indicated that such studies are lacking for various tropical montane forest patches.

The vegetation characteristics and quantity of carbon storage and CO_2 emissions in the forest differs at global, regional and country level. The variation depends on conservation and management of forests, vegetation types, soils, topographic heterogeneity, and land use and level of human disturbance. This study was conducted in Awi Zone of Amhara National Regional State (ANRS), Northwestern Ethiopia in four forest patches (Apine, Bari, Dabkuli and Kahtasa and (TsihareKan) located in Banja and Guangua districts to determine plant diversity, carbon stock and plant communities along environmental and disturbance gradients. The overall forest cover of the five patches is 3,188 ha.

A total of 80 plots (400 m^2) for trees; 160 subplots (area = 25 m^2) each for seedlings and saplings and five 1m^2 subplot within the main plots for the grass and herbaceous species richness were laid out systematically to collect data on vegetation, soil, biomass (carbon stocks) and associated anthropogenic factors such as slope, elevation, aspect, biomass extraction (wood harvesting), canopy opening was measured and recorded. The number of stumps cut and associated canopy opening and grazing had been recorded on each of the main plots. Identification of the plant specimens was performed in the field and then verified at National Herbarium (ETH) University Ababa University. To determine soil physical and chemical properties a total of 160 soil samples in two depths were collected from 80 plots (400 m^2). These factors provide important information that will help design conservation strategy and effective forest management. The information generated in this study are packed to help understand what possible environmental and disturbance factors could influence the forest and how to improve their role in the forest ecosystems.

Major findings and its Importance

Species composition, richness and diversity

A total of 153 plant species, representing 63 families, were recorded in the five forest patches of which 3.92% of species were endemic. Woody species had the highest number (86 species, 56.21%) while the remaining 67 species (43.79%) represented herbaceous plants, including grasses and forbs. Six endemic species were found and out of the total, 38 species representing 28 families were tree species with stem diameter of (dbh) > 5 cm. *Albizia gummifera*, *Apodytes dimidiate* and *Prunus africana* were dominant and the most frequently occurring tree species in spite of the fact that their dominance and frequency varied among forest patches.

Plant communities, population structure and their ecological characteristics

Four community types were identified in the studied forests patches. Twelve indicator species differentiated significantly the four community types. The indicator species were (*Hypericum revolutum, Brucea antidysenterica* and *Clematis longicauda*) in the C4 community, *Albizia gummifera, Hippocratea goetzei* and *Justicia schimperiana* in the C2 and *Lepidotrichia volkensii* in C1. These species are the characteristic features of Afromontane forests. On the other hand, the indicator species of *Bersama abyssinica* in C3 is the characteristic features of Afromontane scrub. About 26% of the species (21 species) observed in the plant community were rare and having a low indicator value (<5%). This might be associated with the effect of harvesting, grazing intensity and topographical factors. The overall density of species varied among forest patches, where Dabkuli was the lowest density and Tsiharekan forest the highest density. The overall dominance of species in the forest patches varied greatly, where the highest basal area was found in least disturbed Bari forest.

The population of dominant tree species revealed four types of population structures; healthy regeneration, distribution showing interruption of regeneration at certain stages and, distribution showing irregular regeneration and pattern showing peak on the intermediate pattern. The seedling density in disturbed Kahtasa forest patch was four times lower than moderately disturbed Dabkuli forest and similarly sapling density in Kahtasa forest was five times lower than the sapling density of moderately disturbed Tsiharekan forest, while adult density in the Kahtasa forest was higher than Dabkuli forest and this forest was found to be more disturbed than the other forest patches and as a consequence the regeneration of seedling in this forest was found to be declining.

Environmental factors affecting species richness, diversity, regeneration

The species–environment relationship of each environmental factor with species distribution explained mostly by altitude, followed by canopy openness, and illegal harvesting, and finally grazing and these factors had partitioned plant species into four communities significantly. Elevation showed positive correlation with species richness of tree species and shrubs whereas negative correlation with woody climber and herbaceous species. Elevation also exhibited negative effects on both seedlings and sapling densities and varied significantly. Slope played negative effects on species richness of trees, shrub and herbs whereas it had shown positive

effect on richness of woody climbers. The slope of the forest patches had shown very weak negative correlation with total nitrogen and aboveground biomass carbon stocks, respectively but played very weak positive role for soil organic carbon stocks. Woody species richness had increased whereas diversity and evenness declined significantly along elevation gradients. Seedling density had increased significantly at the intermediate level of elevation and slope gradient indicating that disturbances might affect the growth and recruitment of seedling in lower elevation or flat slope because they are suitable sites for grazing, harvesting and agricultural expansion. On the other hand, sapling density had increased linearly along elevation gradient.

Above ground biomass and soil carbon stocks of forests

The estimated carbon stocks differed widely among the studied forest patches. The highest and lowest aboveground biomass carbon stocks were found in Bari and Kahtasa forests. Similarly, the soil organic carbon stocks ranged from the lowest in Tsiharekan. The result also demonstrated that the total soil organic carbon stocks were higher than aboveground biomass carbon stocks in all forests. Both spatial distribution of aboveground biomass carbon stock and soil organic carbon stocks showed significant linear relation with elevation despite the correlation become weak and varied. Topographic aspects also influenced positively a considerable amount of carbon stocks of forests. The soil pH had shown negative correlation on the spatial distribution of soil organic carbon and total nitrogen stocks. This relation clearly demonstrates that moderate level of soil acidity enhances soil organic carbon and total nitrogen stocks.

Disturbance effects on species richness, diversity, density, regeneration and carbon stocks

Disturbances had shown both positive and negative effects on specie richness depending on life forms (trees, shrubs, herbs). Significant negative correlation existed between tree species richness and forest canopy opening. This indicates that illegal harvesting of large tree species facilitates canopy openness and impacts on species richness. Forest canopy openness has a positive correlation with shrubs, woody climbers and herbaceous species richness because removal of large trees could improve understory condition through the opening which facilitates sufficient light sources reaching to the ground. This might

create suitable environment to establish and grow of understory vegetation structures but care need to be taken and supported by research. Grazing intensity resulted in negative correlation with shrubs, climbers and herbaceous species richness because livestock trampling, browsing and foot path showed a potential of declining regeneration and establishment of understory vegetation. Forest canopy openness and grazing intensity exhibited negative effects on both seedlings and sapling densities despite that variation are significant in various patches. This suggests that removal of adult trees had caused the declining of seedling and sapling regeneration while livestock trampling, browsing and footpath could result mortality of juvenile species.

Species diversity attained a pattern that changed significantly along disturbance gradient, where higher diversity was observed at intermediate and lower disturbance gradients. The above ground biomass carbon stocks attained negative pattern along disturbance gradient particularly due to harvesting of woody species. The range of disturbance factor favored for storage of biomass carbons but declined as disturbance factors increasing. This clearly demonstrates that biomass extraction increases carbon emission and thus causes the decline of biomass of forests.

Key policy Recommendation

- Sustainable forest management that include management plan shall be introduced to effectively manage forest patches
- Legal and institutional frameworks shall be strengthened for sustainable harvesting of woody species instead of open access and to minimize the current disturbance regime such as illegal harvesting (i.e open access), and uncontrolled high grazing intensity.
- Establish area exclosures, design enrichment planting of rare plants in gaps of the disturbed forests and demarcate the boundaries of forest patches so that biodiversity will be enhanced and the reduction of carbon emissions and improve sequestration potential of forest patches is assured.

Potential users of the information

- Environment and forestry sectors at national, regional and district level,
- Local communities of the districts bordering the studied forests,
- NGOs, Government and Private Forest Enterprises.

Reliability of the information

We confirm that the information packed are the original works of the specified research topic and are true.

23. Woody Plant Diversity and Carbon Stocks of Lowland Woodlands in Guji and Borena Zones, Southern Ethiopia

Responsible researchers: Nesru Hassen, Gemedo Furo and Genene Tesfaye

Brief description of the information

The sustainable utilization of biodiversity especially in climate vulnerable areas ensures food security of the pastoral and agro pastoral people in dry land areas. The species diversity, structure and carbon stock of woody plant species were investigated in woodland of Guji and Borena Zones of Oromia Regional State, Southern Ethiopia. Vegetation sample was taken using systematic sampling method. The vegetation in Guji was stratified in to three homogenous altitudinal gradients (higher, middle and. Lower) while the vegetation in Borena didn't have altitudinal gradient. Chave et al. (2014) biomass equation was employed to determine the biomass of the vegetation. A total of 65 species belonging to 24 family and 49 species belonging to 23 family were recorded from Guji and Borena Zones, respectively. Woody species distribution varies with altitudinal gradient in Guji zone. *Terminalia brownii*, *an e*conomically important species was dominant at higher elevation while the known encroaching species *Acacia mellifera* was recorded as dominant species in the lower altitude than higher and medium elevation. The vegetation in Guji zone has relatively higher species diversity than the vegetation in Borena. The diameter size structure of woody plant species after seedling stage in the study areas revealed ecologically healthy population structure. However, some economically important species like *Terminalia brownii* and *Combretum molle* had few individuals in the lower diameter classes. The total carbon stock (above ground and below ground biomass carbon) of the woody plant species were 19 and 16 t h^{-1} at Guji and Borena Zones, respectively of Oromia Regional State, Southern Ethiopia. The findings of this study revealed that both vegetation composed economically important species with good structure that can be sustainably utilized to ensure food security of the local community. However, the encroaching species shall be managed and highly economic important woody species with low regeneration profile should be protected to maintain them in the vegetation for their sustainable utilization.

Introduction

African woodlands that include woodland, bush land, thicket and wooded grassland are rich in biodiversity. This rich 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. Sustainable management of woodland vegetation renders continuous flow of forest products and other ecosystem services like water. Almost river basins in sub-Saharan Africa are either located or have most of their headwaters in the woodlands. The sustainable management of these African woodlands would avoid the main challenges of dry land areas: shortage of forest products and lack of adequate water supply.

Ethiopian lowland woodlands are the dominant vegetation formation in most parts of the Country. The woodlands are composed of economically important forest products like frank incense, gum arabic, and myrrh, edible plants, forages and many other timber and non-timber forest products. These forest products are either consumed locally and/or traded national and internationally. Livestock production is the dominant mode of livelihood in the lowland dry areas of the country. The lowland woodlands play great role for grazing and sheltering the livestock population. Despite such huge economic and ecological importance of the woodlands, the vegetation is disappearing in alarming rate due to a number of anthropogenic factors like expansion of farmlands, excessive wood harvest for fuel wood and construction purpose, over grazing, manmade fire and other factors. These had damaged significantly the floristic diversity and regeneration of woody species. So far very little attention has been given to develop, protect and sustainably manage these vegetation resources.

The lowland woodlands of Guji and Borena Zones are among the lowland woodlands located in the southern part of Ethiopia. The vegetation consists of ecologically and economically very important plant species. Floristic compositions of vegetation in similar localities have been investigated by different researchers. We quantitatively determined the species composition, pattern of woody plant diversity, structure, density and sequestered carbon stock of the indicated vegetation to provide comprehensive scientific information and knowledge on the status of current stock and dynamics of the plant populations housed in these vegetation resources. Such scientific information and knowledge are very important for planning and implementing

conservation strategies, sustainable utilization of the plant resources and detecting vegetation dynamics over time.

Systematic sampling method was employed for vegetation inventory. The vegetation in Guji was stratified in to three homogenous altitudinal gradients (higher, middle and. Lower) while the vegetation in Borena didn't have altitudinal gradient. A total of 95 quadrants having a size of 30mx30m were established for the vegetation survey. Chave *et al.* (2014) biomass equation was employed to determine the biomass of the vegetation.

Major findings and its Importance

Species composition

A total of 65 species belonging to 24 family were recorded from Guji Zone while 49 species belonging to 23 family were recorded from Borena Zone. The vegetation in Guji zone had higher species diversity and evenness than the vegetation in Borena Zone. *Terminalia brownii***,** *Chionothrix latifolia***,** *Combretum molle*, *Pistacia lentiscus* and *Commiphora africana* were the top five dominant tree species at higher (1600-1400 meter) altitude. *Acacia bussei*, *Commiphora africana*, *Acacia etbaica*, *Acacia mellifera* and *Commiphora kua* were the top five dominant tree species at medium (1400-1200 meter) altitude. *Acacia mellifera*, *Acacia bussei*, *Grewia bicolor*, *Acacia etbaica*and *Chionothrixlatifolia*were the top five dominant tree species at lower (<1200 meter) altitude. The three most dominant species were A*cacia busei*, *Acacia mellifera* and *Terminalia brownii.*

Vegetation structure

Generally, the woody plant species with DBH > 2 cm in in lower altitude showed inverted-J shape (healthy) population structure. Also, better natural regeneration of woody plants species in this stratum was observed. However, the population structure of woody plant species differed with altitudinal gradient. Woody species in the higher and middle altitudinal gradient showed serious problem of natural regeneration. Similarly, individual woody species showed different population structure. *Terminalia browinii* and *Combretum molle* had limited regeneration while *Grewia bicolor* and *Acacia mellifera* had good regeneration but few individuals after sapling stage. *Acacia busie* showed a bell like population structure which indicates of lack of individuals in the lower and higher diameter classes.

Carbon stocks

The vegetation in Guji and Borena zone provide different goods and services. The above and below ground carbon stock of the vegetation in Guji and Borena zone was estimated to be 19 and 16 t h^{-1}, respectively.

Key Policy Recommendations

The lowland woodlands of Guji and Borena zone had good number of woody plant species that can sustainable utilized to enhance the livelihood and food security of the pastoral community. Given good number of woody species in the vegetation, due attention should be given to conserve the vegetation in both zones.

Wood products can sustainably be harvested from the dominant species with good population structure like *Acacia etbaica* and *Acacia bussie* and from the encroacher specie *Acacia mellifera*. However, some of the economically dominant woody species showed limited regeneration which requires active management intervention that enhances their natural regeneration. The encroaching species like *Acacia mellifera* becomes dominant in the lower altitude. This calls for management of species using controlled burning.

We therefore recommend managing the vegetation sustainably by lifting up any anthropogenic factors that affect the regeneration of economically important woody species with limited seedlings and sustainable harvest from the dominant woody species and control of the encroaching species.

Potential users of the information:

- Local communities
- GO's,
- NGO's
- Higher learning Institutions
- Research Institutions
- Government and Private Forest Enterprises

Reliability of the information

The authors would like to assure that this research information is the output of their original research works.

24. Socio-economic contribution of Lake Ziway and threats to its existence, in the central rift-valley of Ethiopia

Responsible Researchers: Shiferaw Alem, Tamiru Lemi, Nesiru Hassen, Belay Gebrie, Genene Tesfaye;

Brief Description of the Information:

The rift valley lakes, found in Ethiopia, are playing a significant role on the socio-economy of the local community and to the country. Lake Ziway, is one of the central rift valley lakes that is under threat, caused by deforestation, agriculture, and development. Despite, the importance of the lake and its mounting threats, there is limited information on the socio-economic importance of the lake, and also published works on the threats to the lake is scant. In this paper the socio-economic contribution of Lake Ziway to the local communities and the major threats of the lake were identified and presented. The data were generated using a questionnaire survey from a total of 297 households, 12 fish cooperatives and 47 key informants. It is found that out of the total yearly income from different sources (US$[2]1918.15 or 44117.45ETB) to the surrounding communities, irrigation farming using the lake water and Fishing contributed about US$ 834 (19182 ETB) and US$ 77.6 (1784.8 ETB), respectively. The fish cooperatives on average sold about 39375 Kg of fish/year and got an average yearly income of about US$ 39152.35 (900,504.05ETB). Floriculture farm expansions around the lake, excessive water pumping for irrigation from the lake, agricultural expansion, and pollution from different sources such as wastes from the city, pesticides from the agricultural practices; soil erosion etc. and sedimentation are the major threats of Lake Ziway. We recommend that sustainable management that minimizes the effect of the threats to the lake is important.

Introduction

Ethiopian Central Rift Valley area is known to have a number of lakes (Jensen *et al.,* 2007); and along with their associated watershed areas the lakes are known to have lots of socio-economic importance. Lake Ziway, one of the centeral rift valley lakes, has a great importance for irrigation, fish resources (Gebremedhin and Belliethathan, 2016). The lake and its basin are home to part of a seasonal migration route for Palearctic birds (Ayenew and Legesse, 2007).

[2] In 2017 1 USD is equivalent to 23 Ethiopian Birr

We depend on nature for our survival and without healthy ecosystems our drinking water isn't clean nor is the environment we live. The resources we gate from the Lakes are also not safe. Knowledges on the values of an ecosystem and the threats are important for decision making purposes. Despite its importance, increasing population pressure and economic developments put an increasing claim on the Lakes' resources (Hengsdijk and Jansen, 2006). The different factors that are considered as threats of the lake have put it and its surrounding bird's habitats under great pressure (Wetland International, 2002). There is lack of information on the socio-economic contribution and threat of Lake Ziway. In the present study, the socio-economic contribution and threats of Lake Ziway was studied. A structured questioner was used for data collection. Using a purposive sampling a total of 297 households residing in six Kebele's, 12 members of fish cooperatives, and 47 key informants were participated for the data collection. Descriptive statistical methods and a percentile ranking method were employed to analyse the data.

Major findings and its Importance

The average income of the individual household in the study area/year was about US$ 1920 (44,160ETB). These incomes were generated from Rain fed farming (US$ 751 or 17,273ETB), irrigation farming using the lake water (US$ 834 or 19,182 ETB), livestock (US$ 166 or 3818 ETB), fishing from the lake (US$ 78 or 1794ETB), off-farm activities such as labour work ($US 90 or 2070ETB), and through charcoal production (US$ 0.23 or 5.29 ETB). This may show that the lake is playing a vital role as a source of irrigation water for crop production and also for fishing purposes. Household respondents indicated that the lake provide them a number of products. Almost all products are used at household level and some are used for sale to generate cash income (Table 12). This result shows the importance of the Lake for small scale irrigation purpose and its significance for livelihood improvement.

Table 12 The product types from Lake Zeway and their contribution to the nearby households

Product types from the lake	Household respondents (%) that use for household use	Average yearly income per year from Product types (USD and ETB)
Fish	33%,	348.3 (8010.9ETB)
grass	40.7%	3.8 (87.4ETB)
water for irrigation and drinking	36%	180.5 (4151.5ETB)
wood	35.7%,	88 (2,024ETB)
wild fruit	32%	129 (2967ETB)
medicine		5.2 (119.6ETB)

The fish cooperatives stated that they caught on average 39375 kg fishes per year. Their average yearly income from the sale of the fish was US$ 39,152.35 (900,504.05ETB). Out of this total number of fishes sold per year about 7102 Kg were marketed after frying of them while the remaining were sold as fresh, without value addition. The study also revealed that a kg of fried and un-lake fried fish was sold at a price of US $1.95 (44.85ETB) and US$ 0.78 (17.94ETB), respectively. Overall, these results show the importance of the lake for generating incomes, and supporting the livelihoods of the local people, in addition to its significance for recreational purposes.

The ranking test result by the surrounding households indicated that the floriculture farm expansion is ranked as the 1st threat to Lake Ziway. While, excessive water pumping for irrigation and sedimentation problems were ranked as the 2nd and 3rd threats to Lake Ziway. While, the key informants indicated that excessive 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. Whereas, the fish cooperatives, indicated that water pumping for irrigation to the floriculture farm and for cultivation of crops considered as the 1st and 2nd threat to the lake while they ranked sedimentation as the 3rd threat to the lake. The variations on their rankings in the major threats of the lake by households, fish cooperatives and key informants could be associated with level of education, knowledge on the Lake, frequency of exposure (travel) to the Lake and distance from the Lake. Generally, it is indicated that despite variations on the ranking result; the entire respondents indicated that floriculture farm expansion, excessive water pumping for irrigation, sedimentation problems, and farm land expansion around the Lake are the major threats of Lake

way and sustainable water resource management plan has to be developed and implemented to reduce their effects.

Key Policy Recommendations:

When the results from the study participants (households, fish cooperatives and Key informants) is summarized, for the sustainability of the Lake the following management options are recommended

- Enhance economic importance of the lake
- Minimize threats
- Develop management plan with active participation of all relevant stakeholders
- Strong government intervention required
- Protect and conserve the existing natural forest;
- Create buffer zone around the lake;
- Practice soil and water conservation measures around the lake and in its catchment, area including tree planting activities;
- Reduce over irrigation and use the lake water wisely and efficiently;
- Apply sustainable fish management and harvesting method;
- Develop integrated management plan to the lake and its resources;
- Make awareness creation;
- Formulate a policy and establish a local institute that will control the use of the water from the Lake.

Potential users of the information:

- Local communities (Districts surrounding Lake Ziway)
- Higher learning Institutions (Universities)
- Research Institutions
- NGOs
- CBO's
- GO's
- Agriculturalists and Extension Agents,
- Policy Makers etc.

Reliability of the information

We confirm that the information packed is the original works of the specified owners and all the results are reliable.

25. Comparative economic analysis of three competing land use types in Southern Ethiopia

Responsible Researchers: Alemayehu N. Ayana (PhD) and Lemlem Tajebe

Brief description of the Information

In Ethiopia, the demand for land to increase agricultural production often creates 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. Lack of comprehensive information on socially, environmentally, and economically feasible land use options are 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. Using economic performance indicators such as Net Present Value (NPV) and Benefit Cost Ratio (BCR), the study compares the economic value of three 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. The results reveal that the economic values of Wood Based Mono-Cropping (WBMC)[3] are significantly higher than Tree Cereal Mixed Cropping (TCMC)[4] and Cereal Based Mono Cropping (CBMC)[5]. Thus, WBMC is economically feasible compared to the two-competing land uses and is a lucrative enterprise in the study area. This study also indicates that labor, product price, land, tenure security, and rainfall variability are key factors that determine farmers' land use choices. The outputs of this study 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 of land use planning. Moreover, government should put in place performance-based incentives and credit facilities to encourage farmers engaged in tree planting. The challenge associated with property right and tenure security need to be resolved.

[3]Consists of only Eculyptus plantation/woodlot

[4]Consists of only Maiz crop

[5] Coffe/enset based Agroforestry

Introduction

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, Franks et al (2017) 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 was 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.

Major findings and its Importance

- The aggregate economic return of WBMC over fifteen years is significantly higher as compared to CBMC and TCMC land use types.

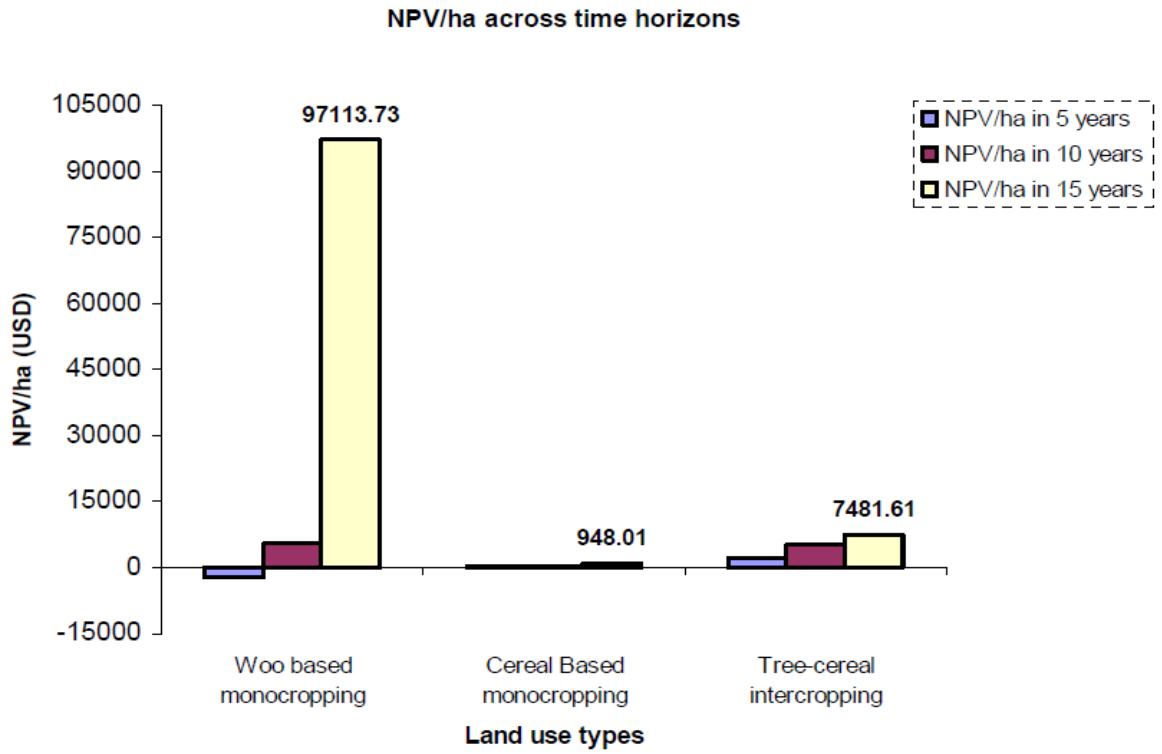

Figure 19 NPV of different land use types across three-time horizons

The mean comparative economic return of WBMC is about 13 and 32 times higher compared to TCMC and CBMC land use types and the BCR of WBMC was 97 and 505 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. WBMC is the least input requiring land use type. Despite its moderate economic return, farmers attach higher overall importance to multiple cropping, i.e. TCMC, mainly because of the utility various products obtained from this land use at household level. Labor, product price, land, tenure security, and rainfall variability are key factors to determine farmers' land use choices. Under the current prevailing farming conditions, farmers are striving to balance the

economic drive of producing cash crop such as *Catha edulis* and Eucalyptus in the form of mono-cropping and maintaining the traditional multiple crops.

Key Policy Recommendations:

The valuation results can guide which land use alternative is economically feasible for sound decision making by smallholder farmers and investors who like to engage in forestry enterprise.

Assists decision-makers and practitioners to improve the current practices in land use planning and support the development of better integrated land-use planning.

Wood Based Mono-Cropping (WBMC) is economically feasible enterprise in the study area and Cereal Based Mono-Cropping (CBMC) is the least desirable alternative in all criteria. Therefore, performance-based incentives and credit facilities to farmers engaged in tree planting should be devised and put in place.

The challenge associated with property right and tenure security need to be resolved to encourage tree planting by smallholders.

Potential users of the information:

Policy makers, researchers, investors and farmers (tree growers) can be beneficiary of this information.

Reliability of information-evidence of originality, publicity

The study is based on original data and analyzed following standard research methods. The results are publicized for decision makers and beneficiaries through a policy brief and published in peer reviewed journal.[6]

[6]Alemayehu Negassa and Lemlem Tajebe. 2017. Comparative economic analysis of three competing land use types in Gedeo zone, Southern Ethiopia: tools for informed decision-making on land use choices. Journal of Development and Agricultural Economics. ***Journal of Economics and Sustainable Development***. **9(1)**: 37-45.

26. Impact of Alternative Livelihood Interventions on Household welfare in Rural Ethiopia

Responsible Researcher: Kebebe Ergano, Shibru Fekadu and Omer Hinde

Brief description of the Information

Livelihoods of a large number of households in Ethiopia depend on environmental resources. On the other hand, excessive reliance of households on environmental resources for their sustenance has already lead to high rates of deforestation and forest degradation in Ethiopia. A project was set out to provide alternative livelihood activities in order to improve the welfare of vulnerable families who derive their livelihoods mainly from selling firewood and charcoal. The project provided support to women groups on production and selling of energy saving stoves, and tree seedlings to engage in income generating activities that create alternative means of livelihoods. This information package provides the impacts of participating in alternative livelihood activities on household welfare and environmental protection in rural Ethiopia. The researchers collected data from cross-sectional survey involving 450 sample households to examine the difference in household welfare between project participants and non-participants using propensity score matching, and inverse probability weighting estimator with regression adjustment. The empirical results show that participation in alternative livelihood activities has contributed to increment in total grain production, increased household income and adoption of natural resources management technologies. Project households consumed food that is more diverse across food groups and earned an extra $35 per month from local market sales of tree and fruit seedlings. The findings support the notion that new streams of income generating activities can lead to improvements in household's well-being as well as reduction in environmental degradation.

Introduction

In Ethiopia, a significant number of households depend on forest environmental resources to meet subsistence needs and generate cash income. Like in many parts of the developing world, households in Ethiopia use food, fuel, fodder, construction materials, medicine and other products from forests and other natural environments to meet subsistence needs and generate cash income (Angelsen et al., 2014; Vedeld et al., 2007). Excessive reliance of households on environmental products for their sustenance has already lead to high rates of deforestation and

land degradation in Ethiopia (Babulo et al., 2008). There is growing evidence, which shows that the less a household has access to livelihood assets, the more it relies on forest environmental resources (Angelsen et al., 2014). Proponents of REDD+ (Reducing Emissions from Deforestation and Forest Degradation) are advocating for development interventions, which allows households to create assets and pursue high return livelihood activities, thereby reduce the pressure on environmental resources. The rationale behind this approach is that creating alternative livelihoods opportunities to poor people whose livelihoods directly or indirectly depend on forest related resources could provide more money for them, limit cutting forests for firewood and charcoal making and gives the natural resources a chance to recover.

While family based economic strengthening, approach could potentially enhance the livelihoods of vulnerable people and curb environmental degradation, there is little evidence about the relative effectiveness of such interventions. Project financing and implementing agencies seek empirical evidence that establishes if they are investing finite resources in the most efficient and effective projects. The survey was conducted in Silti district in Southern region and Boset district in Oromia region using sample of 450 households. This study examined the difference in household income and nutrition between project participants and non-participants using propensity score matching, complemented with inverse probability weighting estimator with regression adjustment to check robustness of the results.

Brief Methodology

- Sample households were selected using simple random sampling from the list of farmers who participated in the project. Non-participant households were selected from the neighborhood of the randomly sampled project households using snowball-sampling method. From purposely selected villages, sample of 450 households (225 project participant and 225 non-participants) were selected.
- Probit model is employed to estimate the influence of explanatory variables on adoption of natural resource management technologies. The probit model specification employs a latent variable y_i* to an observable dependent variable y_i according to the rule. $y_{i^*}=\chi_i\beta_{i+\varepsilon_i}$, $y_{i=}\begin{cases} 1 if\, y_{i^*>0} \\ 0\ otherwise \end{cases}$ where χ_i is a vector of explanatory variables, βi is a vector of coefficients, and ε_i is a stochastic disturbance term.

- Propensity score matching (PSM) applied for controls of observable characteristics and test for the robustness of results to handle the unobservable characteristics. It estimates the predicted probability that a household participates in the project, also known as the propensity score. It`s approach balances the observed distribution of covariates across the project participants and non-participants based on observables. The propensity score (Rosenbaum and Rubin, 1983) can be expressed as:

P (Z) =pr {D=1|Z} =E {D|Z}, Where D= {0, 1} is the indicator for adoption and Z is the vector of pre-adoption characteristics. The conditional distribution of Z, given by p (Z) is similar in both adopter and non-adopter groups.

- Inverse probability weighting estimator with regression adjustment (IPWRA***)*** is used to control bias when the treatment model or the outcome model is affected by confounding unobservable factors

Major findings

- Households in treatment group have significantly higher level of participation in natural resource management awareness creation campaigns, use higher level of energy saving stoves, produce higher levels of grain and adopt natural resource management technologies at higher rate.
- Family size & household participation in natural resource management awareness creation campaigns increase the likelihood of households adopting natural resource management technologies
- The use of energy saving stoves show that adoption decisions are positively influenced by distance to electric grid and participation of households in natural resource management awareness creation campaigns.

Table 13 PSM & IPWRA estimator results on welfare effects of household project participation

	PSM results		IPWRA estimator	
Household welfare indicator	ATT	P>|t|	ATT	P>|t|
Total number of physical assets	-1.78	0.00***	-2.24	0.00***
Household income ($/month)	37.14	0.00***	35.03	0.00***
Adoption of NRM technologies	1.29	0.00***	1.22	0.00***
Dietary diversity score	0.22	0.21	0.38	0.07*
Household Food Insecurity Access Scale	0.20	0.79	-0.88	0.25

Notes: *** p<0.01, ** p<0.05, * p<0.1

- Adoption of natural resource management technologies raises incomes of smallholder farmers. PSM & IPWRA estimator results indicate the average gain for project participants reported is $ 37 and 35 respectively as better impact indicators.
- The significant depletion of physical assets could be associated with severe drought during the years of project implementation in the project sites.
- Household project participation had a positive and considerable impact on household income and household adoption of natural resource management technologies.
- There is an indication that interventions that couples income-generating activities with environmental protection could improve rural households' welfare whilst ensuring environmental protection.

Key Policy Recommendations

- Adopting of natural resource management technologies such as energy saving stoves and tree seedlings as the new stream of income generating activities may lead to improvements in household's well-being as well as reduce environmental degradation
- Creating alternative livelihoods for vulnerable groups would ease poor people dependence on environment. Therefore, policy makers and NGOs should focus on creating alternative livelihoods for vulnerable groups to curb environmental degradation.

Potential users of the information

The information has dual purpose; enhancing livelihoods of vulnerable groups while controlling environmental degradation. Therefore, development actors both governments and non-governments investing on alternative livelihoods and environmental protection programs could be beneficiary of this information. Moreover, Universities, research institutions and natural resource extensions could use this piece of information to scale up to farmers and wider public.

Reliability of the information or evidence of originality, publicity

Researchers were seeking evidence about relative effectiveness of family based economic strengthening approach, which enhance the livelihoods of vulnerable people and curb environmental degradation. The information is based on empirical evidence and published on Journal of Economics and Policy (2016) – Elsevier Editorial System(tm) for Forest, Manuscript Number: FORPOL2412R3

27. Institutional performances of bylaws for successful scaling up of Area closures in Northern Ethiopia

Responsible researchers: Gonche Girma, Beliyu Limenih, Alemayehu N Ayana, Azmera Belachew, Abdulkerim Getachew, and Kassa Chanie

Brief description of the Information

Recently, area closure is widely adopted approach in Ethiopia. It protects mainly through social fencing from any form of cultivation, tree and shrubs cutting or grazing by livestock to allow regeneration and natural ecology succession for the rehabilitation of deforested areas or degraded lands. However, this social fencing mechanism (By-law) are not efficient and seen as penalizing tools against offenders. In addition, they lack integration among stakeholders. The aim of this study was to assess the performance of bylaws in northern part of Ethiopia and develop national framework of bylaws on area closures. The study was conducted in Amhara and Tigray regional states. Before the actual survey, in consultation with stakeholders, 18 area closures were selected. Following that 272 users and 90 key informants were interviewed. Moreover, 54 focus group discussions were undertaken with women and men farmers' separately. A collected data was analyzed by using different analytical tools. The finding revealed that the institutional bylaw enables users to utilize resources equitably. In addition to that, it defined resource boundaries, conflict resolution and enabled users to reach on common conscience. Conversely, bylaws have lesser rule for enforcement regarding action on offenders. So, to improve the current situation, institutions set up should be advanced. Moreover, to improve the functionality of bylaws, the government should regularly monitor the institution and give technical backups.

Introduction

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% remained (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 been taken place. Among the various rehabilitation techniques used, the predominant is area exclosure (MulugetaLemenih, 2004; Betru Nedessa 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 Nedessa et al., 2005; Wolde Mekuria et al., 2007, Tesfaye Mebratu, 2002). Degraded lands that almost lost their production potentials are set aside for nature-based rehabilitation. These areas, if properly managed and rehabilitated through closure system, allow native vegetation to regenerate (Emiru Birhane and Tefera Mengistu, 2002). Area closure approach mainly contextualized under social, institutional and environmental aspects. According to Elino (1990), institutional analysis rule consists formal and informal position, boundaries in order to access a particular position, choice of action, voting schemes, information channel, pay-off and scopes of criteria's. Absence of an appropriate institutional framework gives rise to (inter-institutional) rivalries thus making implementation and integration at local level difficult. So, developing national framework of institutional by-laws through possible suggestion would help to maintain natural resource utilization.

The study was conducted in Amhara and Tigray regional state in six zonal administration. Based on area closure experience, under each zone, three woreda and kebeles were selected purposively. By using simple random sampling techniques respondent farmers were selected from each kebele. So, a total of 18 area closures were approached. Before the actual study, questionnaire was developed by using Ostrom (1990) Institutional Analysis Development (IAD) principles. Following that, 272 user farmers, and 90 key informal were interview by using structured questionnaire. In addition to that, separate women and men focus group discussion (54) were conducted in the study areas. Finally, the collected data was analyzed by using different analytical tools.

Major findings and its importance

- Almost all bylaws are highly accepted by user groups. And have well defined members and resource boundaries.

- More than eighty per cent of respondents revealed that the current bylaws have enabled group members to use resources fairly, penalize opportunism, and creat group consciences. And the findings also indicated that bylaws are significantly contributing on the institutions to have a regular monitoring system.
- However, the respondents have also pointed out the presence of conflict among group members and with the surrounding communities. And undertakings towards conflict resolving measures in a group functions lesser.

Key Policy Recommendations

- Bylaws have lesser rules for enforcement regarding actions on offenders. So, to improve the current situation, institutional set up should get better.
- To improve the functionality of bylaws, the government should regularly monitor the institutional set up and give technical backups.
- To minimize conflicts, government should support each land management group to have legal resource boundaries.

Potential users of the information:

- Woreda Land Administration, Ministry of Environment, Forest and Climate Change, Woreda Bureau of Agriculture and Non-Governmental Organizations

Reliability of the information-evidence of originality, publicity

The results of this research were obtained from original research work conducted by EEFRI research team.

28. Air Pollution as a Consequence of Pre-harvest Burning of Sugarcane in Ethiopia

Responsible researchers of the Information: Birhanu Hailu

Brief description of the information

Sugar is one of the most common and highly demanded commodities in the global market. Around 70% of the world's sugar consumption is derived from cane, which is cultivated in tropical climates. The government of Ethiopia has launched new sugar development projects and expansion of the existing ones. Accordingly, greater attention is given to increase and improve sugarcane plantation farms. Meanwhile an increased sugar production would rise the amount of by products such as molasses, bagasse, filter cake, and vinasse. Apart from these, huge amount of cane tops and trash are also wasted from the sugarcane fields by open burning in Ethiopia. Due to this practice a great deal of biomass that can be converted into other useful resources is wasted. More importantly, the burning practice would cause environmental and human health problem. Therefore, this project quantified the amount of trash biomass burnt and measured the level of gaseous pollutants emitted from pre-harvest burning of sugarcane in the country, every year. Direct measurement of ambient air quality during burning was made at different distances from the burning field at Wonji and Metahara. The second method was estimating the gases emission by using 2006 IPCC inventory software. In 2015/2016, a total of 26,903.49 ha of sugarcane plantation were burnt at five operating factories in Ethiopia. Consequently, a total of 1.51 million tons of trash or biomass fuel, i.e., dead, dry and fresh leaves, burnt every year. The mean ambient air quality measurement at Wonji showed that 1,437.43 ±406 of CO_2, 82.8±17 of CO, 4.9±2 of NO_2, 7.36±3 of SO_2 and 2150.47±170 of VOC (μgm^{-3}) were emitted. For the case of Metahara 1,447.8 ±141 of CO_2, 45.2±11 of CO, 4.7±1 of NO_2, 8.9±3 of SO_2 and 2320.333±27 of VOC (μgm^{-3}) were emitted. These results are grab measurements which couldn't be compared with national and other global continuously monitored standards for air quality purpose. However, these instantaneous values are indicative for the presence of air pollution based on the standard set by WHO. It implies that, this practice is a potential cause to human health and

environmental problems. This activity could harm especially those who are working in sugarcane cutting since they spend eight hours every day near the plantation.

Based on the simulation results from the IPCC inventory software, the total emission of CO_2, CO, NO_2, N_2O, and CH_4 were 3.24, 6.3, 2.3, 0.54 and 2.01 gigagram in the study year respectively for all sugarcane plantations in Ethiopia. This indicated that approximately 32,400 tons of CO_2 is contributed from this practice to the total emission of the country. As Ethiopia pledges to reduce its emission level to 150Mt CO_2 equivalent, the amount of CO_2 emitted from this activity would be substantial requiring attention. In general, pre-harvest burning of sugarcane was major source of air pollution and biomass resource wastage. Therefore, green harvesting technologies should be adopted and applied to harvest cane to improve resource recovery and air quality.

Introduction

Pre-harvest burning of sugarcane has been practiced for quite a long time to remove unwanted part of the cane such as dead, dry, and fresh leaves to facilitate the manual harvesting operations. Though burning is quick and efficient to remove the trash, it has impacts on air quality. Pre-harvest burning of sugarcane contribute to emissions of air pollutants that may adversely impact human health, environment and cause resource degradation.

Ethiopian sugar corporation 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) to be realized which increase the farm to over 400,000 ha. The Sugar Corporation has targeted to produce 2.25 million tons of sugar and 181,604 m^3 ethanol upon the finalization of the projects with the productivity of 155 tons (t) cane ha^{-1}. Consequently, huge number of byproducts are expected both at the field and in the factory, which require due attention. Particularly, the amount of biomass lost during pre-harvest burning of cane is eminent. Currently, only part of the by-product (molasses) and bagasse is utilized for the production of ethanol and electric power generation, respectively.

Meanwhile the government of Ethiopia pledge to reduce it emission to 150Mt CO_2 equivalent. The main goal of CRGE is reducing emission of gases which emit to the environments to insure the green economic developments. However, burning of sugarcane on fields does contradict with

the ambition set. This implies that the attention given to gaseous pollutants that can be emitted from the practice and the biomass resource wasted is null. Moreover, the issue of biodiversity, soil fertility as well as effects on human health are hardly considered. Therefore, this project tried to measure the emission level of gaseous pollutants released from the burning process and quantified the amount of biomass resource burnt. The finding give insight to sugar corporation and other organizations about the pollutants released.

Figure 20. Pre-harvest burning of sugarcane fields

This research was done in Wonji and Methara sugar factories sampling and study areas. Data was collected by direct measurement of ambient air using standard air quality device from different spatially varying points. Additionally, by using the IPCC (version 2006) inventory software, the annual emission of gases and the amount of trash wasted from sugarcane burning were calculated.

Major findings

Table 14. Measured mean ambient air quality

Study area	Parameters ($\mu g/m^3$)														
	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

*Ambient Environment Standards for Ethiopia: -

- ✶ Sulphur dioxide [10-minute averaging time] …500μg/m^3
- ✶ Nitrogen dioxide [1hour averaging time] …200μg/m^3
- ✶ Carbon monoxide [15-minute averaging time] …100, 000μg/m^3

☛ There is no national guideline set for VOCs

- Generally, all the five operating sugar factories were found to burn a total of 26,904 hectares of sugarcane plantation in the 2015/16 G.C. Consequently, from the IPCC inventory software an estimate of 38 tons of trash is generated per hectare and a total of 1.51 million tons of trash is burnt every year. This informs the amount of biomass wasted with no practical and economic use.
- The instantaneous measurement for CO, NO_2 and VOC taken from the study area exceed the standard set by WHO.
- Therefore, the likelihood to observe air pollution in area is practical.

- Based on the simulation results from the IPCC inventory software, the total emission of CO_2, CO, NO_2, N_2O, and CH_4 were 3.24, 6.3, 2.3, 0.54 and 2.01 gigagram in the study year respectively for all sugarcane plantations in Ethiopia.
- This indicated that approximately 32400 tons of $CO_{2\ is}$ contributed from this practice to the total emission of the country.
- As Ethiopia pledges to reduce its emission level to 150Mt CO_2 equivalence, the amount of CO_2 emitted from this practice would be substantial which require attention.
- In general, pre-harvest burning of sugarcane was major source of air pollution and biomass resource wastage. Therefore, it calls for new green harvesting technologies for improving air qualities.

Recommendations

- Green harvesting technology utilization should be applied to stop sugarcane burning.
- Policy makers, Sugar Corporation, and Ministry of Environment, Forest and Climate Change are expected to use the information to curb the pollution.
- Biomass energy harvesting companies should study feasibility study for practical energy harnessing.

Potential users of the information

This information can be used as baseline for;

- Ethiopia Sugar Corporation
- Ministry of Environment, forest and climate change,
- Policy makers at all levels
- NGOs
- Researchers and environmentalists and other stakeholders working for the transformation of sugarcane harvesting system in to green harvesting technology.

Reliability of information

The information provided here is obtained from data collected from air qualities measurement and experienced expert consultation. The research findings are not duplicated or copied from any other source. As a means of reliability, experimenting of another research with similar methodology is warranted.

29. Wastewater Characteristics from Unit Operations and Process at Batu and Modjo tannery, Ethiopia

Responsible researchers: Abdrie Seid Hassen and Tesfalem Belay

Brief description of the information

The leather industry is one of the serious polluting sector whenever it fails to treat its wastewater. 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 sludges to the environment. Characteristics of the effluent vary from tannery to tannery and in any of the manufacturing unit operations and processes such as wastewater from beam house process viz. soaking, liming, deliming etc. In most considerations, the pollution load of a single factory is audited by taking the final wastewater exhaust. However, to reduce the cumulative pollution load from the industry, characterizing the wastewater released in each manufacturing process is important. This will help specially to employ new/modified manufacturing process at specific unit for economic reason so then total contaminant load can be reduced in the final wastewater.

Therefore, this project aimed at identifying and comparing the major pollutants released at each stage of tanning process and evaluate 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

Ethiopian has the 10th largest livestock inventory in the world. The hides, skin and leather is a critical strategic sector for the economic and industrial development of Ethiopia. The government has identified the leather and leather products value chain as one of the top four most promising industries in the country due to its strong backward linkages to the rural economy, and potential for poverty reduction. 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 are located in Modjo leather city. The tanning industry is characterized as disposing of solid, liquid, gaseous and sludge to the environment. Hence, the waste management of the tanneries is a major environmental concern. The wastewater from beam house process viz. soaking, liming, deliming etc. are highly alkaline containing decomposing organic matter, hair, lime, sulphide and nitrogen with high BOD, and COD. Several studies have shown that most tannery industries are causing major environmental pollution to the nearby aquatic system. Since the problem is known, solution can be suggested as an alternative to the practice at the polluting tanneries. Development of conventional wastewater treatment is a well-known approach to pollution abatement. However, it is an end-of-pipe approach of waste management. The best approach in economic terms is to reduce the waste at the source. This can be handled by various mechanism, however, to the context of this research focusing on process modification is with due emphasis. Therefore, identifying and characterizing the critical waste generating processes is the first stage pushing to solution. Accordingly, the objective of this research is to fill the gap observed on the above explanation. Characterizing each unit operations and processes would give insight to devise the possible process modification. If the critical pollutant contributing processes are identified, the factories could consult with experts and modify that particular process so that reduced pollutant can be maintained in the final wastewater discharge.

Wastewater samples were collected from Batu and Modjo tanneries, Ethiopia. The samples were taken from all unit operations and processes of tanning viz., soaking, liming, deliming, pickling, chrome tanning and retanning. The samples 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 solids (TDS), total suspended solids (TSS), chlorides, sulfides and chromium were analyzed as per standard procedures.

Major findings

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 12 and 13 respectively.

Table 15. Results of the wastewater 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

Table 16 Results of the wastewater 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 solid	23171±4625.15	23380.4±4575.05	20971.8±3268.14	25508.5±5324.54	17963.2±3662.8	7288±1562.17
Sulphide	0.8±0.1	1.7±0.23	0.54±0.09	0.5±0.013	0.4±0.08	0.3±0.02
Chromium	-	-	-	-	1.46±0.556	4±1.03
Chloride	15224.44±102.16	13199.3±24 4.31	11332.15±183.78	14786.6±15 2.7	9728.3±7 0.64	8402.15±49.43

- 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).
- 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 US EPA (200 mg/l).
- COD level from different tanning processes exceeds the permissible COD level of US 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.
- Hexavalent chromium also exceeds the standard set by US EPA(0.1mg/L).
- Generally, Total Solids (TS), Total Suspended Solids (TSS), Chloride, Sulfide, Total Alkalinity exceed the US EPA standard significantly.

- ✓ The standard used for this study is US EPA because there is no national standard for wastewater discharge from specific unit operation and unit process.

- Characterizing the wastewater from each process give clue where has to take measure and what has to be done. In practical term, constructing conventional and advanced wastewater treatment is expensive. Therefore, focusing on either of the unit operations or processes with high contaminant load could have comparative economic advantage to the companies.
- From this study it is noticeable that the discharge at each stage is above the recommended values, however, for economic reason choosing one or two processes and modifying the process could give relief.

Recommendations

- Regulatory bodies should work with tanning companies to reduce the pollution level.
- Both studied industries and other factories that have similar manufacturing processes should consume the result and consult with relevant expert bodies.
- The ministry of industry and MEFCC should work in harmony to control the import of outdated manufacturing machines and operation with traditional manufacturing process.
- Tanning industries need to have a research and development department that focus on the development of technology for the growing opportunities and challenges.

Potential users of the information

- Batu and Mojo tanneries and other tanning industries with similar mode of manufacturing process.
- Ministry of Environment, Forest, and Climate Change, and regional environmental offices.
- Scientific community who has a stake in environmental management.

Reliability of information

- The finding of this research is the original property of the institute and its researchers. It is no where produced before and the reliability of the data could be checked with similar procedure of experimentation.

30. Teleconnections between Ocean-atmosphere Coupled Phenomenon and Droughts in Tigray Region: The case of Alamata district

Responsible researchers: Moges Molla, Martha Kidemu, Tefera Ashine, Berhu Tesfamariyam, Adefires Worku, Melaku Getachew, Agena Anjulo

Brief description of the Information

Climate change has become one of the major challenges facing the world. Since the past few decades, incidences of extreme weather events such as droughts, large fluctuations in precipitation patterns and shortening of the lengths of growing periods have been occurring in increased frequencies. In Ethiopia, alarming vulnerability of different production sectors, ecosystem functions and livelihoods call for understanding of the teleconnections between Ocean-atmosphere coupled phenomenon and droughts in the country. One of such phenomenon is the periodic occurrence of El-Niño. During El-Niño episodes the normal patterns of tropical precipitation and atmospheric circulation are disrupted, triggering extreme climate events: droughts, floods and affecting the intensity and frequency of hurricanes. This package of information presents key findings of a study aiming at understanding the teleconnections between Ocean-atmosphere coupled phenomenon and droughts taking Alamata district in Tigray Region as case study area. For this district, the deficiency of July-September rains in 1972, 1982, 1987 and 1997 is linked with El-Nino Southern Oscillation (ENSO) events. Likewise, deficiency and abundance of rains in April-June appeared to be influenced by the ENSO events. In addition, the July-September and April-June seasonal mean of Southern Oscillation Index (SOI) is positively and negatively correlated to the July-September and to the April-June rains of the district respectively. The Sea Surface Temperature (SST) of central and eastern Pacific (Nino 3.4) is negatively correlated to July-September rains and positively correlated to April-June rains. In addition to El-Nino effects, other events such as Pacific Decadal Oscillation, Southern Oscillation Index and Indian Ocean Dipole are important factors triggering meteorological and agricultural droughts at the study area. Such cascaded understanding of the evolution of our climate system in response to global climate phenomenon will enhance the capacity to scientific monitor the evolution of hazards and seasonal forecasts of extreme events and provide early indications and warnings to manage possible adverse effects at national, regional and local scale.

Introduction

Climate change is the sever problem that the world is facing today which is manifested by changes in the intensity, duration or time of climate variables. Since the past couple of decades there is demonstrated increase in the incidences of extreme weather events such as drought and flood, change in the rainfall patterns, and shortening of growing periods. Similarly, the assessment carried out by IPCC (IPCC, 2007) shows that warming of the climate system is univocal, where the influence of the human being is clear. Among the various extreme weather events, droughts are the most important for many countries, particularly for sub-Saharan African countries. Since few decades, in Ethiopia, severe, frequent and extended droughts have been ramifying the already existing poverty and natural resources degradation and undermining sustainable development. It is hence important to holistically understand factors driving droughts, its patterns and trends as such knowledge will help design appropriate intervention measures to minimize risks.

Atmospheric and oceanic teleconnections govern the variability in our climate system on a broader range of time and spatial scales. 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 and 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 Indian Ocean Dipole (IOD) and El Niño–Southern Oscillation (ENSO) peaks at 0.53 in September–November. This means that only one third of IOD events are associated with ENSO events. Current limited understanding on the teleconnections between ocean-atmosphere coupled phenomena and drought occurrences in Ethiopia has been undermining our early warning system and implementation of El Niño-related contingency plans. Drought plans in particular should contain three basic components: monitoring and early warning, risk assessment, and mitigation and response. This study was initiated to investigate the teleconnections between Ocean-atmosphere coupled phenomenon and droughts at Alamata district in Tigray Region.

Different methods were developed to detect, assess and monitor droughts quantitatively. Two drought indices such as Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) were used for correlation and lag correlation with global indices such as El-Nino Southern Oscillation (ENSO), Oceanic Nino (Nino3.4), Indian Ocean Dipole (IOD) and Pacific Decadal Oscillation (PDO) to investigate the relationship of droughts in the study area with global phenomenon. The indices were obtained from their respective database of the National Center for Environmental Prediction (NCEP). Historical EL-Nino and La-Nina years and Ethiopian drought years were collected from literatures. MET (meteorological) data on seasonal mean rainfall, maximum and minimum temperatures and Potential Evapo-transpiration (PET) of the study area stations (from 1916-2016) were collected from Tigray regional meteorology agency. In addition, the Cru/Model data was collected from KNMI climate explorer.

Major findings

- The results of analyzed stations indicate that, El-nino 3.4 and other global ocean-atmospheric phenomena teleconnections such as Pacific Decadal Oscillation (PDO), Southern Oscillation Index (SOI) and Indian Ocean Dipole (IOD) are important factors of Meteorological drought (Standardized Precipitation Index (SPI)) and Agricultural drought (Reconnaissance Drought Index (RDI)).
- It is also worth to mention that, there are many cases where decisions on early warming without knowledge on the coupled ocean-atmospheric phenomena and local weather system were resulted in mal-adaptation in various parts of Ethiopia and in other countries.

Key recommendations

- Future national and local seasonal rainfall forecast, associated early warning and drought interventions in Ethiopia should consider independent as well as combined effects of global indices such as El-Nino Southern Oscillation (ENSO), Oceanic Nino (Nino3.4), Indian Ocean Dipole (IOD) and Pacific Decadal Oscillation (PDO).
- Understanding the teleconnection patterns of IOD or ENSO and their positive or negative interference during years of co-occurrence is very important while designing and implementing national and local adaptation and mitigation strategies, because the regional influences of these phenomenon affects the successes of national and local strategies

Reliability of the information

The findings of this research are based on data from meteorological stations and KNMI climate explorer

31. Application of Traditional Ecological Knowledge System for Climate Change Adaptation and Mitigation in Central Rift Valley, Ethiopia

Responsible researchers: Martha Kidemu, Martha Gebreyesus, Mihiret Semere, Adefires Worku, Agena Anjulo

Brief description

Rural communities in developing countries rely to a greater extent on their 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 time through direct contact with their environment (Folke, 2006). Despite of its marginalization due to the industrial revolution for a long period of time, since recent decades there is a growing acknowledgement of the TEK system such as in areas of natural resource management, climate change adaptation and mitigation, biodiversity conservation, pharmaceutical development and conflict resolution. This information package summarized type, application and benefits of TEK system relevant to climate change adaptation and mitigation among the stallholder farmers at the central Rift Valley of Ethiopia. The objective of the research was to facilitate the re-vitalization of indigenous practices, skills, institutions and social mechanisms into the extension system, and thereby, enhance sustainable development in the arid and semi-arid areas. Among the various indigenous practices identified were rainfall prediction methods that can play key role in the absence of formal weather prediction methods. The communities use various indicators to predict the weather condition such as meteorological indicators (wind, cloud, tornado and lightning); astronomical indicators (moon, sun and star); animal behavior (mainly that of cattle and frog) and other environmental and social indicators. Using these indicators, the study communities are able to predict weather condition from daily to seasonal basis, and based on the prediction, they make decisions related to land preparation and early warnings and preparedness. The TEK system-based climate change adaptation and coping strategies identified were farming along river/lake banks, seasonal migration to wetter area and to towns, collecting and saving crop residue for livestock feeding, destocking of livestock, savings, and income diversification, mainly from fuel wood and charcoal making. The overall analysis shows that, the study communities heavily rely on their TEK system to facilitate preparedness to minimize the impacts

of extreme events such as drought and encourage the communities to design new adaptation and coping strategies.

Introduction

Information on climate change is lacking in Ethiopia in general and at the local level in particular to inform decision on agricultural and forest activities. Traditional Ecological Knowledge (TEK) which refers to the evolving knowledge acquired by indigenous and local people over many years through direct contact with the environment was used as an option by farmers to fill this gap. Regardless of this, little emphasis has been given to document, analyze and integrate TEK system into conventional climate change adaptation and mitigation interventions planning. The marginalization of the TEK system has resulted in the increase of the vulnerability of society and their ecosystems in various ways. Cognizant to these, and mainly since the Rio Declaration, there are some developments to acknowledge the diverse roles of TEK system, mainly in areas of natural resource management, climate change adaptation and mitigation, biodiversity conservation, weather forecast, peace building and conflict resolution (Adefires, 2016).

Ethiopia is known for its diverse culture and livelihoods whereby the quite large portion of its population still depends on their indigenous knowledge system. This study was conducted in the rift valley of the country where vulnerability to climate change and variability and landscape degradation has become severe challenge. The study aims at understanding and documenting how traditional ecological knowledge system is applied in rainfall forecast and planning and implementation climate change adaptation practices by smallholders. The goal of the study was to facilitate the re-vitalization of relevant indigenous practices, skills, institutions and social mechanisms into the extension system, and thereby, enhance sustainable development of dry zones of the country.

Data was collected on the overall environmental and livelihood problems and driving factors, community manifestations on the social-ecological change processes such as climate change and associated impacts, rainfall prediction strategies and community-based coping mechanisms and adaptation strategies. Different social data collections methods such as key informant interviews, focus group discussions and field level observations were used. Checklists and questionnaires were used to collect the data. Qualitative data analysis method was used to summarize the information.

Major findings

- Risks as a result of climate change and variability related extremes and other environmental degradations were the most critical challenges that intensify social-ecological vulnerability at the study areas;
- Indigenous knowledge has played important role in managing those risks in the day-to-day agricultural activities of farmers even in absence of formal weather information;
- Communities use various indicators such as animal behavior, wind circulation, cloud cover, water bodies, plant characteristics etc. to predict the onset and ending of rainfall and to make informed decisions on needed interventions (Indigenous early warning system);
- Communities also used different names when the rain starts to predict a season: women's *ayana* day-good season; day of *ayana* of horse- season with erratic rainfall; day of *ayana* of elephant- season in which heavy rainfall is expected; day of ayana *korma*-season in which drought is expected
- Due to cultural degradation, indigenous knowledge weather prediction methods are less trusted by the present generation which leads to reluctance of the extension system and formal institutions to recognize and integrate into the actions of development interventions and early warning system. However, these opinions have created misconception between the scientific weather forecast and indigenous knowledge weather forecast and have resulted mismanagement of agricultural and natural resource activities by farmers.
- This implies that, development interventions should effectively use combined information from climate data and indigenous knowledge while planning so as to have sustainable adaptation. The Geda System of the community has informal rules and regulations in conflict and natural resource use management system thereby plays greater role in enhancing socio-ecological adaptive capacity and resilience.

Recommendations

- Policy makers should integrate indigenous knowledge, practices, skills, institutions and social mechanisms part of the sustainable development planning.
- Choice on future adaptation strategies should acknowledge existing and age-old traditional ecological knowledge system of a given communities as the lessons learnt from this

research results showed exclusion of these system has facilitated social-ecological vulnerability of rural communities.

- Understanding and integrating traditional knowledge system into the formal planning system has a multiplier effect on other government interventions such as through facilitation of technology adoption and or absorption, building trust among differentiated societal groups and between people and government, enhancing rural-urban linkages, and minimizing transaction costs, among others.

Beneficiaries: Policy makers, Meteorologists, extension agents, NGOs and farmers

Reliability of the information

- The information is obtained based on an original research done at field level by primary data collection.
- The data is collected from representative samples of the population.

31. Dry forests for climate change adaptation in semi-arid areas of Ethiopia

Responsible researchers: Musse Tesfaye, Wondimagegn Amanuel, Adefires Worku, Gezahegne Seyoum, Zenebe Mekonnen

Brief description of the Information

Dry forests are life for the people and the ecology in drylands. Despite that dry forests play important socio-economic and ecological roles in climate change adaptation and mitigation across the world, the diverse contribution of these resources has given less attention in the national and regional development planning in Ethiopia. To magnify these roles and give development directions, this study has evaluated the roles of dry forests to livelihood income contribution and for climate change adaptation in Borana zone by using qualitative and quantitative research approaches. Data was collected using household survey (74 households), key informant interviews (15), focus group discussion (30), and observation. It was understood that, there is growing dependence on dry forests as means of coping and adaptation strategies against climate change impacts as dry forests products are less affected by such impacts and generate income (12% of total household's annual income) for safety nets during shock. This implies that dry forests can contribute a great role in household's income contribution and hence builds adaptive capacity of households for climate change adaptation.

Introduction

Ethiopia has larger portion of drylands (60-70%) with low and unpredictable rainfall patterns. These regions are poorly developed and suffer historical, political and economic marginalization. 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 by which dry forests are a complement to these livelihoods.

A continued severe environmental degradation, shrinking resource bases and transhumance mobility routes are becoming major problems facing these livelihood systems (Fekadu, 2013). A post drought livestock re-stocking, a common phenomenon in the drylands, has affected dry forests. The increasingly uncertain climatic conditions and resource degradation in the drylands of Ethiopia demand new and integrated resource management approaches that facilitate more

resilient land use planning.

Dry forests can provide sustained provision of ecosystem goods and services and can play roles in climate change adaptation and mitigation if and only if they are managed properly (Robledo *et al.,* 2012). The roles of dry forests are important in arid lands than it is elsewhere, by contributing vital roles (e.g. income from gum and resins) to the livelihood of communities. Despite all those roles, dry forests are trapped in a spiral of deforestation, fragmentation, and degradation and are given little attention in the national as well as regional planning. The potential of dry forests to enhance the local and national economies has been overlooked, and their contribution to sustainable environmental management has not been recognized. Dry forests of Borena are rich of species in the genera of *Combretum, Terminalia, Acacia, Pistacia, Commiphora, Lannea, Euclea, and Olea.* Therefore, providing information on contribution of dry forests and forest products to livelihood income and for climate change adaptation is important. To get the information, it was used household survey with 74 randomly selected households, 30 focus group discussions and 15 key informant interviews.

Major findings

- Dry forest products (e.g. gum and resin, firewood, charcoal) have contributed 12% of the total annual income of sample households. To maintain this contribution and increase livestock fodder and combat desertification pastoralists and agro-pastoralists are accustomed traditional ways of managing dry;
- Households have used different coping strategies such as livestock destocking (82 %), off-farm activities (49%), sale of gum and resin (70%) and other forest products (82%), aid support (76%) and migration (85%). This also shows the considerable role of dry forests in coping strategy whereby acting as safety net during climate change and variability extreme such as droughts;
- Sixty-eight percent of the surveyed households have agreed that their livelihood dependency on dry forest products has increased in recent time. Respondents agreed that income generation from dry forests has increased not by better management of the forests but due to excessive exploitation;
- Nearly 90% of the respondents perceived that dry forest are highly declining with a knock-on effect on the adaptive capacity of communities to climate change adaptation. Respondents

agreed that the major driving factors that triggered the change in forest cover, species diversity and regeneration are population increase, deforestation and degradation, over-exploitation of the forest resources, and decrease in amount of annual and distribution of rainfall in the area.

Recommendations

- Despite the significant contribution of dry forests to household's income in semi-arid areas of Ethiopia like Liben district in Borena Zone, there is high degradation of these resources. It needs an improved management of dry forests to sustain their livelihood contributions, while also securing their long term ecological functions
- Forest products from dry forests are harvested and/or collected in most traditional ways that degrade the resource and leading lower income contribution to the community than expected, hence it is recommended to establish proper value chain for dry forest products such as gum and resins to increase the income gained from these resources.

Potential users of the information

Natural resource managers, resource economists, local communities, educational and research institutions, civic and private institutions

Reliability of information

- Data was collected from different profiles of the population that made the data collected representative of the population
- It is original work and replicable

32. Laboratory Manual for Analysis of Organochlorine Pesticides (Manual No. EEFRI 003)

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Brief description of the information*:*

Pesticides were first imported to Ethiopia in the 1960s, and import data shows that pesticide use in Ethiopia is increasing from time to time. The major use of pesticides in the country is to control vectors of diseases such as mosquitoes, and agricultural pests. This evidence shows that it is important to regulate and monitor the presence of pesticides in the environment. To monitor pesticides, we need a laboratory with state of the art facilities, trained professionals, as well as reference manuals to follow during chemical analysis. This laboratory manual is the first attempt to address lack of such documents in EEFRI. The manual provides basic information to researchers and laboratory technicians on how to analyze environmental samples suspected of containing organochlorine pesticides (OCPs). The manual has nine chapters. The first chapter provides introductory information about analysis of organochlorine pesticides in environmental matrices. The second chapter deals with analysis of OCPs in water and waste water. The third chapter deals with analysis of OCPs in aquaculture products. The fourth chapter deals with analysis of OCPs in soil and sediment samples. The fifth chapter deals with biological tissues. The sixth chapter deals with analysis of OCPs in air samples. The seventh chapter provides information on analysis of OCPs in human & cow milk. The eighth chapter provides information on techniques for analysis of OCPs in human serum. The ninth chapter deals with analysis of OCPs in Cereal grains. All the chapters provide information on scope, principle, apparatus, reagents, sample extraction, clean up, and instrumental methods of analysis.

Introduction

Persistent organic pollutants (POPs) are very difficult to remove once they enter the environment. The reason is simply because they do not disintegrate into less harmful substances; they rather stay in the environment for a long time, accumulate in living tissues, and eventually lead to deleterious health effects. Understanding of this behavior of POPs has thus resulted in the signing of the Stockholm convention (22 May, 2001), a legally binding agreement to create persistent organic pollutant free world. Most of these pollutants included in the convention are organochlorine pesticides (OCPs). Article 16 of the convention requires the

signatory parties shall monitor and report to the Stockholm Secretariat on the status of these chemicals in the environment.

The Ministry of Ethiopian Environment, Forest and Climate Change (MEFCC) has the key responsibility and mandate to strategically implement the signed agreement on behalf of the country. The Ethiopian Environment and Forest Research Institute (EEFRI) is an institution under this ministry to generate information and technologies that could solve societal problems. And research on solving issues related to pollution by organochlorine pesticides is one of the focus areas of the institute. Moreover, there is a need to have a laboratory manual with standard operating Procedures (SOPs) for this specific group of compounds. The advantage of having a standard manual is that when different analytical laboratories use the same SOPs, it would be possible to compare the quality of analytical data generated by these laboratories. Therefore, it is believed that the writing of this manual is an attempt to fill the gap observed in analysis of OCPs.

Key Recommendations

- As this manual is prepared based on documents of international acceptance, it is recommended that researchers, laboratory technicians, postgraduate students, and other potential users of this manual use it effectively to obtain quality analytical data in relation to environmental monitoring and regulation.

Potential users of the information:

- Government and Private higher learning institutions, research institutes, and analytical laboratories
- Researchers, laboratory technicians, postgraduate students, etc.

Evidence of originality, publicity

- The manual is developed based on standard reference materials prepared by international organizations working on environmental protection such as UNEP, USEPA, etc.
- Appropriate citation and acknowledgement are included in the document.