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

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Ethiopian Environment Forest Climate Change Commission

Regional Environment, Forest and Climate Change Bureaus/Authorities

Tree farmers

Forest products processing enterprises

Wood based industries

Volume II
2019

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Package of Technologies and Information

Foreword

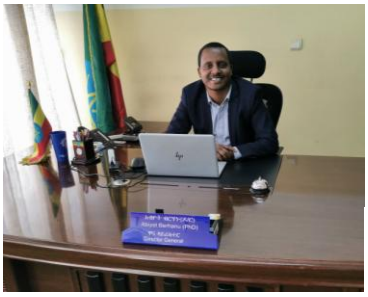
Ethiopian forests have been subject to unsustainable utilization and deforestation in the last millennia for agriculture, settlement and household consumption. The problems of deforestation and over-exploitation of our forests are nationally recognized as one of the worst threats to the remaining plant biodiversity of the country. Similarly, environmental pollution and degradation has become paramount challenge in recent days as to the expansion of cities, industries and agriculture. Climate change is also playing its role in aggravating the root causes of deforestation and environmental degradation.

It is well recognized that forest and environment sectors have immense potential to contribute to sustainable development goals by nourishing 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). A long-term target of increasing the forest cover of Ethiopia by 30% in 2030 is also on the table; which requires huge investments in the forest sector. At the same time, the country has given maximum attention to manage environmental pollution and degradation. It is apparent that 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 environmental and forestry national targets is heavily dependent on delivery of state-of-the-art technologies, pertinent information and knowledge generated from rigorous research activities. Consequently, 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.

So far, **Volume I,** with selected packages of technology and information generated by EEFRI, has been published and distributed to relevant institutions, individuals and general users. Here, in **Volume II**, we have selected a number of technologies and information as a continuance of our efforts to meet national targets in areas of environmental protection, forestry and climate change mitigation. Users are also encouraged to visit our official website (www.eefri.gov.et) to access useful information, technologies, manuals, guidelines and other publications.

Abiyot Berhanu (PhD)



Director General
Ethiopian Environment and Forest Research Institute
Addis Ababa, Ethiopia
December, 2019

Preface

Ethiopia has put forward ambitious climate resilient development goals in all economic sectors. Forestry, as a pillar in the CRGE strategy, is set to be protected and re-established for its economic and ecosystem services including its role as a carbon sink. Forestry plays its main roles in sustaining agricultural production, enhancing rainwater infiltration for increased ground water recharging and regulated stream flow for irrigation and hydropower dams. Forestry and agriculture jointly employ about 80% of Ethiopian people, where this contribution may incline more to forestry in the coming years with more value added products coming to markets substituting the current import of timber and wood based products from abroad. Forestry's contribution to rural livelihood is becoming more meaningful as farming communities are converting their acidified and unproductive agricultural plots to energy plantation woodlots and exportable poles and posts production. By surging the same demand to tree farming, for sure, the GDP contribution of forestry from its estimated 4% in 2015 will reach beyond the stipulated 8% in 2020. To achieve this target, scientific guidance and support from forest service providing institution is crucial. However, to ramp up and benefit from forest development, the current forest sector institutional setup proved not serving beyond organizing tree planting campaigns. World Bank and Ethiopian Development Research Institute report (2017) on country environmental analysis of Ethiopia revealed that forest clearance/deforestation is being driven by land conversion to open woodland, agriculture, and grassland; these being the main land uses converting the forest. This encroachment into forest lands can be managed as it's elsewhere in many countries, through robust forest service provisioning institution. Ethiopian Environment and Forest Research Institute (EEFRI) is preparing a policy advice on why the country needs such a service.

Much of the emission reduction targets set for forestry contribution are expected to be achieved from reducing forest degradation and deforestation, improving rural land management, restoring landscapes through afforestation and reforestation endeavors. And much of the biomass energy for rural and urban dwellers comes from smallholder plantations, and more is said to be from unknown sources, but largely from unmanaged natural forests. This calls for substantial increase in fuel-wood production to save the already degraded remnant natural forests. The bulk of fuel-wood also needs to be converted to value added, efficient and less carbon dioxide emitting carbonized energy source such as briquettes and pellets. In this regard, EEFRI has more to contribute. Environment pollution management research in the institute emphasizes on processing and utilization of the bulk of solid waste in the country, and invasive plant species management by harvesting and converting into biomass energy.

EEFRI, in its 2018 annual research review on completed research outputs has identified and categorized seven technologies and 24 information to be packaged on how to manage environmental, forest and climate change issues; which are extendable and feasible as package of practices for use by different stakeholders, entrepreneurs, tree farmers, and small and large scale wood based industries. This volume II of package of practices, therefore, presents issues on biochemical composition of bamboo culm, briquette molding and production machine designing and testing results, invasive plant species management with environmental solution, wood utilization technology on certain tree species, screening fast growing tree species for fuel-wood production in the highlands, agroforestry practices socio-economic and carbon storage roles, woody species population structure, study results on diversity and composition, pollution monitoring reports as well as climate change vulnerability, resilience, and adaptation study. I hope users of these package of practices will benefit from the research outputs and practice in the same or similar ways, as proposed, to amplify at larger scale production line.

Wishing pleasant reading to all, I would like to assure that our volume III package of practices will follow soon.

Agena Anjulo Tanga (PhD, Associate Professor, Agroforestry)

Deputy Director General,
Ethiopian Environment and Forest Research Institute,
Addis Ababa, Ethiopia
December, 2019

Acknowledgement

The present volume II of the packages of practices is based on EEFRI's regular research out puts resulting from the seven research centers of the institute. The centers research and support as well as administrative staff are duly acknowledged for managing research sites and laboratories for successful accomplishment of the respective centre based research projects. Researchers in all EEFRI centers are appreciatively recognized for accomplishing the research undertakings under very constrained research infrastructure and facility.

Many are the contributions of research directors in initiating the write ups of the packages, getting the first drafts from respective researchers, modifying to simplicity and easy understanding of stakeholders and users until final submission for review to team of reviewers. I therefore, extend my sincere thanks to Dr Teshome Tesema, Mr Yalemsew Adela, Mr Berhane Kidane, Dr Abeje Eshete, Dr Adefires Worku, Dr Alemayehu Negassa, Dr Alemayehu Esayas, Dr Yigardu Mulatu, Mr Abraham Yirgu and Mr Getachew Kebede.

Dr Abayneh Derero, Dr Zenebe Mekonnen and Dr Tatek Dejene also deserve recognition for replacing the former directors and contributing to get the packages in the present form. Team of researchers in EEFRI culture, have taken the painful task of correcting, modifying and questioning the contents of the documents for improvement. They are listed in another page for distinguishing and honoring their support for bringing this volume II in the current form. I affectionately thank them on behalf of the institute.

All service providers in the administration wing from janitors, messengers, drivers, guards, secretaries, library and copy centre workers, experts and directors in their respective field are duly recognized for their support without their meticulous engagement this could not have been materialized.

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Package of Technologies

Chemical Composition of Highland Bamboo (*Yushaniaalpina*) Culm

Responsible researchers*:* Fikremariam Haile, Amsalu Tolessa, Abraham Dilnessa, Buzayehu Desisa, Daniel Gebeyehu, Tewabech Alemu, Yihun Bekalu, Lemesa Abera and Tegene Tantu

Brief description of the information:

Ethiopia has an estimated one million hectares of natural bamboo forest, which is the largest in the African continent. Currently, there is an acute shortage of forest products, annually with an expected increase of demand for lumber and wood-based products in the future. Bamboo is becoming the major substitute of wood for rural and urban house construction and inputs for chemical industries in Ethiopia. However, the chemical composition of *Y. alpina,* and its potential for industrial application is not yet well-studied.So, to use the species for different purposes, chemical characterization is very important.

The main objective of the study was to determine the chemical composition of *Y. alpina*and to identify its applicability for different industrial uses. The study analyzed the influence of age,culm position and growing site on the chemical composition of *Y. alpina*. In addition, culm age and height relationship were considered while investigating the chemical composition of the species.

Introduction

Ethiopia has two indigenous bamboo species; namely highland bamboo (*Yushaniaalpina)* and lowland bamboo (*Oxytenantheraabyssinica)*, covering over 1.4 million hectares (ha) with a wide distribution and is the largest in Africa. *Y. alpina*is estimated to coverabout 300,000 ha out of which 19,000 ha were planted by farmers.The choice of bamboo species for various applications is dependent on physical, mechanical properties and chemical composition. However, there is a lack of scientific evidence on chemical compositionof the species for the utilization in chemical industries of Ethiopia.

The chemical composition is claimed to be influenced by culm age (maturity), height position and growing site that also influences the processing and utilization of bamboo culm. Besides,

these factors are also expected to influence the physical and mechanical properties of the bamboo species. The aim of this work focused on evaluating the influence of age, culm position and growing site on the chemical composition of *Y. alpina*to identify its industrial utilization.

Brief methodology

- *Y. alpina*culmwas harvested from the northern part of Ethiopia, taking age and culm position into account;
- The collected *Y. alpina* culm was chopped to appropriate size in the range between 0.4 to 0.5 cm and dried in an oven at 40^0C for three days;
- The dried samples were ground into powder by Willey mill Machine to pass through 250μm sieve size;
- The ground sample was subjected to ASTM standard methods of analysis, which includeextractive yield, ash, cellulose and lignin content;
- Data obtained from laboratory analysis were analyzed by using Statistical Analysis System (SAS) software;

Major findings and its importance

- The results showed that bamboo age, culm position and growing site have impacted the chemical composition (cellulose, lignin, extractive yield and ash) content of *Y. alpina*.
- Bamboo culms grown at *Injibara* site where the top of the culm position reached age of three to five had better cellulose content.
- Cellulose content of *Y. alpina* was found to be 44 - 64%, indicating suitability of the species as raw material for paper and pulp industry. In addition, if technologies are available to process, it can be used for the production of bio-ethanol and other similar gas products.
- Extractive yield for *Y. alpina* was found to be maximum at the bottom culm position, indicating suitability of the species for different industrial applications such as pharmaceuticals, creams, and beverages products.
- Bamboo culm of age three grown at *Shenen* and *Injibara* sites possessed relatively better lignin content at the bottom culm position (i.e. for *Shenen* 31.56% and *Injibara* 30.03%).
- *Y. alpina* ash content was found low (i.e. minimum mean value 1.48% and maximum mean value 2.42%) indicating suitability of the species for charcoaling and using it in the

form of pellet and briquette. Besides, bamboo ash can be used to polish jewels and manufacture electrical batteries.

Key Policy Recommendations

- Investment on *Y.alpina* species development and utilization should be encouraged for the reason that it has multiple uses including industrial applications, energy supply, polishing jewels and manufacture of electrical batteries.

Potential users of the information

- The beneficiaries of the research output are diverse group of stakeholders including: Environment, Forestry and Climate Change Commission, Entrepreneurs who are willing to invest on pulp and paper production industry.

Reliability of information: The study is the original work of the Forest Resources Utilization Research Directorate, EEFRI.

Seasoning Technologies of *Acacia caffra* Lumber

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

Brief description of the technology

The wood of *A. caffra* when planted as an exotic is acceptable for sawn lumber, light and general structural uses and flooring. Its density and seasoning characteristics imply its suitability for vehicles, food containers, box and crate manufacture, shingles, furniture, cheap joinery, framing, pallets, broom sticks, poles, turnery and fuelwood. Quality and performance (mechanical characteristics, suitability, usability, stability, serviceability) of wood and wood-based products have been seriously affected by the major factors, among which moisture content (MC), inappropriate drying (seasoning)and density are the major ones.

Lumber seasoning makes wood easy to process, surface finish and decorate, which will also have improvement in-service performance. The moisture content of wood should match the equilibrium moisture content of outdoor conditions (about 12%) while being processed or when it is used as structural member, and to about 8% for indoor uses. However, the moisture content of green wood is often greater than fiber saturation point, ≥ 30% which calls for an optimal method of removal for the excessive moisture. The drier a wood, the easier to process, the more durable and thestronger it becomes. The moisture removal or seasoning is efficiently done through artificial methods such as kiln, solar and other seasoning techniques. However, each lumber species needs separately prepared and optimized kiln schedule in which step wise change of seasoning conditions (temperature [T], relative humidity [H], duration of stay at each T and H and rate of seasoning) so as to minimize seasoning defects.

Therefore, investigation was conducted on seasoning and density characteristics of *Acacia caffra* with specific objective of generating appropriate seasoning technology (kiln schedule) and assess potential applications. Results revealed that mean initial and final MC of *A. caffra* lumber for both air and kiln seasoning stacks was 60.04% and 13.28%, respectively. The kiln seasoning technology in this case was much useful to shorten very much the seasoning time required to season the lumber to 12% MC. The time duration required for sawn boards of 3 cm thickness to attain about 12% MC using air seasoning method was 46 days, while kiln seasoning took 12 days to attain the same moisture content. Rate of kiln seasoning was 1.11% day^{-1} and the rate of kiln

seasoning was ~ 3.8 times faster than the air seasoning method. The species was classified as very rapid in air and kiln seasoning when compared to other timber species.

Mean values of the tangential, radial and volumetric shrinkages when the lumber was dried from 60.04% to 13.28% MC were 4.22%, 3.87% and 6.37%, respectively. The longitudinal shrinkage was nil (0%). Seasoning defects such as cup, bow, twist, crook, end split, wane, collapse and honeycomb were observed with differing extent on air and kiln seasoned boards, besides the natural defects dead knot, and heart rot. Mean density values of the species at green condition and when seasoned to 12% MC were 1056 and 815 Kg/m^3, respectively. Density of *A. caffra* at 12% moisture content was classified as very heavy density[1]. It has been comparable with many indigenous and exotic timber species in density, rate of seasoning and shrinkage characteristics. *A. caffra* has both timber and non-timber values in addition to its benefits for soil conservation and other services.

Kiln seasoning delivers good quality of seasoned wood within a short period of time with high cost. Cities like Addis Ababa, where land values are high, kiln seasoning is a better technology choice. Therefore, kiln seasoning technology of wood is generally preferable than the air seasoning for *A. caffra*. Proper seasoning will increase quality and suitability of lumbers for different applications thereby productivity of industries and their profit will increase.

Suitability

- The air seasoning technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.
- Comparatively the kiln technology is expensive that could be affordable and recommended to medium and large-scale forest products processing industries, construction sectors and marketing enterprises.

Requirement

- Sawmill
- Radial arm saw, jointer, planer and circular saw for sample preparation

[1]Density classification (Kg/m^3) at 12% MC:Exceptionally light < 300, Light 300 – 450, Medium 500 – 650, Heavy 650 – 800, Very heavy 800 – 1000, Exceptionally heavy > 1000. Adapted from Chudnoff (1980), Farmer (1987) and TDEB (1994) and Anonymous 2012.

- Air seasoning shed/yard (to reduce moisture content of lumber ≤ 30% before kiln seasoning, thereby reducing electricity charge/cost)
- Dry kiln machine with all accessories
- Skilled kiln operator
- Electric power
- Seasoning oven and moisture meter, multi-channel temperature loggers
- Sensitive balances (000 decimal digit)
- Digital caliper with 0-150 mm measuring capacity
- Psychometric chart (Relative humidity and wood equilibrium moisture content charts)
- Loads made as concrete slabs/clamps
- Grooved stickers with a uniform cross-section (2.5*2.5 cm, thickness and width)
- Seasoning kiln schedule (Written manual or guideline).

Practice

- Practices/techniques of natural or air seasoning and artificial kiln seasoning technologies are described in this section

Harvesting of trees

- The trees to be harvested should be mature with minimum top diameter of 12 cm (and mean DBH of 30 cm).
- Felled trees should be bucked into appropriate log lengths (preferred 3-5 m) but it depends on the depth/capacity of the particular dry kilns in operation.

Figure 1 *A. caffra* trees and logs during sample selection and harvesting at Pawe.

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 have to be sawn through and through into a uniform thickness of 3 cm mixed tangential and radial boards but possible to use a thickness more than 3 cm based on the end use
- Select representative boards and convert them into seasoning monitoring samples with a dimension of 100 cm in length, 3 cm thickness and width equal to log diameter since samples have to be taken from full dimension of boards.

Stacking sawn boards for air and kiln seasoning

- Boards may need to be transported to the air seasoning yard/shed (Figure 2) and/or compartment kiln-seasoning chamber (Figure 2) areas as soon as they are sawn.
- Boards are stacked horizontally in vertical alignments at 3 cm spacing between successive boards and separated by well-seasoned, square and grooved, uniform sized and standard stickers, having a dimension of 2.5x2.5cm (width x thickness).

Figure 2 Air seasoning stack with stickers

NB: Principles of stacking for air and kiln seasoning boards are similar.

- Each sticker should be long enough to run across the stack without a joint. This ensures that each layer of timber is uniformly placed and adequately supported to hold the next lay
- Stickers are placed at an equal distance across each layer of lumber and are aligned one on top of the other so as to separate boards, facilitate uniform air circulation and seasoning, minimize warp, avoid stain and decay occurrence during the seasoning process.
- Short strips (2.5 x 2.5 x 20 cm) are placed up on the long stickers to easily access the control sample boards of each stack
- Top load of 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. Clamps can alternatively be used.
- In each stack of the air and kiln seasoning, heartwood, sapwood and tangential boards should be segregated in the stack.
- the heartwood boards, which have less moisture content, are placed in the middle, while the sapwood and tangential boards are placed along the sides, top and bottom of the stacks.
- Boards with equal dimensions should be stacked together and the ends of boards should be made equal and flush in both directions.

- The control sample boards should properly be distributed and positioned in the pockets of the different layers (bottom, middle and top) of each stack (Figure 2).
- The control sample boards should be used to monitor and determine the progress of seasoning (moisture reduction rate) and the final moisture content.

Air seasoning method

- Boards have to be stacked under shed, on firm foundations/ yards having 45 cm clearance above the ground and a dimension of 1.80x0.45x4 m.
- The boards should be aligned in a north-south direction where the ends should not be exposed to the direct wind hit.
- Initial moisture content of the stack should be determined using oven seasoning method by preparing section (with size having 1.2 cm length and 3 cm thickness) from the moisture sample/ representative boards Estimate of the final mean equilibrium moisture (EMC) content of the wood is about 12%.

Kiln seasoning method

- The conventional type of artificial kiln or any other similar seasoning chamber can be used he 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 shown on Table 1 should be used for this species
- When the moisture content of the wood reduced below fiber saturation point, the steam should be injected into the chamber to avoid checking and splitting.

Table 1 Kiln Schedule Ethiopia 3

Initial MC (%)	**Temperature (°C)**		**Relative humidity (%)**
	Dry-bulb	**Wet-bulb**	
100-70	38	35	80
70-60	42	37	70
60-50	44	39	65
50-40	50	40	60

40-30	53	42	55
30-20	55	43	50
20-10	60	45	40

- The seasoning process should continue until the required final moisture content level (about 12%) is reached.

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 the following 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.

Potential applications of *A caffra* lumber

Appearance

Appearance, one of the physical characteristics of the lumber *A. caffra*(Fig.3) showed that sapwood was creamy white while the heartwood was dark brown.

Figure 3 Appearance of *A. caffra* lumber.

Industrial and construction uses

- The tree species, *A. caffra* has multipurpose lumber and non-timber forest products and services.
- The wood of *A. caffra* when planted as an exotic has proven in this study to be acceptable for sawn lumber, light and general structural uses and flooring.
- 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, kraft and thermo-mechanical pulp, paper.

Management

- To facilitate lumber to dry evenly, it has to be stacked properly,
- Between the stacked layers of boards, stickers have to be placed to facilitate ventilation of the stack.
- All stickers should be of the same size and be seasoned.
- The stickers should be arranged in line one above the other in order to distribute the weight evenly.
- Pockets has to be made for sample boards in the stack, which are checked for their moisture content at weekly and daily intervals for air and kiln seasoning stacks, respectively.
- The initial moisture content should be determined by oven-dry method.
- Top loading of about 50 kg should be applied on the top of the stack
- Steaming should be applied to increase relative humidity of the kiln and as remedy for kiln seasoning lumber. This is when the moisture content decreased below fiber saturation point and serious seasoning defects occurred while seasoning.
- Forest products processing industries, construction sectors and marketing enterprises need to follow the research results and methodologies of seasoning as guideline.

Comparative advantage/yield

- Kiln seasoning is faster than air due to higher temperature, ventilation and air circulation
- Kiln seasoning inhibits/ kills insects and their eggs.

- Kiln seasoning avoids/ minimizes seasoning defects like warpage (cup, bow, twist, and crook) and shakes, associated with seasoning.
- Kiln seasoning enables wood to be seasoned to required moisture content regardless of humidity condition.
- Air seasoning time for sawn boards of *A. caffra* of 3 cm thickness to reach to about 12% MC took 49 days, while kiln seasoning took 4 days.

Cost effectiveness

- No cost effectiveness analysis was done. However, from experience, the air seasoning technology is affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.

Risk and uncertainty:

- If technologies followed by processing industries and kiln operators, very minimal risk of fire during kiln seasoning will be occurred. Thus, care should be taken.
- During air seasoning bio-deteriorating agents (powder posting/beetle, fungi and termite) may attack the lumber. Thus, seasoning time shall be shortened using grooved stickers.
- Follow up is also needed against bio deteriorating agents and seasoning defects.

End users: Beneficiaries include urban communities, Wood Industries, House Constructing Companies and other construction sectors, Investors, Civil Engineers, Vocational Training Colleges, H

Charcoal Briquette Production from *Oxytenanthera abyssinica, Yushania alpina, Acacia mellifera,* and *Prosopis juliflora* Biomass

Responsible researchers: Sisay Feleke, Fikremariam Haile, Degnechew Genene, Gemechu Yadeta, Amsalu Tolessa, Tegene Tantu, Tewabech Alemu and Yihun Bekalu

Brief description of the technology

Production of sustainable and renewable energy from locally available biomass feedstocks provides great opportunities to achieve sustainable growth and development in economic, social and environmental aspects for all nations across the globe. Production of pellets from different biomass and biowaste materials for household and industrial energy generation is considered as efficient utilization of the resource. The present study focuses on the development and characterization of charcoal briquettes from the forest biomasses such as, *Oxytenantheraabyssinica, Yushaniaalpina, Acacia mellifera,* and *Prosopis juliflora,* which were collected from*Pawe, Yabello, Injibara,* and Awash districtsof Ethiopia. Then, the collected samples of specified species were chopped into suitable size (in the range between 0.4 to 0.5 cm), dried and milled. The milled sawdustwas carbonized with furnace at a temperature of 500 ^{O}C for 60 and 90 minutes. Then, the charcoal was removed immediately from the furnace and cooled under tap water. The cooled and dried charcoal wascrushed using a hammer to reduce sample size for making briquette. The powder samples were mixed proportionally with 5% *Acacia seyal* and *Gum talah* as an organic binder to make briquette. The binder was manually mixed with the prepared charcoal powder, at anaverage solid to liquid ratio of 8:1. Then, the mixture was compacted with Peterson Press machine.

The maximum calorific values of *Y.alpina*and *P. juliflora*were7106.8cal/gm and 6755.6cal/gm, respectively. The percentage of Sulfur content for the species type studied falls between 0.02 - 0.39 %. The present study suggests that charcoal briquette produced from the above specieshas a positive outcome with a higher calorific value, less moisture content, and high level of fixed carbon, and low Sulfur content in the range within the internationally acceptable standard.

Suitability

There is complete suitability of these briquettes for cooking and heating with no smoke, no sparks produced, no irritating smell released and ash remains intact on cooling. It improves combustion performance and efficiency, reduces the demand for fuelwood and thus improves

access and usage for cleaner fuels. These briquettes can be used as an alternative energy source in places where cooking fuels are not easily available.

Requirement

To implement this briquetting technology, the pre-requisite materials are *O.abyssinica, Y.alpina, A.mellifera, and P.julifloraa*sawdust, 5% *A.seyal* and *Gum talah* binder and briquetting machine. In addition, the working manual, training of producers and efficient biomass stoves are also important.

Practice

To produce *O.abyssinica, Y.alpina, A.mellifera, and P.julifloraa*charcoal briquettes, the collected log/branch samples of the species are dried in the open air; then the dried samples are cut into 5cm length size and carbonized in a furnace at 500 ^{0}C. The carbonized samples are milled in Wiely Mill and mixed with a pre-selected organic binder at an average solid: liquid ration of 8:1. Finally, briquettes are made by the briquette press machine. Then, it is dried in the sun for two days and is ready for use.

Figure 4 Charcoal briquettes from *Oxytenantheraabyssinica, Yushaniaalpina, Acacia mellifera,* and *Prosopis juliflora* biomass

Comparative advantage/yield*:*

- Compared to firewood or loose biomass, briquettes give much higher thermal efficiency because of low moisture and higher density. Briquettes are producedto make handling, storage, and transportation easy as compared to raw agricultural residues and wastes; it also resolves the disposal and pollution issues often created by biomass residues
- Convenient to use and reduces more harvesting of biomass due to conversion of char waste into briquettes
- Creates a chain of income generation ventures from production to consumption
- Creates employment opportunity for the youth

- Helps to reduce the areacoverage of invasive species such as*Prosopis juliflora* and *Acacia mellifera* in woodland and rangelands/pasture areas
- Provides an alternative low-cost energy source for domestic cooking from waste materials
- Reduces indoor air pollution

Cost-effectiveness:

No financial analysis has been done

Risk and uncertainty:

- ☛ No product certification or standardization in the country;
- ☛ Financial barriers to starting the business;
- ☛ Operational and markets related barriers;
- ☛ Inefficient utility cooking stoves for utilizing the briquettes;
- ☛ Inadequate skills and training on carbonization; and
- ☛ Inefficient use and/or lack of manufacturing tools and equipment in the local market.

Purpose:

Theses briquettes are:

- Used in places wherever cooking fuels are not available;
- Produced to convert biomass wastes like sawdust, charcoal dust, and municipal waste as a solution to the scarcity of firewood, and a source of income for many families.
- Produced to avoid dust pollution associated with direct combustion of loose biomass.
- Used to reduce deforestation by providing a substitute to fuelwood.

End-users:

- ❖ Farmers, households, women retailers, heating plants, power stations, and boiler plants, universities and hotels.
- ❖ These briquettes can be used for any type of thermal application like steam generation in boilers, heating purposes, drying process and gasification plant to replace existing conventional fuel like coal, wood & costly liquid fuel like FO, Diesel, LDO, Kerosene, etc. The use of Eco-Friendly Briquettes as fuel to save non-conventional fuels has shown very promising results. However, the product will have more use at the household level in developing countries like Ethiopia where biomass energy takes lion share in the energy supply.

Harvesting Techniques and Intensities of Lowland Bamboo (*Oxytenanthera abyssinica*) for Productivity Enhancement in North Western Ethiopia

Responsible researchers: Abera Getahun, Yared Kebede, Zebene Tadese, Gemechu Jibiso, Mitiku Alemu, Belayneh Azene, Yigardu Mulatu, Berhane Kidane and Ambachew Getnet

Brief description of the technology:

Lowland bamboo(*Oxytenanthera abyssinica*), locally known as *Shimel* (Amharic), is a clump-forming bamboo with solid culms of height up to 13 m and diameter up to 10 cm.It has clump forming, short neck sympodial rhizome. The species is found in lowland areas of western and north western Ethiopia mainly in the *Benishangul Gumuz* region. It is widely used for many local applications such as construction, fencing, food (shoot), for industrial lumber-based and stick-based products. Traditionally, users harvest younger culms that often grow at clump peripheries where extracting out culms is easier; older culms that do not produce new shoots and often found in the interior part of the clump remain standing, creating congestion. This has been resulting in limited recruitment and deteriorated clump productivity as a result of which sustainable harvest of mature culms becomes jeopardized. Thus, it is important to introduce systematic harvesting technique with a certain harvesting intensity which lessens congestion of culms, encourages recruitment of bigger sized new culms and reduces destruction of culms.

Based on this understanding, an experiment was conducted within the compound of *Pawe* Agricultural Research Center, on clumps of spacing 2 m x 2 m and of age four years. Four clumps, which are close to each other, were considered as one plot. Factorial experiment with two factors; i.e. harvesting techniques with two levels (X-shape and Horse-shoe shape techniques)and harvesting intensity with five levels (no harvesting/control,25%, 50%, 75% and 100%) were the treatments used to investigate their effects on recruitment and size of new bamboo culms. Thus, ten factorially combined treatments were used in a block and treatments were replicated three times. Initially, all dead bamboo culms were extracted out and the number of culms per clump were counted through age class (< 1 year, 1-3 year and > 3 years old). In addition, mean culm diameter and height of each age class and height of clumps were measured. Then, the experimental area was

fenced. Treatments were applied every year in the dry season (February to March) that is the recommended harvesting season for its low damage on regenerating new shoots and low starch content of the mother culm. Afterwards, sprouted, recruited, dead culms and mean culm diameter at breast height (DBH) of recruited culms were recorded in each treatment each year until the end of experiment period (2018).

The result showed both harvesting techniques and cutting intensities had a significant effect on mean culm diameter. X-shape harvesting technique yielded thicker bamboo culm (average 57.61 mm) than Horse-shoe harvesting technique (48.03 mm). Slightly higher shoot sprouting (17) as well as culm recruitment(10.3)were observed with X-shape harvesting technique compared to Horse-shoe harvesting technique (shoot sprouting =16; recruitment =10). Harvesting mature culms using X-shape technique and with the higher rate of cutting intensities yielded higher number of shoot sprouting, culm recruitment and higher DBH. DBH of culms at 75% intensity and 100% intensity was 59.72 mm and 62.5 mm, respectively, under the X-shape harvesting technique whereas 41.11 mm and 52.11 mm for Horse-shoe harvesting technique, respectively. Therefore, it is important to harvest mature *O. abyssinica* culms using X-shape cutting technique with higher cutting intensities. Considering maintenance of clump stability and ensuring sustainable harvest over years, applying 75% harvesting intensity of culms of age three and more years using the X-shaped harvesting technique is recommended.

Suitability:

This technology is suitable for harvesting three and more years old culms of *O. abyssinica* clumps with less destruction and enabling sustainable production of higher yield. The experimental site where this study was conducted is a flat to slightly slopping (5-10% slope) land; hence in steep slopes, the type of harvesting technique might need validation.

Requirements:

For this technology to be successful, use appropriate sharp tools to open up bamboo clumps in an X-shaped design and harvest mature culms with reduced damage of young bamboo culms in the clump.

Practice:

- Harvesting of mature culms should be done only in the dry season. It reduces the risk of borer attack that is associated with the lower moisture content of culms during dry season. It also enhances shoot/culm sprouting ability because the meristematic buds of the rhizome proper under the soil are inactive during the dry season, hence remained unaffected.
- Carefully identify mature bamboo culms, i.e. culms which are older than three years, by using its age identification characteristics such as presence or absence of culm sheath, branches, feature of its culm sheath rings, and culm flour. Local experience can be utilized to determine age of culms. Then, annually, cut more than 75% of mature culms in four directions of the clump based on the accessibility of mature culms (it will make X-shape).
- Harvest around 15 cm above the ground or cut just above the first node from the ground level.
- Clear cutting is not allowed, because the stand could be damaged critically.

Management:

O. abyssinica can be established both from seedlings and rhizome-based vegetative techniques. Establishing lowland bamboo plantations need to have wider spacing, a minimum of 4m x 4m. Few years or three to four years after establishment, lowland bamboo forests start congestion, requiring harvesting of mature culms. As lowland bamboo is a clumping bamboo, harvesting mature culms cannot be done by freely getting into clumps and selectively cutting mature culms. Thus, harvesting of mature culms need to be done using X-shaped harvesting technique and by using sharp tools such as machetes, saws and axes. Age of culms can be done by employing age identification characteristics.

Comparative advantage/yield:

This technology provides sustainable production of bamboo culms by cutting mature culms with highest rate of cutting intensity under X-shape harvesting technique. The newly sprouted bamboo shoots benefit from the space obtained from harvesting of mature culms. Thereby, newly sprouted bamboo culms would be thicker and taller compared to culms sprouted in the previous year. As a result, productivity of bamboo stand could increase.

Cost effectiveness:

The present treatments can be applied by family labor of producers. It requires tools mainly machetes, saws and axes that incur limited costs, but still affordable by a bamboo farmer. Machetes and axes can be produced by the local metal workshops. Cutting culms while making the X-shape design and afterwards inside the crowded clump needs special sharp machete that has proper shape and fits into the narrow space where free hand movement is not possible. Saws can be bought from local or national markets. Thus, applying treatments is cost effective.

Risk and uncertainty:

Applying the treatments will have no risk.

Purpose:

This management technology will be applied by bamboo growing farmers, enterprises and the private sector so as to ensure sustainable and high production of lowland bamboo culms for different applications.

End users

End users are bamboo growing farmers, enterprises and the private sector.

Charring Kiln for Water Hyacinth Biomass Conversion into Briquette (ከእንቦጭ የሚሰራ ከሰል ለማምረት የሚያገለግል ማክሰያ)

Responsible researchers: Getu Derbew, Yalemsew Adela and Mohamed Berhanu

Brief description of the technology

Converting different biomass into briquette is common practice globally. This practice requires a carbonization process which demands equipment. Utilizing efficient carbonization kiln machine has significant role to reduce environmental pollution, save energy and conversion time, and the quality of briquette produced. The main concern raised in traditional briquetting practice is the environmental pollution observed. In Ethiopia, this kind of technology is still at the infant stage where the traditional carbonization process is commonly dominating. In this particular study, the conversion process of water hyacinth into briquette used the traditional carbonizer (charring kiln made from used barrels). Though the initial work has indicated the potential of water hyacinth as an alternative energy source, the charring process was environmentally unsafe and has some usability gaps. Based on these limitations, this study aimed at developing appropriate biomass charring kiln that suits the local condition in terms of production and domestic uses. Accordingly, a charring kiln has been designed and fabricated using locally available materials. The charring kiln has a cylindrical shape with an opening at the top for loading the dry biomass and sealed at the bottom. It is composed of three parts, namely the chimney, the central cylinder and the air inlets. A double layer kiln filled with thermal insulator having a drum carrying capacity of 50 Kg biomass and carbonizer (1 m height and 0.7 m diameter) was designed and fabricated. The drum has 12 tubular hollow extensions at the side in symmetrical arrangement in three stages for regulating the air and generating the required thermal energy for carbonization process. The produced manually operated briquetting machine and carbonizer is technically feasible; so, it will be useful to small and medium scale briquette manufacturers.

Suitability

One of the main constraints in the advancement of biomass briquetting in developing nations in general, and in Ethiopia in particular, is the development of appropriate devices required such as carbonizer kiln that suits the local condition. Therefore, this technology would be very suitable to carbonize the water hyacinth biomass to produce briquette charcoal from the perspectives that it

is replicable, cost effective, easy to make, environment friendly and culturally acceptable technology.

Pre-requirement

It is very simple to develop new design, modify or adopt such technology. The required preconditions and materials are the following:

- Design of the kiln/paper based/
- Iron sheet/metal plate or sheet/
- Pipe/metal based/
- Thermal insulator in this case gypsum/ clay soil can be used as insulator/
- Cutting and welding machines
- Skill in metal work
- Training on the design and fabrication of the technology.

Practice

The charring kiln is a cylindrical double layered structured filled with gypsum as thermal insulator (i.e. used to keep heat energy not to dissipate to the surrounding).It is designed with an opening at the top for loading the dry biomass and sealed at the bottom. It is composed of three parts, namely the chimney, the central cylinder and the air inlets. The internal wall is made up of 6mm thick metal sheet (as alternative cylindrical clay made briquette wall can be used) and the external wall is made of 1mm thick metal sheet.

A 100 cm long chimney is attached with metal plate which is placed on the top of the central cylinder. The drum capacity is about 50 kg of biomass. The drum size is about 1 m height and 70 cm diameter. The drum has 12 tubular hollow extensions at the side in symmetrical arrangement in three stages for regulating the air for generating the required thermal energy for carbonization process.

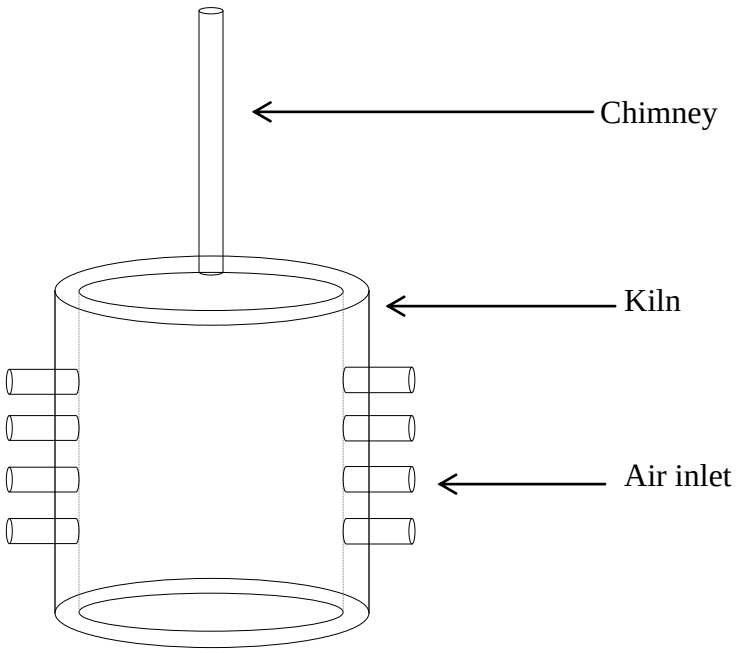


Figure 5 Schematic drawing of the Charring Kiln

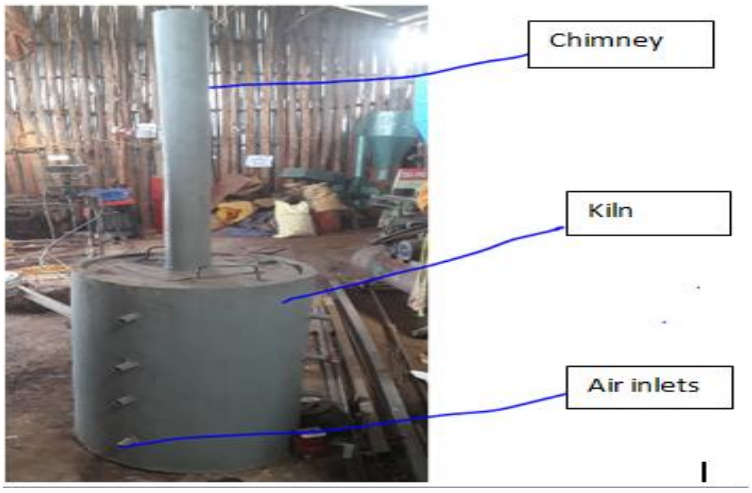


Figure 6 Fabricated charring kiln

Management

In designing, developing and utilizing this technology, the following are key points to be considered:

- Well defined/objectively defined/ design is required(amount of biomass, number of air vent holes, type of insulator to be used, simplicity for production and utilization)

- Metal sheets should be good quality and must be painted with anti-rust chemicals
- The gypsum or clay to be filled as insulator must be filled uniformly after mixing with water. After filling the kiln should be given enough time to let the fill get dry(usually under ambient dry condition of approximately three to five days)
- In case of using clay made insulator, the inner metal sheet may not be required. The only thing to do is producing cylindrical clay made insulator coating which will be fixed inside.
- During welding, every joint must be confirmed for no visible opening presence.
- After carbonization process the char should be removed from the kiln in a 450 slant position using scrubber. Upside down removal of char will destroy the inner structure of the thermal insulator.
- If the producer prefers clay based briquette liner as insulator, proper and stable fixing material must be used to avoid breakage during char removal from kiln.
- Sun dried water hyacinth biomass which released its water content approximately70-85% can be ignited in the kiln.
- The collected biomass is loosely loaded into the cylindrical kiln. After loading the biomass into the kiln, close the top of the kiln with metal plate attached to a conical chimney. Use little amount of biomass in the firing portion to ignite in the kiln and close the doors tightly to start the pyrolysis process.

Comparative advantage

Since the common carbonization process is carried out using barrels which dissipate energy into surrounding, without a barrier that takes longer time to complete the pyrolysis and emit huge amount of smoke. Therefore, we claim that using our technology for briquette production can provide the following advantages:

- Easy to fabricate and operate
- Allowing a shorter cycle time
- Produce char of excellent quality
- Efficient and portable
- Ease of loading the biomass and discharging of char

This comparison is basically against the traditional kiln used in vast majority of the public for waste to briquette conversion activity and also the previous trial used in this study. Accordingly,

upon using 18 Kg of dry (water hyacinth) biomass and average of 5.13± 0.5 Kg of char can be obtained in 83.75 ± 6.5 minutes (~1.4 hours). Using the traditional kiln made from barrel, the average time to complete the process was above 2 hours. Though the study didn't analyze the quality of the exhaust during pyrolysis, the present technology was not seen to emit white smoke and transfer heat through the wall of the kiln indicating the efficiency and comparative advantage of the technology.

Cost effectiveness

Although the technology's cost effectivenessis not yet compared with the market available kiln, market price is not significantly different from buying and using barrel as a kiln. Moreover, the time required to complete the process has shortened by 35% which indicates the cost effectiveness too.

Risk and uncertainty

The possible risks and uncertainties that can be associated with this technology are:

- Poor design and fabrication can lead to poor (inefficient in quality of briquette and time taking to mold) machine performance.
- Inappropriate use (upside down char unloading) of the technology while removing the char.

Purpose

The main purpose of this technology is to support the concerted effort exerted to manage water hyacinth. Since water hyacinth is mainly removed using mechanical and manual interventions, the removed biomass can be converted into various products. In the scope of this study, it is planned to convert into briquette charcoal and this requires efficient carbonizer/charring kiln/. Accordingly, this technology is designed and fabricated so that the effort to manage this invasive species would be holistic.

End user

This technology can be used by anyone who is involved in briquette production or those interested in briquette production technology. However, the following can be listed as potential users:

- Entrepreneurs who are interested to produce the kiln and put into the value chain.

- Small and micro finance enterprises to manufacture and sell which will improve their livelihood.
- Individual farmers who can produce char with little training.

Reliability of information

The finding of this research is the original work of the researchers at Environmental Pollution Management Directorate, EEFRI. The reliability of the data could be checked with similar procedure of experimentation.

Water Hyacinth Biomass Briquetting Machine (ከእንቦጭ የሚሰራ ከሰል ለማምረት የሚያገለግል የከሰል ቅርጽ ማውጫ)

Responsible researchers: Getu Derbew, Yalemsew Adela and Mohamed Berhanu

Brief description of the technology

Converting different biomass into briquette is a common practice globally. This practice requires different equipment such as biomass collectors, drier, carbonizer and molder. Utilizing efficient briquetting mold machine or device has a significant role on the quality of briquette produced. Accordingly, a manually operating biomass briquette making machine was designed and fabricated using locally available materials. The machine has three main parts; molding unit, mechanical pressing unit and the stand unit. On the molding unit, there are 49 cubic holes with 3x3 cm dimension where the mixed char is filled and molded. There are movable pistons in each cubic hole to compress the char. The pistons are welded on a flat metal plate, where the plate is also welded on a hydraulic jack of 10 tones capacity. The jack drives the pistons in and out of the hole during operation. The machine can produce 49 briquettes of each 3x3x3 cm in size at a time.

Suitability

There are several types of molds available on the market used to make briquette from different biomass. The essence of this research is to convert the water hyacinth biomass into briquette as a means for integrated management of water hyacinth invasion. The commonly existing molds are circular in type with a diameter of 20-30 cm which requires specific type of cookstove to use. Moreover, once this type of briquette starts burning, the list of tasks should be in line without interruption. Consequently, this will dictate the user to complete the cooking activities once without interruption otherwise it will be wasted. In this technology, small sized briquette which has suitable utility shape and ease of transporting can be produced. For instance, the user can add the briquette to the cook stoves whenever the need arises. The other feature of this technology is that it is equipped with hydraulic jack that eases extra energy.

Pre-requirement

The technology can be adopted from the institute and can be manufactured for the desired level of consumption. The required preconditions and materials to produce this technology and use for the intended purpose are the following:

- Detailed design of the machine
- Metal work skill/cutting and welding/
- Workshop to make the machine
- Different materials such as hydraulic jack, metal sheet, pipe, etc.
- Binding material/clay or other agricultural wastes/
- Training on the use of the technology

Practice

Based on the shape and size of the briquettes to be produced, this machine is designed and fabricated from locally available materials. Accordingly, the machine is designed to have three major components, i.e. molding unit, pressing unit and stand unit. In the molding unit, there are square holes with a size of 3.5 mm ×3.5 mm ×3.5 mm aimed to produce cubic shape briquette. The machine consists 49 molding holes on the molding unit welded together and each hole has piston at the bottom movable in and out to compress the feed. During molding, the cover at the top is closed and the piston from the bottom is moved upward to press the char and produce the briquette. The piston was welded on a flat metal plate hinged on a 10 ton capacity hydraulic jack. As the jack drives the plate the pistons start to move in and out of the holes during operation. In order to compress the char, the molding unit has cover to be locked while the piston starts moving where compaction can be realized.

The vertical motion of the pistons in and out of the molds, and the ejection of compressed briquettes from the molds were pressured by the hydraulic jack that is welded on the angle bars on the frame of the machine. By this arrangement, the force from the hydraulic jack is centrally applied to the metal plate bearing the pistons. The sample char produced from water hyacinth was mixed with binder and fed into the molding unit in the compaction chamber and rammed until they are full. The lid of the machine was then closed and screwed to position. The hydraulic jack which was under the base plate was used to lift the plate assembly carrying the transmission rods, which then pushes the piston against the mixture inside the various dies of the compaction chamber. The mix is thus compacted against the lid of the machine. The mix was then left to set

for about five minutes after which the lid of the machine is opened and the briquettes were then ejected.

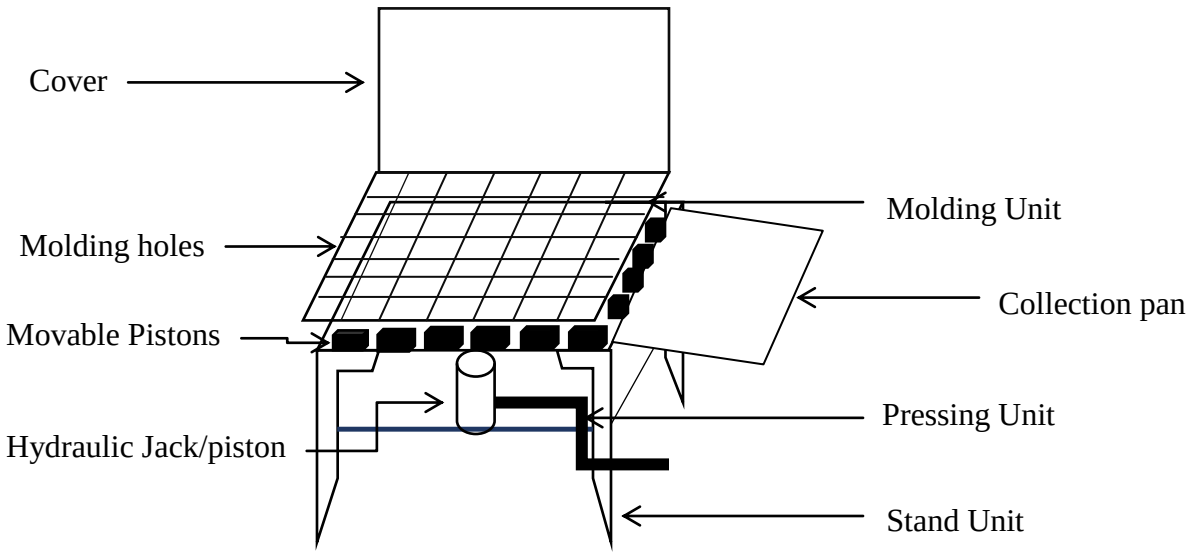


Figure 7 Schematic drawing of the mold machine

Figure 8 Manufactured mold machine

Management

This technology can be produced or used by different groups in the community with careful management of the following:

- Proper design of the machine is required to manufacture.
- Moderately skilled metal worker is must to manufacture.
- Proper fitting of every joint is required to make compression smooth.
- Proper fitting of the piston is must to produce stable briquette.
- Good quality hydraulic jack is important to have durable machine.
- The loading capacity of the hydraulic jack should be determined based on the number of the pistons.
- During the manufacturing of the machine, the position of the hydraulic jack must be at the centroid of the piston plate.
- During operation, the mixed char is filled in the holes found on the molding unit and locked with cover plate from the top. Then, the hand of the hydraulic jack is rotated clockwise to compress the char. After adequate compaction, the upper cover will be unlocked and the briquette will be pushed by the jack and collected by the collection pan.
- Since the compaction removes the water from the char mix, there must be liquid collection system under the machine.

Comparative advantage

This technology is designed with the basic concept of producing briquette that can be used in any type of cookstove. The existing briquette made from waste biomass has a circular shape that fit to the local cook stoves such as '*Lakech'* and others. This kind of briquette dictates the user to accomplish list of cooking activities at the same time until the briquettes completely burn and exhaust. Because it is not possible to put off the glow once it is ignited, consecutive cooking activities should be carried out. Therefore, the 3.5 mm cubic briquette would become suitable to utilize and avoid the above challenge observed which gives better comparative advantage than the circular briquette. Being small sized briquette and made with piston-based compression, the physical stability of the briquette is relatively high, which gives better stability during storage and transportation. An evaluation on the stability of the briquette showed that only 3 briquettes were broken out of 196 produced. An average time of 15 minute is required to prepare the char mixed with binding agent and molding the first 49 cubic briquettes.

Cost effectiveness

The cost effectiveness analysis is not carried out for this machine. However, one can realize that once the machine is bought, with proper operation, it can be used for a long timeindicating cost effectiveness indirectly.

Risk and uncertainty

The possible risks associated with this technology could be the following

- It may be difficult for the manufacturers and users to practice the technology if training is not obtained.
- Weak combination among the biomass collection, carbonization and molding phase may discourage the user
- Access to welding shop in the rural areas if maintenance is required.

Purpose

The problem that has been observed in many of our water resources is the rapid expansion of water hyacinth. In tackling this problem, applying an integrated management (mechanical, chemical and biological) which encompasses the removal of the weed and utilization is very important. Accordingly, this technology is aimed at contributing to the conversion of water hyacinth into briquette. **Purpose wise this specific technology is used to produce small sized briquette with the basic intent of producing manageable charcoal.**

End users

This technology can be used by anyone who is involved in briquette production or those interested in briquette production technology. The following users can also be listed as potential users:

- Small and micro finance enterprises to manufacture the machine and also produce the briquette.
- Individual farmers can produce briquette charcoal with little training.
- Regional bureaus as a means for job creation and management of water hyacinth.

Reliability of information

The finding of this research is the original work of the researchers at Environmental Pollution Management Directorate, EEFRI. The reliability of the data could be checked with similar procedure of experimentation.

Plastic Waste Use as a Raw Material in Concrete Mix (የተወገዱ ፕላስቲኮችን ለኮንክሪት ቡኮ እንደ ጥሬ ዕቃ መጠቀም)

Responsible Researchers: **Yalemsew Adela, Mohammed Birhanu and Biruk Gobena**

Brief description of the technology

The twenty first century is marked by the huge use of plastic materials for various purposes. Recent reports showed that about 2 million plastic bags and 1 million plastic bottles are used every minute globally. Similarly the consumption of plastics in Ethiopia is growing by 17% in the recent decade by which the packaging industry account for 58% of the plastic use nationally according to the Euromap Business Report. Due to the poor waste management system in Ethiopia, huge amount of plastic bags and bottles are dumped everywhere. This has caused serious environmental sanitation and pollution problems across the country. Though there are efforts to manage this problem, the magnitude of the problem surpasses the interventions exercised. Henceforth, diversifying the interventions to manage plastic wastes could play meaningful role. This study has identified the construction sector as potential area where plastic wastes can be recycled. Therefore, the aim of this study was to investigate the technical feasibility of plastic wastes as a partial replacement of coarse aggregates in concrete mix using volcanic pumice as an admixture. The experimental design employed evaluated the effect of two factor variables, i.e. quantity of coarse aggregate replaced and effect of pumice as an admixture. The response variables measured were compressive and split tensile strength of the concrete specimens prepared. Standard concrete grade of M20 (1:1.5:3) with Indian IS-4562000 and ASTM C496 testing methods were employed. Plastic bottles and plastic bags were collected and cut to average size of 2-3 cm. River sand, Portland Pozala Cement, potable water and pumice(< 2µm, 10% of cement admixture) were used to prepare the test specimens. Cubic specimens (15 cm*15 cm*15 cm) and cylindrical specimens (15 cm diameter and 30 cm length) were prepared. A total of 108 test specimens which comprise both treatment and control were prepared. The percent plastic bags and plastic bottle replacement range from 0-35% and 0-75% respectively. The compressive and split tensile strength test was done on day 7, 14, and 28. The result showed that nearly 5 % (without admixture) and 6% (with admixture) plastic bag aggregate replacement is feasible to maintain a compressive strength of 15 MPa load. Meanwhile, 11% (without admixture) and 13% (with admixture) plastic bag aggregate replacement is working for the 10

MPa compressive strength. In the case of plastic bottle aggregate, a replacement of 16.5% (without admixture) to 16.8% (with admixture) was found to have a compressive strength of 15 MPa. However, for a meaningful working load of 10 MPa load, the percent replacement extend from 35 (without admixture) to 37.5 (with admixture). In terms of the split tensile strength, 35% replacement was found feasible upon 2.17 MPa loading where the standard load is 3.13 MPa. Conclusively, the wasted plastic resources could be potential alternative of coarse aggregate in concrete mix which would have both environmental and economic benefits.

Suitability

Even though plastic wastes are reused and recycled at various level of consumption, the problem is still underway which requires versatile reuse and recycle of plastic wastes. In Ethiopia recycling efforts focuses on recycling for industrial use and converting plastics into different products such as terrazzo, fuel and others. Provided that the amount recycled is very low, the exercise is not environmentally friendly and economically feasible. To prepare a terrazzo from plastic waste, heat energy, molting kiln and molding pan is required, and burning plastic is not recommendable practice globally. Therefore, using plastic wastes as a coarse aggregate is much easier for making, economical and environmentally friendly. In economic term, replacing the stone aggregate by plastic waste aggregate has more suitability apart from environmental considerations.

Pre-requirement:

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

- Plastic wastes/both bottles and bags where bottle is recommendable/
- Scissors to cut plastics/ if possible plastic mills/
- Pumice
- Sieves/2 micrometer/
- Different shapes of mold to make concrete bricks / can be made from any available material locally/
- Cement, coarse gravel, water, sand and manual mixer

Practice

- River sand, coarse aggregate size of 2 cm, portland pozala cement, PET bottle, plastic bags, potable water and pumice were collected.
- Both plastic bags and bottles were cut to a size of 2 cm.
- Pumice was grounded and sieved through a 2 µm sieve.
- Mixing ratio of 1:1.5:3(cement, sand, coarse aggregate) was employed.
- Mixing was done manually.
- Curing period of each cast was 28 days to maintain for the reported strength value.

Figure 9 Cubic cast (left), plastic aggregate (center) and specimen (right)

Management

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

- Curing period of the cast should be 28 days.
- Cement used should be as per the requirement of the standard.
- Volume mix ration is used.
- The amount of pumice should be 10% of the cement ratio.
- Mixing of each components of the concrete mix should be uniform.

- The plastic bag aggregate usability is compromised upon increasing the amount of replacement.

Comparative advantage/yield*:*

- The technology doesn't emit any dangerous gaseous chemical for human health in comparison with the use in terrazzo making.
- Reduction of coarse aggregate use by plastic aggregate replacement.
- The increasing consumption of plastic material would suggest for presence of sustainable source.

- No special devices/equipments are required in comparison with other mode of recycling processes.

Cost effectiveness

- The cost effectiveness of the technology bases the availability of plastic bags and bottles with low expense and ease of use. The comparison below show the direct economic gain/saving/ based on the lowest percent plastic bag aggregate replacement and highest plastic bottle aggregate replacement for a compressive strength of 10 MPa without admixture.
  - Suppose a 2 km pedestrian pavement made from concrete brick with a thickness of 0.05 m with a mix ration of 1:1.5:3.
  - **Assumption:**
    - The collection cost for plastics from different sources is equivalent to the cost incurred to crash and transport coarse aggregate.
    - The change in price for collection of plastics for the future holds the same for the change that can be observed to get coarse aggregate.

    <u>Analysis</u>
    - Based on the above information 200 m^3 mix is required and 36.4 m^3, 54.55 m^3, and 109.1 m^3 of cement, sand and aggregate is required respectively.
    - With arbitrary market price of 1 m^3 ~ 535 ETB
    - A total of **<u>58,368.5</u>** ETB is required.

    <u>Case 1:</u> 9% plastic bag aggregate replacement
    - Saving of 9.82 m^3 aggregate
    - Saving of **<u>5,253.7</u>** Birr
  - **<u>Case 2</u>**: 35% plastic bottle aggregate replacement
    - Saving of 38.18 m^3 aggregate

- Saving of **20,426.3** ETB

Risk and uncertainty

- The probable associated risk with this technology is:
  - Developed culture of using stone aggregate might challenge the use of plastics as an aggregate.
  - Incomplete curing period may cause the cast fragile.
  - Unable to have consistent plastic collection route for the use of plastics.

- A shift into the use of plastics to other sort of recycling modalities.

Purpose

- The main goal of this technology is to evaluate the technical feasibility of plastic aggregates in concrete mix so as to introduce diversified use of plastic wastes and become competitive choice among other recycling efforts. Consequently, the likelihood to see plastics as a waste in the environment will be reduced.

End users

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.
- Micro-enterprises can use the technology and improve their livelihood.
- Construction sector in general.
- Policy making organs can consume this technology as a source of information and devise a strategy to manage plastic wastes sustainability.

Reliability of information

The finding of this research is the original property of the institute and its researchers. It is nowhere produced before and the reliability of the data could be checked with similar procedure of experimentation.

Package of Information

Exclosure for Woody Species Diversity and Aboveground Biomass Carbon Stock Enhancement

Responsible researchers: Melkamu Terefe and Abdella Gure

Brief description of the Information

Area exclosure is the fastest and moderate approach of recovering degraded sites, and it is practiced in different parts of Ethiopia. A study was conducted in *Jabi Tehnan Woreda*, West *Gojjam* Zone, North western Ethiopia to assess and compare diversity, composition, population structure and above ground biomass carbon in two exclosures (with tree plantation intervention) and adjacent open lands. Data was collected from randomly selected40 sample plots with a size of 50m by 50m each. A total of 29woody species and 1.24±0.27 Mg ha^{-1} of aboveground biomass carbon were recorded in the exclosures whereas there were only 17 woody species and 0.11±0.07 Mg ha^{-1} of aboveground biomass carbon in the open grazing lands. Furthermore, population structure of woody species in the exclosure of both sites exhibited better regeneration status than in the adjacent open grazing land.Therefore, it is recommended to scale up the exclosure practices with tree plantation interventions to wider degraded lands for better environmental benefits including enhanced tree diversity and carbon stock.

Introduction

Rehabilitation of degraded lands puts positive impact on soil water holding capacity, productivity and soil organic matter. Previously, exclosure and enclosure have been done in different parts of Ethiopia with objectives of restoring degraded lands. However, studies to generate empirical data on the contribution of exclosures to biodiversity and aboveground biomass carbon enhancement are required for informed decision making. Moreover, the role of exclosures in protecting environmental degradation thereby facilitating vegetation recovery across sites and land uses is not uniform. Existing information on its impact on natural regeneration, species composition and carbon stock in comparison with adjacent open grazing lands is not enough, and this is especially true in the case of *Amhara* region, West *Gojjam* Zone,

Jabi Tehnan district where exclosure measure has been taken. Therefore, a study aiming at quantifying the role of exclosures in tree diversity and carbon stock enhancement was carried out at the district by selecting two exclosures and adjacent grazing lands. This package of information is, therefore, an effort to inform decision makers at all levels about the importance of exclosures in vegetation restoration and carbon sequestration.

Brief methodology

Two exclosures (with tree plantation intervention) and their adjacent open grazing lands were purposively selected from the district. A total of 40 quadrats (50mx50m) as main plots at 50 m intervals were established in both land uses. A total of 8 parallel transect lines, 100m apart from each other, were used inside and outside the exclosure land. Data on trees and shrubs were collected in the main plot whereas data on seedlings and saplings were collected in sub-plots.

Major findings and justification of its importance

A total of 29 woody species were recorded in the two exclosure sites (*Wega Guansa* and *Gay Wubeshet*) and 17 in the two adjacent open grazing lands. The commonly found species in the exclosures were *Vernonia auriculifera, Cupressus lusitanica* and *Osyris quadripartite.*

The aboveground biomass carbon stocks (mean± SE) woody species in adjacent open grazing and exclosure land use of Gay *Wubeshet* site was 0.11±0.07 and 1.24±0.27Mg ha^{-1}, respectively. While in adjacent open grazing and exclosure land use of *Wega Guansa* site, the value (Mean±SE) was 0.27±0.03 and 2.79±0.27 $Mgha^{-1}$, respectively.

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.

Key policy recommendations

- Scaling up the exclosure practices with tree plantation interventions is essential to restore degraded forest lands and enhance tree diversity and carbon stock accumulation.
- A separate strategy of tree growing should be formulated for exclosure and adjacent open grazing land since tree species could have different performance under different site conditions.

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 *Amhara* region and beyond. Therefore, this package of information can be an additional useful material for decision makers at all levels from the grass roots woreda level to higher officials at the federal level.

Reliability of information

This information package is based on two published articles by Melkamu Terefe and Abdella Gure. *Ecosystem Health and Sustainability*, 5(1), pp.98-109; *Ecosystem Health and Sustainability*, 5(1), pp.79-85.

The Contribution of Agroforestry Practices for Food Security in Some Selected Areas of Ethiopia

Responsible researchers: Abu M., Sinke M, Samrawit B, Abdu A., Teshome T., Fekadu H., Melkamu T., Biruk B., Kedir A. and Fikadu D.

Brief description of the information

Three studies conducted: *Study 1* in *Endamehoni*, *Kola Tenben* and *Merebleh Woredas* of *Tigray; Study 2* in *Gomma Woreda* of *Jimma;* and *Study 3* in *Arbaminch Zuriya* and *Wenago Woreda* of SNNPRS in Ethiopia reported on the importance of agroforestry systems for food security. The studies carried out informal and formal surveys, focus group discussions (FGDs) and key informant interviews.

Results of the multi-locational studies show that traditional agroforestry systems have developed as a result of the multifaceted ecological, social and economic interactions. For example, in*WenagoWoreda* home gardens of *Coffee-Tree-Enset* based Agroforestry are the identifying features whereas *Banana-Mango* Fruit based traditional agroforestry practice dominate *ArbaminchZuriyaworeda*. Respondents agree home garden in the study area play vital role in providing food and valuable cash crops for the household. In Jima area, respondents stated that agroforestry practice positively affected crop and pasture production as well as improved the local condition/environment.

On the other hand, in the midlands and lowlands of *Tigray* scattered tree agroforestry is the common practice mostly dominated by species like *Ziziphus spina-christi, Faidherbia albida, Acacia seyal, Clutea lanceolata* and *Cordia africana* while the highland agroecology of *Tigray* is dominated by woodlot and farm boundary of *Eucalyptus globulus*. Respondents of the study area as well agree the important role played by agroforestry practices in income generation and food security.

Introduction

Ethiopian farmers have a long history of incorporating/maintaining various tree species in their farming systems; and as result, the selection process has led to high variations in the number, size, and placement of specific component diversity and arrangement. However, no systematic in-depth study has been undertaken to characterize and fully understand the existing structural

and functional attributes of component admixtures and their synergistic interactions. Currently, little attention is given to describe and analyze the existing traditional agroforestry practices (TAFPs). There is a need to have an in-depth knowledge of the existing TAFPs to fully benefit from their economic and ecological uses. Therefore, the multi-locational studies were intended to generate information that can help to better understand the various forms and practices available in many areas of the country and identify the role each practice contributes towards food security and livelihoods of farmers.

Brief methodology

The methodology followed by each study is presented as follows:

Study 1: A total of 201 households were interviewed in three Woredas, each representing three different agroecologies in *Tigray*: *Endamehoni* (highland), *Kola Tenben* (mid land) and *Merebleh* (lowland). Both primary and secondary data were employed to achieve the research objective. The primary data mainly related to the role of agroforestry for food security were collected using both formal and informal survey methods. All the necessary quantitative data required for the study were gathered through a farm household survey. Moreover, secondary data were collected from relevant sources.

Study 2: The study was conducted in three sites that represent highland (*Omafuntule*), mid land (*Ganjiilbu*) and lowland (*Choche*) in *Gomma Woreda* of *Jima* Zone. Household interview was done on a total of 150 respondents to extract information about the role of selected agroforestry practices to enhance food security through structured questionnaire.Furthermore, semi-structured interview and group discussions were conducted to determine the preference of the local people for tree species and agroforestry practices and prioritize the tree species based on their economic and ecological benefits. Moreover, knowledge on forest and woodland resources management in general and on fruit and fodder tree species was assessed. In addition, tree planting practice, if any was assessed. Furthermore, the contribution of forest and woodland resource in general and fruit and fodder tree species to the livelihood of the community was assessed through the questionnaire and group discussions. Both qualitative and quantitative data was collected and analyzed.

Study 3: The study was conducted in two agroecologies: Lowland (*Arbaminch Zuria woreda*) and midland (*Wenago woreda*) of SNNPR. Data were collected from both primary and secondary sources. A total of 220 representative households were interviewed in the two sites using structured questionnaire. Focus group discussions and key informant interviews were also conducted to extract information about the trend of vegetation change and categorize trees and shrubs of the traditional agroforestry practices. The preference of the local people for tree species, knowledge on forest and woodland resources management in general and on fruit and fodder tree species was assessed by key informant interview. Furthermore, the contribution of the traditional agroforestry practices in general and fruit and fodder tree species to the livelihood of the community were assessed through questionnaire and the focus group discussions.

Major findings

- ✓ The multi-location studies identified multiple agroforestry practices which have evolved following the unique characteristics of each specific site. Accordingly, the principal traditional agroforestry practices identified in *Arbaminch Zuriya* and *Wenago* include *Banana-Mango* fruit-based agroforestry and *Coffee-Tree-Enset* homegarden, respectively. In areas around *Jimma,* coffee shade tree was the dominant feature while in the midlands and lowlands of *Tigray* scattered tree agroforestry is the common practice mostly dominated by species like *Z. spina-christi, F. albida, A.seyal, C. lanceolata* and *C. africana*. The highland agroecology of *Tigray*, on the other hand, was dominated by woodlot and farm boundary of *E. globulus*.
- ✓ Home gardens maintained high level of species diversity with a total of 38 different multi-purpose trees and shrubs identified which supported the direct or indirect physical and economic access of the households to nutritious food. This study also identified a total of 10 fruit trees in home gardens and farmlands. On the other hand, scattered tree agroforestry practices show relatively low level of species diversity and composition.
- ✓ Major products obtained from home gardens included fruits, timber, *Kocho* and *Bulla* (e*nset* products) and coffee. In addition, vegetables, tubers and different annual crops are also grown and managed to support the subsistence of the household. While products from scattered trees in farm lands provided nutritious nuts for food, fodder for livestock and improved crop yield.

- ✓ In some areas the income generated from traditional agroforestry practices helped farmers in funding school fee of their children, financing different social ceremonies like wedding, grief, social savings (*Edir* and *Ekub*) and subsidize other miscellaneous social expenditures.
- ✓ Respondents invariably agreed that agroforestry play positive roles in maintaining food security, creating economic access, contributing to enough, safe and nutritious food and meet dietary needs of individuals. Home gardens seemed to play vital role in providing valuable cash crops for the household.
- ✓ Traditional agroforestry practices have positive impact on: improvement of soil fertility, soil and water conservation, reduction of the chance of complete crop failure, supply of firewood and fodder, maximization of overall farm income, and creating suitable and comfortable surrounding for living (micro – climate modification).
- ✓ Majority of the respondents from the various locations reported the presence of food shortage in their locality and maintained that agroforestry practices commonly play considerable role in realizing food security during these hard times either by creating direct access to food (fruits, vegetables and annual crops) or by generating cash income for the household through sell of different highly valuable cash crops such as coffee, khat, avocado, banana and mango.
- ✓ The studies also revealed that majority of the respondents integrated trees and crops in their farms
- ✓ In contrast to the significant contribution of traditional agroforestry practices for livelihood of farmers, the practice was reported to be challenged by different factors. For instance, absence of technical support and guidance from government bodies (experts and development agents) and other concerned bodies, water shortage and wild animals attack were reported as the most challenging factors. Other location specific problems like *enset* and coffee diseases and mango pests have been reported to curtail the important role played by agroforestry.

Key policy recommendations

- Policy makers must consider home garden agroforestry and other high yielding AF practices for further scaling up.

- Absence of technical support is determinant issue and needs to be appropriately addressed.
- Government should take the leading position in facilitating the promotion. Awareness creation on agroforestry and providing field visits for farmers for further expansion of high yielding agroforestry practices is necessary.
- In addition, capacity building programs, good quality seedlings and other support programs should assist the AF promotion programs.

Potential user of the information

- Regional, zonal and wereda extension experts, researchers and policy makers could make use of this information to support farmers.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from three original research reports by:

- ☛ Abu M., Sinke M, Samrawit B, Abdu A. and Teshome T. "The Contribution of Agroforestry Practices for Food Security in Selected Districts of *Tigray* National Regional State" (unpublished report).
- ☛ Fekadu H., Melkamu T., Abdu A. "The contribution of agroforestry practices for food security in selected district of *Oromia* South western, Ethiopia" (unpublished report).
- ☛ Biruk B., Kedir A. and Fikadu D. "The contribution of selected agroforestry practice for food security: a case in *Arbaminch Zuria* and *Wenago* districts of SNNPRS, Ethiopia" (unpublished report).

Carbon Stocks in Homegarden and Adjacent Coffee-based Agroforestry Practices in Southwestern Ethiopia

Responsible researchers: Mulugeta Betemariyam, Mesele Negash and Adefires Worku

Brief description of the information

Agroforestry systems harbour different woody species, where their above and below ground biomass contribute to accumulation of carbon and in removing excessive CO_2 from the atmosphere. The southwestern Ethiopia is especially characterized by traditional agroforestry practices that include homegarden agroforestry (HGAF) and coffee-based agroforestry (CAF). A study in *Mana woreda* of JimmaZone identified the woody species in the practice and found out that CAF had higher biomass and carbon than the HGAF.

The estimated mean total carbon stock for home garden was 158 Mg C ha^{-1} and 195 Mg C ha^{-1} for the CAF, and thus the agroforestry practices need to be integrated in the different climate change adaptation and mitigation schemes of the country.

Introduction

The roles of tropical agroforestry in carbon sequestration and in helping to mitigate climate change has only recently been recognized. In Ethiopia, agroforestry practicing is an old-aged land use and widespread in different agroecologies and farming systems. In the south western region of Ethiopia, homegarden agroforestry (HGAF) and coffee-based agroforestry (CAF) practices are the most dominant practices. Such agroforestry systems offer potential opportunity for carbon storage due to their forestlike structure and composition. More importantly, the diverse trees integrated in CAF as coffee shade have an important potential for sequestering and storing carbon in the biomass, soil and harvested products. While several studies have been conducted on the carbon stocks of different agroforestry practices in Ethiopia, there is no report on the carbon stocks from agroforestry practicing in *Mena Woreda*, which is situated in the midlands of south western Ethiopia where home gardening and coffee farms are common in the landscape. A survey was conducted aiming at analysing the carbon accumulation potential in the biomass and soil of HGAF and adjacent CAF at three selected kebeles (lowest administrative unit in Ethiopia) in *Mena Woreda*, *Jimma* Zone of Oromia. This package of information is

therefore prepared to provide decision makers with empirical evidences on carbon sequestration roles of home gardens and coffee- based agroforestry practices.

Brief methodology

The study was conducted at *Mana* district, *Jimma* Zone of *Oromia* region, in south western Ethiopia. The area has bimodal rainfall distribution with mean annual rainfall and monthly temperature ranges of 1200 mm-1800 mm and 13.0 °C-24.8 °C, respectively. The study was specifically conducted in three *Kebeles*, which were selected based on the presence of both HGAF and CAF as common agroforestry practices, with similar dominant soil type (i.e. Nitisol) and climatic conditions. A total of 60 farms, comprising 30 for each studied agroforestry practice, were selected for field level data collection. A nested plot of 20 m x 20 m with three 1 m × 1 m sub-plots were established in each farm to carry out woody species inventory and soil sampling. All trees and shrubs with DBH ≥ 2.5cm and height ≥1.5 m within the sample plot were measured recorded and biomass estimated with already existing allometric equations. Soil carbon was analysed from a total of 120 soil samples, and soil bulk density from similar size of undisturbed soil samples.

Major findings

The basal area of trees in CAF (12.86 m^2ha^{-1}) was 2.3 times higher than HGAF (5.54 m^2ha^{-1}). Similarly, the mean aboveground biomass carbon stock of CAF was approximately 2.33 times higher than HGAF. The total soil organic carbon stocks (SOC) in 0-60 cm depth was 130.37 Mg C ha^{-1} for the HGAF and 131.86 Mg C ha^{-1} for the CAF. The top layer accounted for 56% of the total SOC in the HGAF and 57% of the total SOC in adjacent CAF. The estimated mean total carbon stock for home garden was 158 Mg C ha^{-1} and 195 Mg C ha^{-1} for the CAF.

Key policy recommendations

Since large amounts of carbon accumulated in the biomass and soils of homegarden and coffee-based agroforestry; and it is an opportunity for carbon sequestration and need to be integrated in different climate change adaptation and mitigation schemes of the country.

Potential user of the information

This information is targeted to the different decision makers at all levels starting from the *Woreda* to the federal levels.

Reliability of the information: This information has been extracted from original research report by Mulugeta Betemariyam, Mesele Negash and Adefires Worku "Comparative analysis of carbon stocks in home garden and adjacent coffee-based agroforestry practices at *Mana Woreda*, South western Ethiopia (unpublished report).

Carbon Stock and Woody Species Diversity Patterns in Church Forests in Addis Ababa City

Responsible researchers: Getaw Yilma and Abayneh Derero

Brief description of information:

Most forests of the Ethiopian Orthodox Churches comprise natural and planted ones in their premises. Church forests that are in urban areas constitute important segments of urban forests. A study investigated carbon stock and woody species diversity patterns in churches of Addis Ababa city. Carbon stock and different diversity indices were computed, and the relationships between church age and tree parameters were evaluated. Results showed that the forests were small in area (0.6 ± 0.57 ha), and the tree species with the highest total biomass carbon stock were*Juniperusprocera, Eucalyptus globulus* and*Eucalyptuscamaldulensis*. The mean amount of biomass carbon stock contained in each church forest was 156 ± 92 t ha^{-1}. A total of 90 woody species belonging to 35 families were identified, of which 55.6% were native whereas the remaining 44.4% were exotic. The study also identified that the oldest churches harboured a higher number of tress from the remnant forests. Thus, scaling up the long-term maintenance, development and management of such small-sized forests in urban green spaces is vital for climate change mitigation and biodiversity conservation.

Introduction

Urban forests can be viewed as comprising of tree stands as well as individual trees including all woody perennial vegetation in and near urban areas. More specifically, church forest types often comprise patchy remnants of old-aged forests, and in Addis Ababa city, church forests are one of the dominant urban forest types. However, the potential of the church forests for maintenance of woody species diversity and their contributions to climate change mitigation (by storing carbon) in cities of Ethiopia has not been systematically and comprehensively studied. The role played by the Church in maintaining and managing forests and trees in urban areas is paramount, and understanding the biodiversity conservation, climate change mitigation and urban greening contributions of the church forest is important. Addis Ababa city has several small-sized forests that belong to the Ethiopian Orthodox Churches, which were established over a century ago.

Thus, the general objective of the study was to characterize woody species diversity and estimate carbon stock potential of selected church forests in Addis Ababa along age gradient of the churches. This package of information on church forests will be helpful to increase the understanding of the decision makers and the public on the environmental role of the forests so that enough attention is given for their long-term maintenance as well as scaling up of the practice.

Brief methodology

A total of 17 churches were sampled from various age categories, based on their establishment years. Strata I comprise Pre-Emperor Haile Selassie churches, whereas the remaining strata II to IV comprise churches established during the Emperor Haile Selassie era, Dergue regime and the Ethiopian People's Revolutionary Democratic Front regime. The patches of forest within each church boundary were measured for their areas. Full inventory of all woody species was done in each church forest. The diameter at breast height (DBH) and height (ht) of woody plants were measured. Aboveground biomass was estimated with a generic allometric equation, and then carbon stock was estimated from the biomass estimates.

Major findings

The results showed that the church forests had on average 0.6 ± 0.57 ha of size. They contained an estimated 332.3 ± 196.3 t ha-1 of woody biomass on average with above-ground biomass of 276.9 t ha-1 and below-ground biomass of 55.4 t ha-1. Therefore, there was 156 ± 92 t ha^{-1} of woody biomass carbon stock in the forests on average. The first three species with the highest total carbon stock were *Juniperus procera*, *Eucalyptus globulus* and *Eucalyptus camaldulensis.* These species were also the most abundant and dominant tree species. The mean native trees carbon stock in Strata I was significantly higher than the remaining three strata. A total of 90 woody species were identified, of those 50 of the species were indigenous while the remaining 40 were exotic. Analysis also revealed that the mean native trees carbon stock in Strata I was significantly higher than the remaining three strata, and it also revealed that the carbon stock of native trees had significant positive relationship with the church age.

Key policy recommendations

The essential role the church forests are playing to maintain woody species diversity and the associated biodiversity and their role in sequestering carbon dioxide needs to be appreciated and policy and institutional supports should be given to maximize these highly positive effects.

The study clearly shows that the contribution of such small sized forests (0.62 ha) for carbon sequestration, climate change mitigation and biodiversity conservation should not be underestimated, and results are indicative of the potential roles of such small-sized forests.

Therefore, the practice of maintaining and developing such small-sized forests in church compounds and elsewhere in towns and cities should be scaled up as the integral components in urban green spaces through long-term development and management.

Potential user of the information

This package of information is targeted at informing city municipalities and other decision makers in urban centers on the environmental role of church forests in urban landscapes so that they support such small-scale urban forest management and developments. This is also to inform the Ethiopian Orthodox Church the environmental role of its forests so that they keep up the good practice and scale it up to other church compounds.

Reliability of information

The information is based on an original work that passed through scientific reviews and rigour. This information has been extracted from original research report by GetawYilma and AbaynehDerero "Carbon stock and woody species diversity patterns in church forests along church age gradient in Addis Ababa, Ethiopia" (unpublished report).

Structural Components and Tree Management Techniques in Traditional Agroforestry Practices in Southern Tigray

Responsible researchers: Abu M., Sinke M., Samrawit B., Abdu A. and Teshome T.

Brief description of the information

Agroforestry system and practices are widespread in different forms in the diverse agro-ecologies and farming systems of Ethiopia. The traditional tree management techniques, woody species mix, both vertical and horizontal placements of the system components could vary considerably. A study was undertaken in southern *Tigray* region in *Raya Azebo* and *Raya Alamata*to explore and document existing indigenous tree planting/managing techniques, and the structural attribute of each component across the study areaby interviewing a total of 93 respondents. The finding from the study shows that *Eucalyptus globulus, Acacia abyssinica* and *Balanites aegyptiaca* are the most dominant in homestead and *Catha edulis, Coffee arabica, Carica papaya, Mangifera indica, Citrus sinensis and Rhamnu sprinoides* were the most dominant in thefarmland. On the other hand, *Eucalyptus globulus and Acacia abyssinica* were dominant in gully sides. In terms of tree management watering, guarding and pruning were the most dominant.

Introduction

Agroforestrypractices contribute to ecological benefits, such as woody plant species conservation, soil nutrient improvement and reducing pressure on natural forest through provision of wood and non-wood products. In Ethiopia, cultivating tree/shrub species in an intimate interface with agricultural crops is not a new practice, rather traditional agroforestry practices are widespread in different forms in the diverse agro-ecologies and farming systems of Ethiopia. The traditional tree management techniques, woody species mix, both vertical and horizontal placements of the system components, economic and ecological benefits perceived by farmers could vary considerably with each other between and within the agro-ecological zones and land use systems of the country. A study was carried out in southern *Tigray* to identify the structural components in the traditional agroforestry practices and to explore and document existing indigenous tree planting/managing techniques across the study areas.

Brief methodology

Qualitative and quantitative data types were generated from both primary and secondary data. The primary data sources were households, *Woreda* and local administrators, experts of forest management, elders, knowledgeable peoples, and local administrators, development agents (DAs) and technical forestry supervisors. Secondary sources included manuals on participatory forest management, journals, reports, policy statements, proclamations and regulations. A total of 93 sample respondents were selected from five *kebeles*. Semi-structured interview was conducted using questionnaire to collect primary data from individual households.

Major findings

- Most (65%) of the households obtained tree seedlings through purchase while 22% both produce seedlings in their own nursery and purchase and the rest 13% obtained from own production, as gift and from wildings.
- Different tree species are planted in the homesteads. The commonly planted species is *E. globulus* followed by *A. abyssinica, B. aegyptiaca, M. azedarach*and *O.europaea subsp. cuspidata.*
- Similarly, different tree species are planted in farmlands, the common species being *Catha edulis, C. arabica, C.papaya, M. indica, C.sinesis*and*R. prinoides*.
- Woodlot isn't a common practice in the area, however, those practicing it commonly use *E. globulus.*
- Trees are also planted in the gully sides, and the commonly planted trees are *E. globulus* and *R. prinoides*.
- The vertical structure shows that there are two strata in the traditional agroforestry practice in the area. Common species in the first strata are *E. globulus* (23%), *Z. christi* (9%), *Sesbania sesban* (7%), *O. europaea* subsp. *cupsidata* (5%) and *A. abyssinica* (5%). The second strata is mostly dominated by fruit tree like *C. papaya* (18%), *M. indica* (15%) *and Malus domestica (apple)* (12%), *C. sinensis* (11%), *C. arabica* (11%) and *C. edulis* (8%).
- The finding from the survey indicated that households manage their agroforestry trees by guarding with combination of watering, pruning and thinning.

Key policy recommendations

Problems related to producing and access quality germplasm especially fruit trees coffee should be improved.

Potential users of the information

Regional, Zonal and *Woreda* extension experts, researchers and policy makers could make use of this information to support farmers.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Abu M., Sinke M, Samrawit B, Abdu A. and Teshome T. "Study on Structural Component and Traditional Tree Management Techniques in Traditional Agroforestry Practices" (unpublished report).

Agroforestry Practices and their Socioeconomic Role in *Cheha Woreda* of *Gurage* Zone

Responsible researchers: WondwossenGebretsadik, ZewdeWeldemariam, Tesfaye Humnessa and HabtamneshAdane

Brief description of the information

Agroforestry offers a potential solution to the problem of declining rural agricultural production.It provides combination of several types of productsboth for subsistence and income generation that can be helpful to farmers to meet theirbasic needs and minimizes the risk of crop failure. This study describes the agroforestry practices in *Cheha woreda, Gurage* Zone, Ethiopia based on the existing system components and evaluates their role to livelihood. *Enset*, Coffee and *Khat* based homestead agroforestry and crop raising were found out to be the dominant land uses in the study area. Land holding size did not reveal marked differences across peasant associations (PAs) ranging from 0.6 ha to 0.8 ha with an average of 0.5 ha. Significantly larger areas are allocated for the three agroforestry practices as compared to the rest of the identified land uses. 12 different tree/shrub species are mainly planted in homesteads of the study area. *Eucalyptus viminalis* woodloots are integeral parts of homesteads mainly contributing to household energy demand and income generation. Incomes were found to be prominently generated from sell of khat and eucalyptus wood. Practitioners of agroforestry were found to gain maximum incomes either annually or in the duration of 4-6 years. Water shortage, coffee leaf/stem drying, *enset* stem/root decay and wild animals' raid are among most serious problems that are currently constraining the practice of homestead agroforestry.

Introduction

Several types of traditional agroforestry practices are identified and described by various studies in different parts of Ethiopia. The aim and rationale of agroforestry lies in optimizing production based on the interactions between the components and their physical environment. This will lead to higher sum and a more diversified and/or sustainable production than from a monoculture of agriculture or forestry alone. In the home garden, the production is for consumption and unmarketable surplus can provide a safeguard against future crop failures and security for

interval between the harvests. There is a need to have good knowledge about the potentials of existing agroforestry practices prior to attempting to introduce modifications that are alleged to facilitate complementarities in the existing agroforestry practices. This would call for prior knowledge and description of existing agroforestry practices, evaluating their role to generate livelihoodalternatives in rural communities and assess people's attitude towards management of agroforestry practices. This study describes the existing agroforestry practice in *ChehaWoreda* while evaluating the contributions to the rural livelihood and assessing perception of farmers towards management and problems of agroforestry practices.

Brief methodology:

The study was conducted in *ChehaWoreda*, located in *Gurage* Zone of Southern Nations, Nationalities and Peoples Regional (SNNPR), Ethiopia. The *Woreda* has 39 Kebeles, of which*Emdeber, Wodero, Ewan, GasoreBuchach* and *Worden* that are intensively practicing agroforestry, were selected for the current study. The studied PAs in the *Woreda* can be broadly classified as highlands (*Buchach, Emdeber*and*Wedro*) and lowlands (*Worden, Ewan* and*Gasore*). From the selected six *kebeles,*a total of 114 households were interviewed. In addition, focus group discussion that comprised 10 farmers that are village heads and local farmer representatives were also undertaken to identify the existing agroforestry practices and their products.

Major findings

The major findings are described below in terms of the trends in vegetation cover, land holding and characterization of land uses, the intended use of planted trees, the farmer perception about agroforestry and its contribution to household income and the challenges in practicing home garden agroforestry.

Trends of vegetation cover

- Vegetation cover in the majority of the studied *Kebeles* was stated to be improving from time to time owing to the expansion of *Eucalyptus viminalis* woodlots and the recent integration of fruit trees like mango (*Mangiferaindica*) and avocado (*Perseaamericana*).

Land holding and characterization of land uses

- *Enset*, Coffee and *Khat* based home garden agroforestry and crop production are the dominant land uses in the study area and the major sources of livelihood and income.
- Significantly larger areas are allocated for*Enset*, Coffee and *Khat* based home garden agroforestry practices as compared to the rest of the identified land uses.

Intended use of planted trees

- Farmers plant trees and shrubs mainly for household consumption of products, source of construction material, cash income, shade and for soil and water conservation. Household consumption> cash income > construction in their order of importance were found to be the most predominant uses mentioned for planting trees by respondents.
- Mainly 12 different tree/shrub species are planted in homegarden systems in the study area. Different tree species are planted to address the identified uses. *E. viminalis*, *Podocarpus falcatus* and *Cordia africana* are prefered for planting as sources of construction material.*E. viminalis* woodloots are mainly planted to address household energy demand, income generation and for construction material.
- *Catha edulis*, *Enset ventricosum*, *Coffee arabica*,*Persea americana* and C*itrus reticulata* are predomenantly planted for household consumption purposes. Tree species planted mainly for income generation include *Persea americana*, *Catha edulis*, *Ensete ventricosum* and *Coffee arabica*.

Perception about agroforestry and its contribution to household income

- Environmental role of agroforestry to increase soil fertility and its contribution to farm income and livelihood are well recognized by the community.
- Incomes were found to be prominently generated from sell of *Khat* and *Eucalyptus*.
- Practitioners of agroforestry were found to gain maximum incomes either annually or in the duration of 4-6 years.*Khat* contributed more to the income generated annually while *Eucalyptus* had the highest share of the income generated during 4-6 years and this is because 4-6 years is the rotation age of *Eucalyptus* for production of mature bole for construction material.

Challenges in practicing home garden agroforestry

- Water shortage, coffee leaf/stem drying, *Enset* stem/root decay and encroachment by wild animals were the major problems that were hampering the practice of home garden agroforestry.
- The most frequently reported wild animals that attack fruit trees in the homesteads include monkeys, porcupines, warthogs and apes. The numbers of major crop raiders, particularly monkeys, porcupines, and apes are reported to be increasing.

Key policy recommendations

- It is highly recommended to encourage farmers engagement in integration of improved fruit tree varieties to gain increased production and enhance structural diversification of homesteads.
- Insect /disease attacks on *Enset* and Coffee trees are currently becoming serious threats to age old homestead practices. Immediate isolation of disease-causing agents and provision of preventive solutions is recommended.
- The level of damage on fruits by animal pests must be studied and mitigation measures needs to be taken.

Potential user of the information

Decision makers at all levels and the extension agents.

Reliability of information

This information has been extracted from original research report by WondwossenGebretsadik, ZewdeWeldemariam, Tesfaye Humnessa and HabtamneshAdane "Characterization of agroforestry practices and their socioeconomic role in selected districts of Gurage Zone, Ethiopia" (unpublished report).

Bamboo Utilization Practices and Challenges of Cottage Industries in Selected Towns of Ethiopia

Responsible researchers: Omer Hinde andGemechuKaba

Brief description of the information

Large amount of bamboo resource is found in both highland and lowland areas of Ethiopia. Even though the uses of bamboo culms are numerous, its utilization in Ethiopia has been limited due to lack of awareness about bamboo resource utilizationtechnologies, scientific knowledge about the species, and its susceptibility to biological and physical deterioration. This study is therefore, intended to describe the status and constraints of bamboo cottage industriesproducing furniture. The survey was done by adopting purposive sampling procedure in selected cities/townsdue to absence of registered information of the industries. Both quantitative and qualitative data were collected mainly from primary sources. The study found that bamboo was one of the most neglected sectors and its industries have low capacity and produce low quality of furniture products.Lack of training on improved bamboo technologies for drying and treatment during processing and producing furniture was found by the survey result. Most bamboo furniture industries do not consider its present moisture content during bamboo processing, owing to lack of awareness of the necessity of drying. The survey result showed that there was a problem when joining parts together to produce furniture as well as problems of splitting, lack of correct dimensional measurement and shrinkage problem while and after joining parts. Moreover, the most common problems confronted were the powder posting damage on bamboo furniture and raw materials, shortage of production space and lack of capacity with regard to tools/machine and finance. The study indicated the need to intervene and train bamboo cottage industries practitioners on improved bamboo technologies and capacity building.

Introduction

Bamboo has numerous benefits in day-to-day uses for the local communities where the species is growing. In different parts of the world, it is used as a source of raw material for fodder, construction materials, paper production, laminated boards, energy, food, beverage and medicine due to their easy workability, strength, straightness, lightness, range of size, abundance, short period in which they attain maturity.

In Ethiopia, the uses of bamboo culms are limited to construction, fences and some rudimentary furniture and household utensils. According to literature, some of the major constraints in the sector are lack of awareness about bamboo resource utilization, scarce technologies/scientific knowledge about the natural properties of the species, its susceptibility to biological and physical deterioration and lack of control measures against bio-deteriorating agent's damage. There should be a good understanding on natural properties of bamboo to utilize them successfully and efficiently for multiple uses.

Recently, bamboo-basedcottagefurniture industries are growing in Ethiopia. However, the level of its utilization is still limited due to low capacity and production of low-quality furniture products, which has led to its neglect as a useful resource. Although various technologies are available to increase its service life, people are unaware of utilizing the technologies. This study is therefore, intended to understand the processing and challenges of bamboo cottage industries producing furniture.

Brief methodology

- Survey was done in purposively selected cities and towns taking into account the availability and utilization of bambooin the area. These cities were Addis Ababa, *Hawassa*, *Injibara*, *BahirDar*, *Hagereselam* and *Shashemane*.
- The study is based on mixed research approach using both quantitative and qualitative methods.
- Data from direct observation during bamboo processing and furniture making from bamboo was taken
- Relevant textbooks, manuals, journals and reports regarding bamboo were reviewed.
- Descriptive statistics and inferential statistics were applied to calculate frequency and other tests of significance.
- The key features and challenges hindering the bamboo processing cottageindustries including their capacities, raw material availabilityand their general bamboo utilization practices were analyzed.

Major findings

- Bamboo was among the neglected sectors and its furniture industries have low capacity and produce low quality of furniture products. The furniture has the problem of splitting, lack of correct dimensional measurement and shrinkage problem while and after joining parts.
- Women seem to be under-represented in the work force, but few women in Addis Ababa and Hawassa are business owners.
- The utilization of bamboo localities in bamboo industries depends up on the proximity to the locality and accessibility of that bamboo species.
- Most industries indicated that they preferred *Sidamo* bamboo due to it is relative resistance to attack by bio-degrading agents, its culm nature and size.
- Most of the industries (66.7%) dried bamboo by stacking culms horizontally until they use it. The survey showed that industries lacked information on appropriate drying and storing methods.
- Majority of bamboo workers (73.3%) acquired furniture making skills through experience with an exception of Hawassa town, and partly *Hagereselam* and *shashemene* towns

- Bamboo furniture industries did not have access to credit with exception of those of Hawassa and low price of bamboo products in the market
- Majority of bamboo industry practitioners did not avail any training in appropriate technologies like bamboo culm selection, drying and treatment. Furthermore, industries did not consider its moisture content during bamboo processing, due to a lack of awareness regarding moisture content removal.
- Most common problems reported by all industries included the powder posting damage on bamboo furniture and raw materials, shortage of production space and lack of capacity with regard to tools/machine and finance

Key Policy Recommendations:

- In order to improve bamboo furniture industries, attention should be given to the sector by government and other development actors. Bamboo culm utilization needs to be

improved in furniture production, pressed lumber making and charcoaling and briquette making for energy.

- Bamboo furniture practitioners should be trained on knowledge and skill about improved bamboo technologies like appropriate selection of its culm, drying, treatment and storage.
- Addressing other bottlenecks of the industries like space for processing, access to credit and loans, and market promotion could pavethe way for bamboo industry development.

Potential users of the information:

The information serves as baseline for any development practitioners who can improve current situation of Ethiopian bamboo cottage industries. Therefore, both governmental and non-governmentaldevelopment actors could be beneficiary of this information. Moreover, bamboo cottage industries, furniture factories, construction industries and research institutions could use this piece of information.

Reliability of the information

The information is based on EEFRI research generated empirical evidence and published data on **International Journal of Advanced Research and Publications ISSN: 2456-9992.**

Income Contribution and Adoption Potential of Apple Based Agroforestry on Homestead Farms in West and North *Shoa* Zones of Ethiopia

Responsible Researchers: Lemlem Tajebe and Asfaw Gelan

Brief description of the Information

The study was initiated to estimate and compare households' income from apple-based agroforestry system and identify factors that influence its adoption by smallholder farmers in both West and North *Shoa* Zones of Ethiopia. From three Woredas of the two Zones, four potential *Kebeles* were purposefully chosen, and from which 600 household heads were randomly selected where 85 were adopters and the remaining 515 were non-adopters. To gather the necessary information both primary and secondary data were collected. The results showed that farmers predominantly carryout various livelihood activities such as production of grain crops, livestock, vegetables, and apple fruit. In the agri-horticulture approach, apple trees were integrated with vegetables at homesteads by adopters. In both study areas, the aggregated adopter household mean annual gross income from apple fruit +vegetablewas 24,337.22ETB $ha^{-1}yr^{-1}$($901.38) and mean annual gross income of non-adopters from vegetables was 7480.53ETB $ha^{-1}yr^{-1}$($277.06). The income obtained from apple contributed 16.84 percent to the income of agri-horticulture system, which contributed three-fold higher gross revenue for adopters in addition to its nutritional value. However, adoption of apple-based agroforestry system was significantly influenced by the different factor such as formal educational levels (+), market problem (-), disease and pest (-). In order to maximize the benefits from the system, interdisciplinary research needs to be conducted to reduce the problem of marketing, disease and pest as well as training the farmers on the system management.

Introduction

Fruit-tree-based agroforestry involves intentional and simultaneous association of annual or perennial crops with fruit-producing trees on the same farm unit. Trees grown on farms for their non-timber forest products such as fruits, nuts, and spices constitute the basis for many vibrant and sustainable farming systems. Fruit-tree-based agroforestry have developed over long periods of time in response to interactions between agro-ecological conditions, plant diversity, and

farmer resources and needs. Because of this, the system performance at any given location will depend, to a great extent, on several site-specific features. Nevertheless, the system performance also follows some general characteristics such as their potential benefits and limitations that are applicable to wider regions. Successful establishment of fruit-tree based agroforestry system in the highland areas can increase farm household income, enrich their diets with essential minerals and vitamins, and increase varieties of fruits available in the local markets.

In order to minimize farmers' pressure on the forest and improve the livelihood of the people, the then Forestry Research Centre (FRC), in 2007 and GTZ, in 2008 introduced and provided four apple varieties namely, Anna, Crispin, Dorset-golden and Princesa, to the dwellers of North and West Shoa Zones of Ethiopia. This study is based on the premise that farmers under land-scarce situations can directly benefit by incorporating fruit trees into their homestead with few other trees.This also relieves people's pressure on the natural forest, since fruit trees enjoy great popularity among subsistence farmers and provide tangible benefits in short time frames. Despite the provision of such variety of Apple tree seedlings to the farmers in the area, yet knowledge of critical factors that can lead to the adoption of the systems as a land management alternative is not identified. Thus, the objective of the study was to assess the income contribution and potential for adoption of apple-based agroforestry by smallholder farmers in the North and West Shoa Zones of Ethiopia. We hypothesized that fruit-tree-based agroforestry would be of interest to smallholder farmers, wherethe potential differences in adoption rates could be explained by various socioeconomic determinant factors.

Brief methodology

The study was conducted in West and North Shoa Zones of Oromia region.*Dendi, Degem and HindbuAbote Woredas* were selected based on the areas suitable climatic condition to grow apple trees and for the potential to improve the overallsystem productivity. Before the selection of appropriate *Kebeles*, consultation with the experts of the *Woreda* agricultural office was made to get information related to potential fruit producing*Kebeles*. Consequently, four Kebeles namely, *Gare, Bejiro, Alidoro* and *Yaya Dakabora* were purposefully selected based on high fruit production and road accessibility.

The explanatory variables hypothesized to influence the adoption of apple-based agroforestry in this study were fourteen. In each selected apple growing *Kebeles*, two groups of farmers were identified as adopters and non-adopters. From each category, using simple random sampling technique proportional to the population of *Kebeles* identified, study sample respondents were selected randomly from the list of household heads. Accordingly, from all selected *Kebeles,* a total of 85 adopters and 515 non-adopters were randomly identified.

Major findings

Production and income from apple-based agroforestry system

In the selected districts, samplehouseholds mainly depend on crop and livestock production. Among the total sample households in *Degem* district, about 87.5% of adopters and 97.1% of non-adopters rely on crop production. Besides, in *Dendi* District 76.8 per cent of adopters and 77.6 non-adopters relays on crop production. Farmers in the study area plant various vegetables solely or in integration with apple tree and use the product for household consumption and/or as an income source.

Table 2 Mean household heads total annual income from vegetable in Degem (North Shoa Zone) and Dendi (West Shoa) Districts

	Degem (North Shoa)	*Dendi* (West Shoa)
Adoption	Mean income (ETB)	Mean income (ETB)
Adopters	29277.75 ($1084.361)	18869.86($698.88)
Non-adopters	6768.69 ($251)	8356.13 ($309.49)

In *Degem* district, adopters income from vegetable increased 1.5 times as compared to the adopters' income in *Dendi* district. This is due to the established informal market by the farmers. It helps them to sell apple fruit to travelers from Addis to Bahir Dar. To augment income from apple fruit the overall system productivity must be enhanced, this makes to increase the vegetable productivity as compared to Dendi district.

An aggregated analysis to determine households' annual income from the homestead was conducted. Accordingly, adopters' annual income from the system components viz. vegetables and apple fruit were 24,337.22 ETB ha^{-1} yr^{-1}($901.40)[2]and non-adopters obtained 7,480.73 ETB ha^{-1} yr^{-1}($277). Apple fruit contributedon average 16.84 per cent of the income to the agri-horticulture system in both study districts combined.

[2]In 2017 the exchange rate of $1 was 27 Ethiopian Birr.

Determinants of Apple Tree Adoption

Fourteen explanatory variables were identified to explain factors influencing the adoption of apple tree-based agroforestry system in North and West *Shoa* Zones. The effects of the independent variables on the log odds of adopting apple-based agroforestry system are reported as odds ratio alongside the parameter estimates. For an independent variable, the odds ratio (e^{β}) represent the amount by which the odds favoring the decision to adopt apple-based agroforestry system (adopter =1).

Table 3 Maximum likelihood estimates of the binary logit model for adoption determinant factors in *Dendi* and *Degem* District (North and West *Shoa* Zone)

	B	S.E
Education	1.611***	0.355
Labor shortage	-0.039	0.408
Total Land Holding	-0.370	0.332
Off-farm income	-0.235	0.701
Access to Credit	-1.443	1.093
Extension Service	0.102	0.152
Market Problem	-1.557***	0.347
Water Distance	-0.017	0.172
Longer production period	0.272	0.431
Age	0.072	0.605
Low awareness	-0.082	0.081
Lack Access	-0.393	0.341
Expensiveness	-0.079	0.494
Disease and pest	-3.020***	0.409
Constant	-4.860	2.002

Out of fourteen explanatory variables included explaining the dependent variables; formal educational level of the household head, market problem and the problem of pest and disease were significant independent variables in both districts.

Key Policy Recommendations:

- The current study proved that, even in the presence of limiting factors such as pest and disease, market unavailability, apple-based agroforestry system provides significant economic advantage to the farm householdsin addition to its profound nutritional value.
- In both study areas, the prevalence of pest and disease reduces the productivity and quality of the fruit. Therefore, to improve farmers benefit and interest on the system responsible bodies needto seriously work on the problem.

Potential users of the information:

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

Reliability of information:

The study is based on original data and analyzed following standard research methods. Lemlem Tajebe and Asfaw Gelan, "Income Contribution and Adoption Potential of Apple Based Agroforestry on Homestead Farms in West and North Shoa Zones of Ethiopia." Journal of Development and Agricultural Economics. 10(6):176-185.

Determinant Factors for Large-scale Plantation Development in Ethiopia: Policy Reviews and Stakeholders Analysis

Responsible Researchers: Temesgen Yohannes, Gonche Girma, and Deginet Kumlachew

Brief description of the Information

The total plantation forest in Ethiopia is estimated at 1 million hectare. Only 19% of this plantation forest can be classified under large-scale plantation. Institutionalized and active large-scale plantation schemes had been trivial and impeded by various factors in Ethiopia for decades. This study, therefore, has attempted to identify and analyze the most determining policy, strategy, stakeholder and environmental factors hindering and/or promoting large-scale plantation development in Ethiopia. The study engaged schedule surveys, desk reviews, key informant interviews (KIIs), and focus group discussion (FGD) to assess the determinant factors. Institutionalized and interlinked national level large-scale plantation development schemes have not been emphasized in Ethiopia's forest policy and strategy documents. The policy and strategy documents predominantly emphasize and encourage small and medium scale plantation initiative. Absence of well-defined national land use strategy (94%), the highly decentralized authoritative relations between regional and federal parallel sectors (82%), insecure land tenure policy (65%), as well as overlapping and conflicting land use strategies of sectors (89%) were among the most identified limiting factors for large-scale plantation development in the country. Countries embracing strong sector institutions with secured land tenure systems and/or countries with direct governmental investment in large-scale plantation development have been identified as the most successful forest policy approaches. Direct governmental investment in large-scale plantation development scheme has been suggested (96%) as the best approach for future large-scale plantation development efforts in Ethiopia. Merging adjacent plots (62%), forming plantation cooperatives (65%), pre and post plantation management capacity building trainings, provision of incentives (94%) and offsetting opportunity costs by GO's and/or NGO's (96%) were identified as promoting factors to convert smallholder plantations into a large-scale plantation schemes. Shortage of land (98%), high initial investment cost (84), long gestation period (86%), high opportunity cost (92%) and absence of incentives (73%), on the other hand, were among prominent limiting factors for plantation development in the country. Ethiopia is

environmentally feasible for large-scale plantation development. Close to 27 million ha of land has been identified as potentially suitable for national large-scale plantation development. Reforms in the national forest policy, developing a mandated to obligation active forest strategy and action-plan, synergizing the overlapping sectors, developing a well-defined national land-use strategy, improving the authoritative linkages between the federal and regional parallel bureaus, and developing well-stratified and differentiated land policy and strategy have been suggested as solution for large-scale plantation development endeavor in Ethiopia.

Introduction

The Climate Resilient Green Economy (CRGE) strategy of Ethiopia targets afforestation and reforestation of 3 million ha by 2030 with the aim of re-establishing forests for their economic and ecosystem services, including as carbon stocks. Large scale plantation development started in Ethiopia in the early 1970s for production of sawn wood, wood-based panels and pulp. Of the three, sawmilling is the main forest industry in Ethiopia.

The area of forest plantations in Ethiopia was 972,000 ha in 2010. Of these, industrial plantations, which were developed for timber production for sown wood and poles, covered 190,400 ha of land (19.6%), and the non-industrial plantations, which were meant for fuelwood and construction timber production, covered 781, 600 ha of land (80.4). The tree species planted in the industrial plantations were *Eucalyptus sps.* (56.6%), *Cupressus lusitanica* (32.8%), *Pinus sps.* (2.5%), *Juniperus procera* (1.9%), *Grevillea robusta* (0.7%) and others (5.6%). The non-industrial plantation was mainly woodlots (96.6%) and the remaining 3.4% was peri-urban plantations.

The industrial scale timber and pulpwood production is faced with a number of challenges, and critical gaps in the sub-sector include the following: largely untapped plantation development potential and market opportunities given the strategic location of the country to supply various forest products to the nearby African and Asian markets, and instead Ethiopia becoming a timber trade destination, poor scaling-up of alternative timber species, lack of knowledge on timber quality of some species being widely planted, and lack of management tools. Hence, to improve the large-scale timber and pulpwood production, one among many research questions need to be

addressed is: What factors are limiting the development and expansion of large scale timber and pulpwood plantations in the four regions?

Major findings

Policy document vis-à-vis large-scale plantation development in the country:

- Presence of forest policies and strategies, ratification of related conventions, setting of various forestry promoting proclamations have been found as promoting factors for the forest sector development in Ethiopia. However,
    - ☛ Policy directions towards direct government role in large-scale afforestation, reforestation and restoration are not explicitly chaptered in the policy document;
    - ☛ Responsibilities and emphasis is given to individuals, cooperative (groups) and organization for forest/plantation development and engagements in the policy document. This approach may highly compromise quantified and qualified mass production of forest and forest products in the country;
    - ☛ Forest strategies and action plans are not designed in a mandatory and obligatory comportment between the federal and regional implementing sectors and institutions (only regional forest enterprises have been actively engaged);
    - ☛ Regional, sector and institutional responsibilities, coordination and linkage were not well articulated in the policy documents;
    - ☛ Generally, the policy follows a highly decentralized and grass-root level (individuals, groups or organization) approach towards forest plantation development.

Major Limiting/Promoting factors identified by stakeholders against/for plantation development in Ethiopia:

- The ever increasing local as well as cross-border regional market demand for tree poles, firewood and charcoal was the major driving factor for expansion of smallholder plantation in Ethiopia;
- Shortage and unavailability of lands, high initial plantation establishment costs, and high opportunity costs were some of the identified reasons as setbacks in the plantation development venture.

- Lack of incentives and support from governmental and non-governmental agencies to offset opportunity costs was also pointed out as a major limiting factor by interviewed households;
- The sluggish bureaucratic process to those that wish to lease additional lands for tree plantation has been pointed out by 52% of the household heads and 95% wood industry owners as additional restraining factor;
- Misuse and/or under-planned use of vacant spaces (like wetlands, mountain hills, marginal lands, etc) other than afforestation/reforestation by local administration;
- Over dependence of wood and furniture industry owners on imported timber and other wood products;
- Fear of additional investment cost by wood industry owners and tree plantation long gestation (return) period;
- Little or total absence of compelling pre-requisites to wood industry investors to develop own plantation;
- Poor infrastructures (rail, road, electricity, telecommunication);
- Tenure insecurity and risk (e.g. illegal logging).

Environmental and Administrative Limiting factors

- 26.7 million hectare of the country has been classified as suitable for plantation development in Ethiopia (7 million ha most suitable);
- Agricultural sector dominating the economic policy, strategy, as well as the land use system of the country;
- Highly suitable areas are also highly populated;
- Regionalization policy hindering the federal executive body (e.g. The then MEFCC) from implementing its self tailored strategies, programs and action plans
- Overlapping and sometimes conflicting policies of executive bodies (particularly between Ministry of Agriculture, Investment office, Ministry of Industry, Rural Land Administration offices, Ministry of Energy and Mines, etc)

Key Policy Recommendations:

- Government level paradigm shift is highly required to reform the sector;
    - ☛ Reform in forest strategy and institutions
    - ☛ Develop well-articulated forest action plan

- Active engagement of government (advocacy, mobilizing, extension, and financing)
- Establish strong, centralized, authoritative, and sustaining forest institution
- Advocate reform and harmonization towards other sectors policies, strategies and action plan
    - Land policy
    - Inter-ministerial land use strategies
    - Agriculture, investment, and energy policy
    - Work towards developing secure land tenure system

Potential users of the information:

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

Reliability of the information

The information is based on original work by EEFRI researchers: Temesgen Yohannes, Gonche Girma, and Deginet Kumlachew "Determinant Factors for Large-scale Plantation Development in Ethiopia: Policy Reviews and Stakeholders Analysis."

Farmers' Perception Towards Farm Level Rubber Tree Planting: a case of *Guraferda*, South western Ethiopia

Responsible researchers: Tatek Dejene, Berhane Kidane, Zewdu Yilma and Busha Teshome

Brief description of the information:

In Ethiopia, rubber tree (*Heavea brasiliensis*) plantation has been mainly conducted by the state. Nowadays, attempts are being made to extend the practice towards farm level by the rural communities. Although the interest of enhancing is well recognized, the development of rubber tree plantations has been lower than anticipated. This might be due to the fact that no emphasis was placed on understanding the perceptions of local people on rubber tree species and its environmental and socioeconomic benefits. This study identified the factors that underlie farmers' decisions to engage in rubber tree plantation and evaluated the local people perception towards the forest use and conservation. The result indicated that growing cash crops, food crops, rearing animals and daily labor are the main livelihood activities and sources of income for the local communities in the study area. The concept of forest development is supported by the majority of the respondents since 40% are dependent on forest for income generation. About 68% of the respondents expressed their willingness to plant rubber tree on their farmlands. However, land availability, market for the products, gestation period of the investment, lack of technical knowhow and nearness to available resources such as seedlings are discouraging factors for farmers to engage in rubber plantations in the study area.

Introduction

In Ethiopia, rubber tree (*Heavea brasiliensis*) plantation has been conducted mainly in the south western part of the country, for it has the most suitable climate and soil for cultivation. The cultivation practices are carried out under rain-fed conditions and the practice mainly is undertaken by the state. Now, attempts are being made to extend the practice towards farm level by the rural communities at the potential rubber growing areas of the country. Such a plan may largely depend on addressing farmers' perception as well as the identification of factors that encourage or discourage rubber tree planting on their farmlands. These insights will be helpful in designing effective out–growers scheme for rubber tree plantations by the farmers, thereby

contributing to the betterment of the livelihood of the rural communities. Thus, this study identified the possible approaches and opportunities to promote rubber trees plantations for natural rubber production by local farmers in the study area.

Brief methodology

The study was conducted in *Guraferda Woreda*, in South western part of Ethiopia. It is located between 34°55’59” to 35°26’13” E Latitude and 6°29’5” to 7°13’20” N Longitude. The inhabitants of the study area practice mixed agriculture, crop production and livestock rearing. The information for this study was collected through the survey of 25 farmers. The survey was conducted in two groups, 17 farmers purposively selected, using the criterion of 'having rubber tree on their farmland' and 8 'who were not engaged in planting rubber trees on their farmland'. A semi–structured questionnaire was developed and pre–tested, and interviews were finally undertaken with the selected farmers. Secondary data, mainly from published and unpublished sources, were used to complement and refine the information that had been collected.

Major findings

- The result indicated that the local people are dependent (40%) on the forest resources for their livelihoods. The forest products used include coffee, timber, charcoal, firewood, wild edible fruits, traditional medicinal plants, honey, mushrooms, and bamboo, indicating the forest is a crucial element of rural communities’ livelihoods in the study area.
- The concept of conservation and forest development is supported by 72% of the respondents on the context of the resources use. In case of the forest use ban, 64% of the respondents opposed the decision, the rest are ready to go for alternatives, indicating a new approach is needed to bring community-based forest management and conservation strategies.
- About 68% expressed their willingness to plant rubber tree on their farm. Availability of larger area of land, awareness on the economic importance of rubber tree, training on cultivation and production systems and nearness to the resource such as seedlings are found to be the encouraging factors for engagement of rubber plantations by the local

people. The most frequent discouraging factors mentioned by the local people includes long gestation period of the rubber tree.

Key Policy Recommendations

In this study, the availability of land is reported as a major encouraging factor contributing towards the expansion of rubber trees in the study area. This suggested a need to adopt intensive rubber based agroforestry systems where farming is more directed towards subsistence level. The following could be possible approaches and opportunities to widely promote rubber trees plantations to the study area. These include;

- **Rubber–food crops intercropping (*Taungya* system)**: short–lived plants such as pineapples, chilies, bananas, sweet potatoes, long beans and maize can be grown in between the rubber tree rows up to three years before the trees shade out the crops.
- **Rubber–fruit crop system:** fruit tree species can be grown in between the rubber tree rows throughout the whole productive period, as the fruit trees grow up with the rubber trees and thus continue to gain sunlight.
- **Rubber–timber species systems**: timber species like *Azadirachta indica* can be grown in between the rubber tree rows throughout the life of the rubber trees.
- **Rubber–livestock farming systems**: cows and sheep can be raised in the plantations once the trees are older than 18 months. An average of 6–8 livestock can be raised per hectare.

Potential users of the information

- Farmers and small holder producers involved in rubber tree plantation
- Investors involved in natural rubber production
- Environment, Forest and Climate Change Commission (EFCCC) and investment offices
- Ministry of Agriculture

Reliability of information

We confirm that the information packed are the original works of the specified research topic and are true. Also, the result is published on reputable journals and the full information is available on: ***Forest Res Eng Int J. 2018; 2(4): 192–196. DOI: 10.15406/freij.2018.02.00047***

Screening of Fast-growing Tree Species for Fuelwood Production in Highland Areas of Ethiopia

Responsible researchers: Tatek Dejene, Berhane Kidane, Tinsae Bahiru, Mihret Semere, Kibruyesfa Sisay and Eguale Tadesse

Brief description of the information

The high-altitude areas of Ethiopia encounter problems such as availability of limited tree species. In this study, we evaluated the performance of eleven tree species for fuelwood production for six years in *Diksis Woreda* of the *Arsi* Zone in *Oromia* Region of Ethiopia. The results indicated that *Eucalyptus saligna* showed maximum survival (98%), followed by *Eucalyptus grandis* (89%), *Eucalyptus camaldulensis* (87%), *Eucalyptus globulus* (86%), *Acacia decurrens* (83%) and *Eucalyptus viminalis* (68%); while the lowest survival rate was recorded for *Schinus molle* (37%). The highest average DBH growth was recorded for *Eucalyptus saligna*. In terms of height, *Eucalyptus viminalis* is the fastest growing followed by *Eucalyptus globulus* and *E. saligna*, respectively. The wood volume production six years after planting also showed the highest mean stem volume for *E. globulus* (10 m^3 ha^{-1}), followed by *E. saligna* (8.6 m^3 ha^{-1}) and *E. viminalis* (7 m^3 ha^{-1}). Thus, the first six (*E. saligna*, *E. grandis*, *E. camaldulensis*, *E. globulus*, *A. decurrens* and *E. viminalis*) are recommended for fuel wood production in the study area.

Introduction

Biomass fuel is the most important source of energy in Ethiopia. Hence, plantation of fast-growing trees has become a major forestry practice, thereby reducing pressure on the natural forest resources. However, plantations in the country are dominated by few tree species. Relying on few species has risks and impacts on the productivity and sustainability of the forest farming systems. Wider range of tree species would ensure resilience. Thus, selection and promotion of fast growing species that fit the farming system is one of the strategies for improving the wood fuel availabilities. The past attempts in Ethiopia to reforest and restore degraded forests and thereby fulfill the wood fuel requirements in the rural areas relied on screening of multipurpose tree species in some agro-ecological zones. However, the output from such trials did not reach

many areas of the farming communities in the country. Thus, selection and promotion of fast growing species that fit the farming system is one of the strategies for improving the wood fuel availabilities and thereby reducing pressure on the remaining natural forest. In view of this, we conducted a screening of best performing tree species for fuel-wood purpose in the highland part of the country. In this study, therefore, we selected better performed fast growing and high biomass producing tree species for wood fuel production purpose in the study area.

Brief methodology

The study was conducted from 2013 until 2018 at *Diksis Woreda* of the *Arsi* Zone in *Oromia* Region of Ethiopia. Mean annual maximum and minimum temperatures of the study area are 23 and 6 °C. The altitude of this Woreda ranges from 1800 to over 4100 meters above sea level; the highest point in this *Woreda* is Mount *Bada* (4195 meters). Annual precipitation averages of 1100 mm, most falling between March and October with peaks in July and August. The soil of the study area is classified as Nitisols. We evaluated eleven tree species (Table 4) taking into consideration their fast growing nature, their easy of adaptation to the study area and production of high biomass for fuel as criteria. The evaluation of the species has been conducted for six years. Appropriate seed treatments were applied whenever necessary. Then, treated seeds were directly sown in polythene bags that contained a mixture 4 (local soil): 2 (forest soil): and 1 (sand). Size of the polythene bag was 15 cm in height and 8 cm in diameter. Seedlings were raised in the nursery through similar watering, shading, weeding and hardening practices. When seedlings attained appropriate height and girth growth, they were transported for planting.

Table 4 Scientific and family names as well as seed sources of eleven tested tree species for wood fuel at *Diksis Woreda* of the *Arsi* Zone in *Oromia* Region of Ethiopia

Species	Family	Common name	Seed sources
Acacia decurrens	Fabaceae	Black wattle	CEE-FRC
Acacia melanoxylon	Fabaceae	Australian blackwood	CEE-FRC
Casuarina equesitifolia	Casuarinaceae	Australian pine tree	CEE-FRC
Cupresuslusitanica	Cupressaceae	Mexican white cedar	CEE-FRC
Eucalyptus camaldulensis	Myrtaceae	River red gum	CEE-FRC
Eucalyptus globulus	Myrtaceae	Tasmanian bluegum	CEE-FRC
Eucalyptus grandis	Myrtaceae	Flooded gum	CEE-FRC
Eucalyptus saligna	Myrtaceae	Sydney blue gum	CEE-FRC
Eucalyptus viminalis	Myrtaceae	The manna gum	CEE-FRC
Graveliarobusta	Proteaceae	Silkoak	CEE-FRC
Schinusmolle	Anacardiaceae	Peruvian pepper	CEE-FRC

Field preparation for planting was conducted one week before planting. Planting holes were dug 40 cm deep at *Diksis*. The size of the plot was 7.5 × 7.5 m. A plot consisted of six rows of trees that had a line of six trees. One plot had a total of 36 seedlings. Distance between trees in the same row was 1.5 m while distance between rows in the same plot was 1.5 m. The distance between plots was 2 m and distance between blocks was 3 m. Then, the survival, diameter and height growth was evaluated each year over the evaluation period.

Major findings

- The survival rate was greater than 50% for most of the tree species. The highest survival registered for *E. saligna* (98%) followed by *E. grandis* (89%), *E. camaldulensis* (87%), *E. globulus* (86%), *A. decurrens* (83%) and *E. viminalis* (68%);
- The age-DBH curves showed that there is a very strong correlation (R^2 > 90%) between age and DBH growth for *E. saligna*, *E. grandis*, *E. camaldulensis*, *E. globulus*, *E. viminalis* and *A. decurrens* species. Thus, indicating growth of the species generally followed an increasing trend as age increases;
- The age-height graphs indicated that *E. viminalis* is the fastest growing in height followed by *E. globulus* and *E. saligna*, respectively. *E. camaldulensis* showed the lowest height growth. However, all the six species showed strong correlation of age and height (R^2= 80%) along the growing periods;

- The wood volume production six years after planting also showed *E. globulus* provided the highest mean stem volume (10 m^3 ha^{-1}), followed by *E. saligna* (8.6 m^3 ha^{-1}) and *E. viminalis* (7 m^3 ha^{-1}). The lowest mean stem volume was obtained for *E. camaldulensis* (2.3 m^3 ha^{-1}).
- Thus, based on the survival and their growth performance, the first six (*E. saligna*, *E. grandis*, *E. camaldulensis*, *E. globulus*, *A. decurrens* and *E. viminalis*) are recommended for fuel wood production in the study area.

Key Policy Recommendations

- We recommend the six most survived tree species namely, *E. saligna*, *E. grandis*, *E. camaldulensis*, *E. globulus*, *A. decurrens* and *E. viminalis* for fuel wood production purpose based on their growing nature and performances.
- The results can be used in other areas with similar climate, soil and other suitable growing site conditions.

Potential users of the information

- Farmers and small holder producers
- Investors involved in fuelwood marketing and production
- Environment Forest Climate Change Commission (EFCCC) and related stakeholders
- Ministry of Water and Energy

Reliability of information

This information package is the original works of EEFRI researchers; Tatek D., Berhane K., Tinsae B., Mihret S., Kibruyesfa S. and Eguale T. "Screening of Fast-growing Tree Species for Fuelwood Production in Highland Areas of Ethiopia."

Organochlorine Pesticide Residues Level in *Ziway* Lake Ecosystem

Responsible researchers: Habtamu Wodajo, Fikre Lemessa and Gezahagne Berecha

Brief Description of the Information:

Three sample types (Fish, succulent grass and sediment) were collected from Lake *Ziway* for organochlorine pesticide detection. The organochlorine pesticides analyzed were Dichloro Diphenyl Trichloroethane (DDT) and metabolites; Endosulfan II, Endosulfan sulfate, Endrin Keton, Endrin aldehyde, γ-BHC (Lindane), β-BHC, δ-BHC, α-BHC, Aldrin, Heptachlor and Heptachlor Epoxide using Multi Residue method. Among the analyzed organochlorine pesticides, only DDT and its metabolites were detected.

Introduction

Organochlorine pesticides are persistent chlorinated hydrocarbons used extensively from the 1940s through 1960s in agriculture and mosquito control. Among the organochlorine pesticides, DDT is commonly and widely used for malaria protection in Ethiopia until 2011. People can be exposed to organochlorine pesticides by accidental inhalation, and ingestion through fish and other fatty foods that are contaminated. They are persistent and move long distance in the environment.

Research reports show that the biomagnification of DDT and its metabolites in four fish species (*Clarias gariepinus, Oreochromis niloticus, Tilapia zillii,* and *Carassius auratus*) sampled from Lake Ziway, Ethiopia. Currently, the market demand inclined to the two carp species (*Ciprinus carpio and Carassius carassius*); however, there is no information on organochlorine residue concentrations in these two carp species and the succulent grass that grow in lake Ziway, which are used as fish food and serves as pathway for the bio-magnification of these pollutants.

To fill this information gap, three wild fish species namely, *Oreochromis niloticus*; *Ciprinus carpio* and *Carassius carassius* were sampled from Lake *Ziway*. The muscle part of these freshly caught fishes were separately chopped and ground to give composite samples for the analysis. A replicate composite sediment and succulent grass samples were also collected from three different locations in the lake.

The succulent grass samples were air dried, ground with high speed universal plant disintegrator (model FW100, China) and passed through 2 mm sieve before subsequent laboratory analysis.

The particle size distribution (PSD) of sediment sample was analyzed by laser diffraction method using laser scattering particle size distribution analyzer, while the organic carbon content was determined by Wakley and Black method.

All of the sample types were extracted by EPA 3540C method for Organochlorine pesticides (OCPs) residue determination. The extracts were concentrated to 2 ml using vacuum rotary evaporator and nitrogen gas bubble and re-dissolved in 10 ml hexane and cleaned up in florocil and silica gel and eluted by hexane. The eluent was transferred to 10 ml volumetric flask and diluted to the mark with hexane. Agilent 7890B GC equipped with 5977B MS Detector with NIS software library was used for identification. Calibration curve prepared by a series of external standards was used for quantification of OCPs residue in the samples. Descriptive statistics was applied to analyze the information obtained from the fish, succulent grass and sediment were compared to WHO/FAO recommended tolerable levels.

Major Findings

The sum of DDT concentration in the fish was higher in *Ciprinus carpio* species (35.65 ng/g) followed by *Oreochromis niloticus* (30.29 ng/g) and *Carassius carassius* (27.07 ng/g). There was significant difference between *Oreochromis niloticus* and *Carassius carassius* and between *Ciprinus carpio* and *Carassius carassius*, but not between *Ciprinus carpio* and *Oreochromis niloticus* in terms of pp'^{DDT} in the tissue (Table 5).

The three fish species differed significantly from each other in terms of their pp'^{DDE} concentration (Table 5). The highest pp'^{DDE} was recorded in *Ciprinus carpio followed by Oreochromis niloticus* and *Carassius carassius* in that order.

The ratio of pp'^{DDE} / pp'^{DDT} for *Ciprinus carpio* spices was (0.75) which means 75% of the fresh DDT was degraded, while the ratio was lower in the other two species (0.49, 0.44), respectively which suggests that less than 50% of fresh DDT degradation. The lowest degradation product of DDT in the two fish species is an indication of recent contamination of the fish species by fresh DDT.

The maximum concentration of ΣDDT detected in the edible part of the fish sample was 35.65 ng*/g (ppb)* which is equal to 0.036 ppm in *Ciprinus carpio* and the lowest was in *Carassius carassius* species which was 27.07 ng/g (ppb) which is equal to 0.027 ppm. However, both values are greater than the permissible level of 0.02 mg/Kg and lower than (5 ppm) the action levels established by (FAO/WHO).

Analysis of variance showed that pp'^{DDE} concentration was significantly higher in fish compared to grass and sediment. Mean values of pp'^{DDE} detected on sediment samples were low compared with the other two biotic matrices in fish and succulent grass. Generally, sandy and coarse texture has low organochlorine chemicals affinity which makes the chemicals unavailable for microorganisms for degradation. The total organic carbon (TOC) content of the sediment was between 0.26 to 0.6 %. The finding of this study shows that the low value of total organic carbon (TOC) in the sediment is the reason for low availability of OCPs in the sediment.

Table 5. Concentration of ∑ DDT pp'^{DDT} and pp'^{DDE} in different fish species of Lake Ziway, Ethiopia

Fish species	∑DDT (ng/g)	pp'^{DDT} (ng/g)	pp'^{DDE} (ng/g)
Oreochromis niloticus	30.30 [b]	20.33 [a]	9.97 [b]
Ciprinus carpio	35.65 [a]	20.38 [a]	15.25 [a]
Carassius carassius	27.05 [c]	18.78 [b]	8.31 [c]
p-value	<0.0001	<0.0001	<0.0001

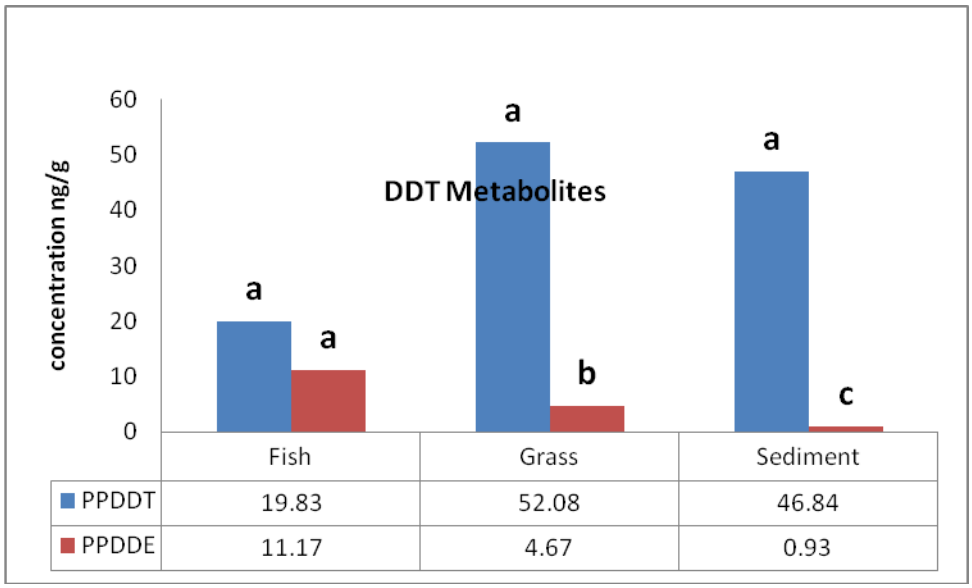


Figure 10 Comparison of pp'^{DDT} and pp'^{DDE} concentration in Fish, sediment and succulent grass collected from Lake *Ziway*, Ethiopia

Key Policy Recommendations

- The findings of this study show that the lake ecosystem is under threat for the concentration of ΣDDT detected in two fish species exceeded permissible level 0.02 ppm established by (FAO/WHO). Hence, continuous DDT spraying to agriculture crops and for malaria control must be avoided near the lake ecosystem.
- Detail assessment on the impact of obsolete pesticides on pollinators, birds, beneficiary microorganisms and farm land need to be investigated in detail.

Potential Users of the Information

Research institutions, universities, GOs and NGOs and Environment, Forest and Climate Change Commission (EFCCC)

Reliability of the information

This information package is extracted from a thesis work of Habtamu W., Fikre L. and Gezahagne B. "Organochlorine Pesticide Residues Level in Ziway Lake Ecosystem."

Environmental Monitoring of Heavy Metal Contamination in Awash River Water, Sediment, Irrigated Soil, and Vegetables

Responsible Researchers: Tizazu Hailemariam, Tesfalem Belay, Birhanu Hailu and Habtamu Wodajo

Brief description of the information

Awash River is a recipient of many tributaries and passes through Ethiopia's major industrial and agro-industrial belt, taking in a whole burden of all types of raw effluents, which can be potential sources of contamination. To determine the levels of trace metals (Cr, Cu, Mn, Cd, and Pb) in the water, sediment, irrigated soil and vegetable samples at upper, middle and lower basin of Awash River water samples were collected from 16 sampling sites in the rainy and dry season in 2010 E.C. The total concentrations of the heavy metals listed above were using were determined after acid digestion. The result of this study showed that, in the upper stream of water samples the concentrations of Cd and Pb at Hatebella, the concentration of Mn at *Hatebella*, *Aba-Samuel* and *Asko* sites were found to be higher than WHO guidelines for drinking water quality in rainy season. Similarly, the concentrations (mg/Kg) of Cr and Mn in sediment samples collected from *Hatebella*, *Modjo* and *Aba-Samuel* were above the permissible limit set by WHO and USEPA sediment quality guidelines. Calculation of geoaccumulation index (I_{geo}) showed that sediments from *Mojo* and *Hatebella* were in the range of uncontaminated to moderately contaminate by Cr and Mn, whereas I_{geo} for Cd and Pb indicated no contamination. The concentrations of heavy metals (Cd, Cr, Cu, Pb and Mn) in irrigated soil samples were below the maximum permissible limits set for agricultural soils by FAO/WHO. However, the concentrations of Cr in all spinach samples and Mn in spinach collected from Lower Awash Basin sites were above the maximum permissible limit set by FAO/WHO. Overall, the results obtained showed that the quality of Awash River water, sediment and vegetables irrigated by the river at some of the study sites were adversely affected by man-made activities carried out in the river basin. It is important to mention here that the monitoring data obtained were based on samples collected only four times in a year, and may not necessarily reflect the whole story of environmental contamination in the basin. The data reflects the contamination at the time of sampling, not before and not after the sampling. Therefore, continuous monitoring and proper intervention should be made to reduce the impact of pollution sources along the river course.

Introduction

Rivers are vital components of the biosphere containing less than one percent of the world's freshwater with higher ecological and social significance; however, they are being polluted by natural and anthropogenic activities that affect their physicochemical properties. Physicochemical parameters in river water provide a basis for assessing the suitability of water for designated use and to improve existing conditions. Ethiopia is rich in fresh water resources mainly rivers, lakes, streams, etc. In Ethiopia, Awash River has a total length and an annual flow of 1250 km and 4.6 billion m^3, respectively. The river originates at an elevation of about 3000 m in the central Ethiopian highlands near Ginchi town about 80 km west of Addis Ababa and passes through Ethiopia's major industrial and agro-industrial belt, taking in a whole burden of all types of raw effluent stands and terminates in salty Lake Abbe on the border with Djibouti, being an end of the basin.

Awash River is used for various purposes, such as for drinking, irrigation, bathing, fishing, industry, recreation, etc. However, the river has been facing tremendous stress due to population growth, expansion of irrigated area in the upper basin, discharge of treated/untreated industrial effluents, agricultural run-off, domestic and municipal wastesdirectly in to the river.As a result of this, river water quality is deteriorated and hence, the wastewater carries considerable amount of trace toxic metals which often leads to degradation of soil health and contamination of the food chain mainly vegetables that are grown on such soils. Many studies have also shown that waste water used for irrigation has elevated the levels of heavy metals in receiving soils. The vegetable from the contaminated soil can accumulate some high concentration of heavy metal and cause some serious risk to human health. So it is important to document the changes in the water quality of the river to use it as an input for reporting the state of the environment. Therefore, this study was carried out to assess the levels of heavy metals in water, sediment, irrigated soil and vegetables collected from the upper, middle and lower basin of the Awash River to generate information on the current status of pollution.

Brief Methodology

The study was conducted in the Awash River Basin, with a total catchment area of 113,304 km2, which is located between latitudes 7°53′N and 12°N and longitudes 37°57′E and 43°25′E in Ethiopia.

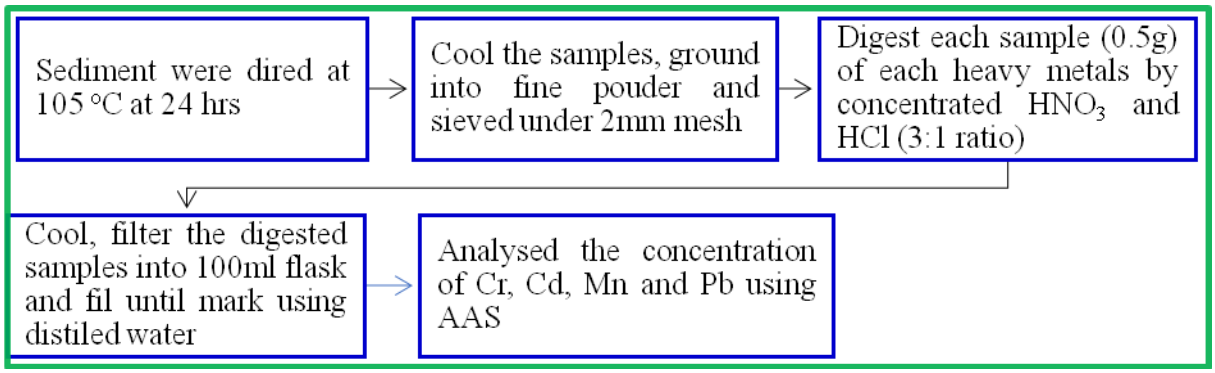
1) Composite surface water samples were collected from sixteen (16) sampling sites shown in Table 1 below using pre-cleaned polyethylene bottles having 2-liter capacity using *Standard Methods for the Examination of Water and Wastewater*. Water samples were preserved with nitric acid at pH less than 2, and finally digested with concentrated HNO_3 acid for analysis of cadmium, copper, lead and manganese and sediment samples were analyzed as shown below.

Table 6Justification of study sites

Stream of Awash River	**Sampling site**	**Site description and activities**	**Coordinates**	
			Latitude	**Longitude**
Lower	Afembo	Used by the community for livestock, domestic and irrigation purposes as well as a waste drainage from sugar	11.54470	41.45048
	Adaytu	Used as water gage station and soil erosion is takes place.	11.12873	40.76299
Middle	Melkaworor	Sources of irrigation of agricultural farm (cotton, vegetable farming), livestock and domestic purposes.	9.20587	40.11947
	Awash Park	Reflect the impact of Metehara sugar factory waste and Lake Beseka on river water.	-	-
	Metehara	Sources of irrigation of agricultural farm (sugar, vegetable farming) animal feeding and other domestic purposes	8.85164	39.921174
	Sodere	Source of water for spiritual bathing, washing, domestic purpose, and small irrigation	8.39492	39.39840
	Mille	Reflect the impact of Borkena (containing industrial	11.41395	40.76068

Lower		waste), Logiya wastes and their impact on river		
Upper	Koka	Sources of irrigation of agricultural farm, fishing and other domestic purposes.	8.40771	39.02130
	Mojo	Serve as drainage for industrial wastes and dumping of solid wastes near to the river.	8.59787	39.11122
	Leather Development Institute	Serve as a waste drain for small-scale industrial, cars and municipal wastes.	8.92219	38.75104
	Bole	Serve as a waste drain for domestic and municipal wastes.	8.99197	38.77758
	Aba-Samuel	Sources of irrigation of agricultural farm, fishing serve as a waste drain for domestic and municipal wastes	8.78739	38.70625
	Asko	Serve as a waste drain for domestic and municipal wastes.	9.05920	38.69699
	Hatebela	Serve as drainage for industrial domestic and municipal wastes.	-	-
	Awash Bello	This site taken as a reference.	-	-
	Entoto	This site taken as a reference.	9.07740	38.77417

2) Composite sediment samples of 500 g were collected from the above selected 16 (sixteen) sampling sites using polyethylene bags by following the US EPA protocol. The sediment samples were also analyzed according to procedures outlined in the *Standard Methods for the Examination of Water and Wastewater*.



3) Three composite soil samples from 0-20 cm depth with an auger from selected farmlands of Lower (Afembo), Middle (Melkaworer) and Upper (Aba-samuel and Hatebela) Awash River basin were collected using clean polyethylene bags and soil samples were air dried in a dry and dust free place at room temperature for 5 days. Then, samples were ground with mortar and pestle to pass through a 2 mm sieve and homogenized. The homogenized samples (0.5 g) were digested in 15 mL of HNO_3 (69 %) and HCl (37 %) mixtures (3:1) at 80 ºC until a transparent solution were obtained.

4) Fresh spinach samples were collected from soil sampling area by random sampling technique method. Composite vegetable sample was made cut into pieces using alcohol disinfected scissors and packed into sterilized plastic polythene bags. Spinach samples then were oven dried ground with mortar and pestle to pass through a 2 mm sieve and homogenized. Finally, the samples were digested in 15 ml of HNO_3 (69 %) and HCl (37 %) mixtures (3:1) at 80 ºC until a transparent solution were obtained. These transparent solutions of each soil and vegetable samples were filtered and analyzed using AAS.

Major findings and Justification of its Importance

- The mean concentrations of heavy metals in water samples from 16 sampling sites are shown in Table 2.

Table 7Mean concentration of heavy metal in water samples collected from the 16 sampling sites

Stream of Awash River	**Site Name**	**Rainy season (September)**				**Dry season (December, March and May)**			
		Mn	Cu	Cd	Pb	Mn	Cu	Cd	Pb
Lower	Afembo	0.255	0.12	BDL	0.02	0.09	BDL	BDL	BDL
	Adaytu	0.42	0.17	BDL	BDL	0.44	BDL	BDL	BDL
	Mille	0.69	0.19	BDL	0.04	0.14	BDL	BDL	BDL
Middle	Melkaworor	0.445	0.1	BDL	0.04	0.65	BDL	BDL	BDL
	Awash Park	0.4215	0.07	BDL	BDL	0.3	BDL	BDL	BDL
	Metehara	1.37	0.11	BDL	0.06	0.4	BDL	BDL	BDL
	Sodere	0.15	0.08	BDL	BDL	0.08	BDL	BDL	BDL

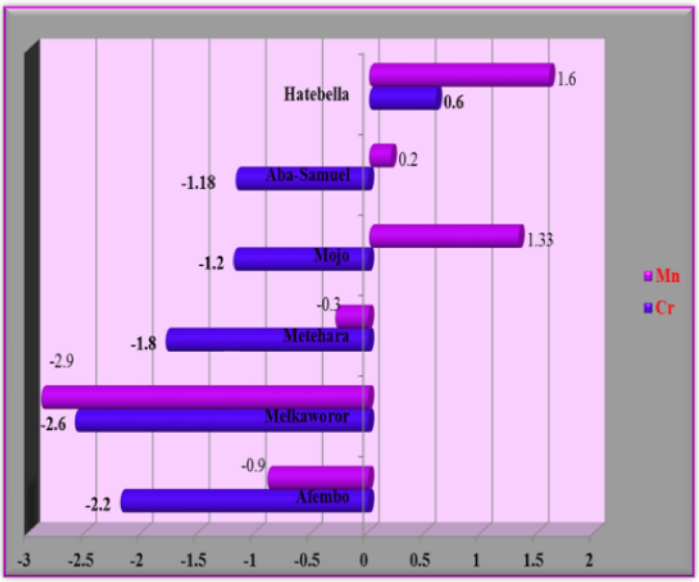
Upper	Koka	0.4645	0.2	BDL	BDL	0.27	BDL	BDL	BDL
	Mojo	0.5215	0.14	BDL	0.01	0.4	BDL	BDL	BDL
	Leather	1.61	0.19	0.39	0.08	1.3	BDL	BDL	BDL
	Bole	1.34	0.17	0.38	BDL	1.2	BDL	BDL	BDL
	Aba Samuel	0.61	0.15	0.4	BDL	3.28	BDL	BDL	BDL
	Asko	2.445	BDL	0.44	BDL	1.53	BDL	BDL	BDL
	Hatebela	3.89	BDL	0.45	0.97	1.4	BDL	BDL	BDL
	Awash Belo	0.118	BDL	0.47	BDL	0.24	BDL	BDL	BDL
	Entoto	0.091	BDL	0.42	0.14	0.26	BDL	BDL	BDL
International standards	WHO(2008)	0.4	2	0.003	0.01				
	USEPA(2003)	0.05	1	0.005	0.015				
	FAO(1985a)	0.2	0.2	0.01	0.1				

BDL – below detection limit

- The mean concentrations of heavy metals in water samples from 16 sampling sites are shown in Table 8.

Table 8 Mean concentrations of heavy metals in sediment samples from 16 sampling sites.

Stream of Awash River	Sampling site	Average Concentration of metals (mg/Kg dw)			
		Cr	Mn	Cd	Pb
Lower	Afembo	30.30	657.70	ND	ND
Middle	Melkaworor	21.90	161.86	ND	ND
	Metehara	26.70	1030.00	ND	ND
Upper	Mojo	60.10	3211.50	ND	ND
	Aba-Samuel	5940	1436.00	ND	ND
	Hatebella	199.00	3828.00	ND	ND
	Minimum	21.9	161.86	ND	ND
	Maximum	199.0	3828	ND	ND
	Mean	66.2	1721.0	ND	ND
Standards	[a]ASV(mg/kg)	90	850	91.3	41.3
	WHO(2004) SQG	25.00	NA	6.00	NA
	USEPA(1999)SQG	25.00	30.00	0.60	40.00



Unpolluted to moderately polluted (0 <*I*geo< 1)

Moderately polluted (1 <*I*geo< 2)

Figure 11 Igeo values of Cr and Mn in sediment samples

- Cd and Pb at Hatebella and Mn at Aba-Samuel, Asko and Hatebella during rainy season in river water were above WHO, USEPA and FAO standards (September).
- Mean concentration of Cr and Mn at Mojo and Hatebella were higher than WHO and USEPA sediment quality guideline.
- Sediments collected from Mojo and Hatebella sites were moderately polluted by Mn and Cr, which could be due to tanning and textile effluents in these areas, but Cd and Pb were BDL in all sediment samples.
- The values found for these heavy metals can be used as an input for assessment of state of the environment report produced at country level.

- Heavy metal concentrations found in the soils and spinach samples are shown in Tables 4 and 5 respectively.

Table 9 Concentration of heavy metals (mg/kg) in the soil from farmlands irrigated with Awash River

Sampling sites	**Cd**	**Pb**	**Cr**	**Mn**	**Cu**
Lower awash River Basin	ND	ND	82.2	1027	27.4
Middle awash River Basin	ND	ND	67.2	1118	ND
Upper Awash River Basin	ND	ND	57.2	89.8	ND
FAO/WHO Permissible limit	3	100	100	2000	100

Table 10 Heavy metals concentrations (mg/kg) in selected vegetables (spinach) irrigated with Awash River.

Sampling Sites	**Cd**	**Pb**	**Cr**	**Mn**	**Cu**
Lower Awash River Basin	ND	ND	89.8	535.8	6.4
Middle Awash River Basin	ND	ND	82.4	5.8	ND
Upper Awash River Basin	ND	ND	125.6	67	ND
FAO/WHO Permissible limit	0.2	0.2	2.3	200	73

- The concentrations of Cr, Mn and Cu analyzed in some of the soil sampling sites were above the maximum permissible limits set for agricultural soils by (FAO/WHO, 2001).

- ❖ The concentrations of Cr in all spinach samples and Mn in spinach samples collected from Lower Awash Basin farmland sites were above the maximum permissible limit set for vegetables by FAO/WHO (2001).

Key Policy Recommendations

- ✓ Continuous monitoring and proper intervention should be made to reduce the impact of pollution sources along the river course.
- ✓ Strong focus should be given to build the capacity of institutions working on producing legally defensible analytical data that enables environmental regulatory bodies to make stringent measures on polluters.

Potential users of the information:

- ✓ Ethiopian Environment, forest and climate change commission, University, water irrigation and Electric City, Awash Basin Authority, Rift Valley Lake Authority, Ministry of Agriculture, researchers, students.

Reliability of the information

- ✓ The findings of this study are the original property of the institute and the researchers. The reliability of the data could be checked with similar procedures.

Preliminary Assessment of Perception towards Genetically Modified Organisms (GMOs) by Regulators and Service Providers in Selected National Regional States of Ethiopia.

Responsible Researcher: **Adugnaw Admas**

Brief Description of the Information

The introduction of GMOs into the world's market started since 1990's, which has led to one of the most controversial issues that exist until today. And yet more than 75 countries import, grow and conduct research on GMOs. In August 2015, the Ethiopian government accepted the use of GMOs for research and commercial purpose by putting clear directives, in each case. This descriptive research was conducted to generate scientific information on perception towards GMOs of regulatory bodies and service providers by administering questionnaires to randomly selected 405 respondents drawn from five regional states (Amhara, Afar, Benshangul Gumuz, Somali, and Southern Nations, Nationalities and Peoples) and two city administrations (Addis Ababa City administration and Dire Dawa City Council). The results obtained showed that perception towards GMOs of majority of the regulators and service providers included in this study was negative. It was found that 50.9% of the respondents, even those who have sufficient information about GMOs, thought GMOs are dangerous for the environment and the society. This study showed that there is a need to increase the awareness and understanding about GMOs in Ethiopian regulatory and service providing institutions. Finally, it is recommended similar study to be conducted to investigate the perception of the larger public towards GMOs in Ethiopia.

Introduction

The commercial development of genetically modified (GM) crops began in 1996 with GM corn. The overall concept behind GM food is changing of the traits of genes in animals and plants in a way that results in more production, to create drought, cold, salt and insect resistant crops and forest trees. This has enabled GM food to become an emerging market segment and most popular in the food product development. Consequently, the planting of GM crops in the world has been increasing over the years, from 134 million hectares in 2009 to 170.3 million hectares in 2012. But commercialization of GM foods still remains a highly controversial and debatable issue among today's global food consumers. In other words, consumer attitude towards GM foods differs from one country to another. For example, consumers in European Union (EU) and Japan have a more negative attitude compared to consumers in the United States of America (USA), where the population willingly accepts GM products.

Ethiopia is a party to the Cartagena Protocol on Bio-safety to the Convention on Biological Diversity. The Cartagena protocol is an international agreement to ensure safe handling, transport and use of GMOs. The country adopted this Protcol in January 2000, which was later ratified on 31 July 2003 by the House of Peoples' Representatives. Ethiopia has officially announced the Bio-safety Proclamation on 9th of Sept. 2009 (No. 655/2009) with an aim "to protect human and animal health, biological diversity and in general, the environment, local communities and the country at large preventing or at least managing down to levels of insignificance the adverse effects of modified organisms". Moreover, the Ethiopian Government has entered into a commitment to be an active venture in the biotechnology industry by 2025 to make Ethiopia a middle income country by solving the existing food insecurity by improving the bio-safety proclamation No.655/2009 that highly opposed the use of modern biotechnology for producing transgenic plant/animals. The country has lately authorized the cultivation of biotech crops by granting two landmark approvals for environmental release of Bt cotton and research trials on biotech maize. However, scientific information on the perception of the public towards GMOs in Ethiopia is not available so far. Therefore, the objective of this research was to generate information on the perception (including attitude and awareness) towards GMOs of government employees serving as regulators including employees of Regional Environmental

Protection Bureaus, and service providers including employees from Federal Ministry of Education and Ministry of Health, and employees of Regional Agricultural, Industry and Investment, and Education Bureaus in the regional states of Ethiopia.

Brief Methodology

- This study employed a survey technique to obtain both qualitative and quantitative information. The required data was collected by administering questionnaire to 405 (male = 387 and female = 87) randomly selected individuals (employees from regulator and service providing institutions) working as permanent government employees in selected national regional states (Amhara, Afar, Benshangul Gumuz, Somali, Southern Nations, Nationalities and Peoples Region), and two city administrations (Addis Ababa and Dire Dawa). The educational status of the respondents was Diploma (3.7%), BSc/BA degree (66.7%) and MSc/MA and above (29.6%).
- The questionnaire of this survey consisted of two parts. The first part seeks to obtain personal information of the respondents. The second part of the questionnaire was designed to obtain information on the perception (including attitude and awareness) towards GMOs of individuals who filled out the questionnaire.

Major findings

- The percentages of respondents that supported, opposed or were neutral were 33.3%, 33.8% and 33.9% respectively.
- The results also showed that 34.6% of respondents want to see GMOs banned from Ethiopia, while 27.6% want to see GMOs grown for some non-food crops. The replies obtained from the respondents suggested that a significant proportion of respondents were very much concerned about the potential risks of GMOs to the society and the environment.
- Possible reasons for the respondents' cautious perception towards GMOs are as follows; 50.8% of the respondents replied that GMOs have side effects, 36.5% respondents replied GMOs are dangerous as a food and 50.9% respondents answered GMOs are dangerous to the environment and society.

- The percentage of respondents who replied they have not at all heard, heard sometimes, and heard repeatedly were 18.8, 64.9 and 16.25 %, respectively. This indicated that high proportion of the respondents have some knowledge about GMOs
- The finding of this study has shown that that the awareness level of regulators and service providers towards GMO concept was below expectation since 18 % reported that they have never heard about GMOs before. The 18 % (73) of respondents could most likely be among those who were neutral 33.9% (137) to either supporting or opposing GMOs.
- The study also showed that environmental regulatory bodies were not interested to see biotech crops in Ethiopia even though they repeatedly heard about GMOs.
- The limitation of this study is that it focused only on employees working as regulators and service providers. It could have been better to take a more representative sample representing the larger public to assess public perception toward GMOs.

Key Policy Recommendations

- There is a need to increase the scientific awareness and understanding about GMOs in Ethiopian regulatory and service providing institutions. It is thus recommended that the Ethiopian government and relevant stakeholders work on improving the awareness of regulators and service providing experts via different means of communication.

Potential users of the information:

- Policymakers, Ethiopian Biotechnology Institute, Higher learning institutions, Researchers, import and export dealers, traders, environmentalists, Ministry of Agriculture, Environment, Forest and Climate Change Commission, and other interested stakeholders.

Reliability of the information

- The findings of this study are the original property of the institute and the researcher. The reliability of the data could be checked with similar procedures. Moreover, this finding has been published in African Journal of Biotechnology.

Drought Characterization in the Awash River Basin, Ethiopia

Responsible researchers: Marta Gebreyesus, Abraham Cherinet, Tefera Ashine, Moges Molla, Adefires Worku, Agena Anjulo

Brief Description of the information:

This information is intended to characterize drought intensity, duration and areal extent of meteorological drought in Awash River Basin. The analysis of drought using reconnaissance drought index (RDI) from rainfall data and evapotranspiration is useful to determine the spatial distribution and characteristics of drought. RDI was used in this study for identification of drought conditions in Awash River Basin. The Mann-Kendall test was used for determining trend analysis. ArcGIs was used to analyze areal extent of drought in different years.

The basin is affected by recurrent drought including mild, moderate, severe and extreme droughts in different years. Duration of dry months ranged between 1- 4 months. Severity increased in the Upper and Middle Awash Basin and the spatial coverage of drought & and its intensity increased in the basin over different years. There was also an aerial shift of extreme drought from lower basin to upper and middle part of the basin. The worst drought was recorded in 2015 characterized by its intensity, duration and areal extent.

Introduction

Ethiopia is affected by recurrent drought events and suffers a severe drought in different years. The causes are either natural or manmade or both. Scientific investigations have revealed that the primary cause is the fluctuation of the general atmospheric circulation. As a consequence of such fluctuations, the rain-forming components for Ethiopia have been weakened or dislocated during drought years. Human interferences such as deforestation, overgrazing and over cultivation enhance the severity and prolongation of drought recurrences.

Droughts in Ethiopia had drastic impacts on agricultural output with total crop failure and massive livestock deaths being recorded in many parts of the country. For instance, the 1984 drought in Wollo province led to a 61% and 94% decline in the yield of two important crops, teff and sorghum, respectively. According to the survey conducted in 2006 in the Upper Awash Basin, drought occurs every two years in the area. Understanding the characteristics of drought is

crucial for establishing an effective and comprehensive monitoring and early warning system. In the Awash River Basin, only few farmers are organized under farmers-managed smallholder irrigation and a large portion of the rural poor are engaged in rain fed agriculture on marginal lands. Therefore, identification of the drought-prone areas in the basin is the basis to planning for improving socioeconomic conditions of the farmers.

Droughts are related to precipitation, stream flow, soil moisture or any combinations of the three. The causes of droughts could be attributed to natural phenomena, but studies in certain places have indicated that water sources which are under the impact of humans (e.g. rivers and groundwater) are two times more vulnerable than sources with less human interference, (e.g. snow cover and precipitation). Meteorological drought which we will see in detail in this document is based on the basis of the degree of dryness (in comparison to some normal or average amount) and the duration of the dry period of an area. This paper is devoted to focus on the identification and assessment of meteorological drought in the Awash River Basin, where it is simple deficit of rainfall from the normal.

Brief methodology

Monthly precipitation and temperature data of 18 meteorological stations were taken from National Meteorological Agency recorded for the period 1981 to 2015 (35 years). The reconnaissance drought index (RDI) was used for identification of drought conditions. Evapotranspiration and standardized RDI were calculated using a newly developed DrinC software package. The Mann-Kendall test was used for determining trend analysis and ArcGIS for interpolation.

Major Findings

Characterization of drought is crucial for establishing an effective and comprehensive monitoring and early warning system and it is mainly focused on the analysis of the historical drought conditions of a given area. A 12-month RDI values were estimated during the period 1981 - 2015 to provide an overview of drought intensity, duration areal extent and trend in the basin. The result indicated that the basin is affected by recurrent drought with the intensity of mild, moderate, severe and extreme droughts in different years. Extreme drought occurred in the years 1984-85, 1985-86, 1997-98, 2002-03, 2014-15, and 2015-16; the maximum RDI value

indicating extreme drought occurred at *Dubti* station in the year 1984. Duration of the dry months ranged between 1- 4 months, and maximum number of dry months (6 months) were recorded in the Middle Awash during 2015. In the Upper Awash, the maximum number of extreme drought events were recorded 4 times, viz. during 1984, 2002, 2014 and 2015.

Most of the stations showed an increasing trend of drought severity during Autumn, Winter and Spring seasons; only one station showed a decreasing trend of severity during Autumn and Summer seasons. This revealed that the short rainy season, *Belg*, was significantly affected and led to consecutive failure of the *Belg* season crops. This in turn implies that there should be short and long-term intervention to manage the impacts.

In 1984, about 99% of the total area of the basin was affected by drought, and 62.4% of the area was covered by extreme drought.The highest meteorological drought occurred in 2015 where 100 % of the total area of the basin was affected by drought where 73.4% was extreme (Figure 12).

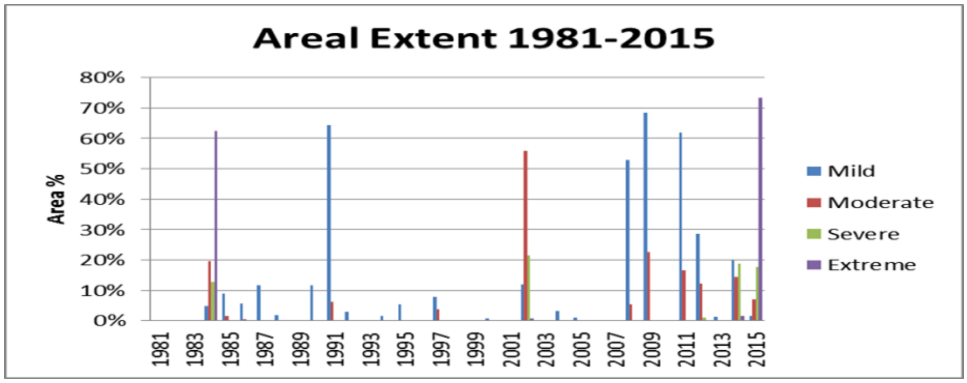


Figure 12 Areal Extent of drought in the Awash Basin

In 1984, the extreme drought was in lower Awash Basin but in 2015 the extreme was in Upper, Middle and some parts of Lower Awash Basin (Figure 13).

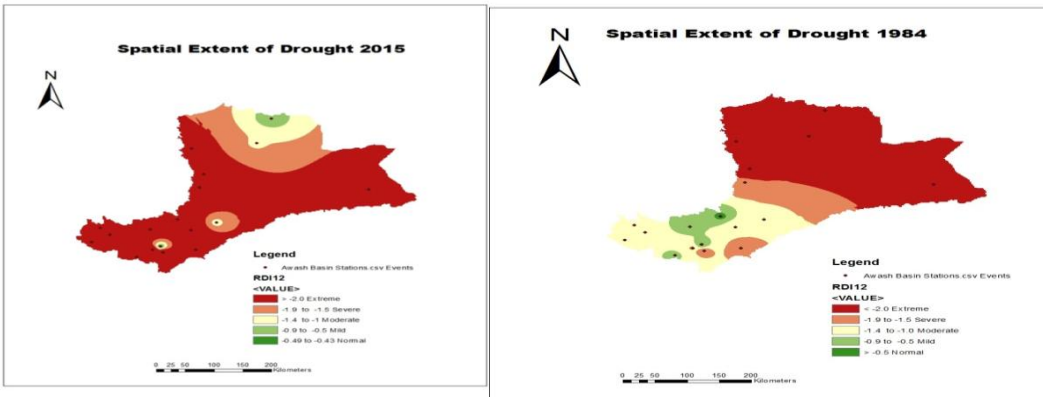


Figure 13 Spatial Extent of drought the year 1984 and 2015

In general, recurrent droughts occurred in the Upper, Middle and Lower Awash Basin due to the below average precipitation. Severity increased in the Upper and Middle Awash Basin and the spatial coverage of drought intensity increased in the basin over different years. There was also an aerial shift of extreme drought from lower basin to upper and middle part of the basin. The worst drought in intensity, duration and areal extent was the one that occurred in 2015.

Key Policy Recommendations

- Developing efficient and properly functioning drought early warning systems, specific to the extremely drought prone area to enable drought management
- Developing short- and long-term adaptation plan
- Implementing water harvesting technologies
- Integration of drought-risk management approaches into long-term development measures
- Involving investors who have an investment around the river in different adaptation and intervention practices

Potential users of the information

This finding can be used by policymakers, researchers, drought early warning governmental institutions, NGOs and others.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Marta G., Abraham C., Tefera A., Moges M., Adefires W. and Agena A. "Drought Characterization in the Awash River Basin, Ethiopia" (unpublished report).

Livelihood Vulnerability to Climate Extremes at Humbo CDM Project area

Responsible Researchers: Wondimagegn Amanuel, Musse Tesfaye, Adefiris Worku, and Zenebe Mekonnen

Brief description of the information

Humbo afforestation and restoration carbon sequestration clean development mechanism (A/R CDM) project, the first of its kind in Ethiopia, has managed to restore degraded forest of 2,728 ha through strategic replanting and protection and thereby generated revenues from carbon sale. However, there are gaps in terms of the impact of the intervention on the resilience of households against climate variability. Household survey was conducted at Humbo district in three representative *kebeles*, 139 randomly selected households, adjacent to the CDM project area to measure the household livelihood vulnerability to climate extremes. Both quantitative and qualitative approaches were employed to collect data. The livelihood vulnerability index was calculated based on LVI-IPCC framework. Livestock production (29.1%), crop production (42.9%), off-farm (17%) and others (42.6% - petty trade and labor) were the major income sources for the households. The overall LVI-IPCC showed that 16% of respondents were highly vulnerable to climate extremes, while 54% and 30% of households were less and moderately vulnerable, respectively. Substantial variations were observed across the *kebeles* with respect to the three dimensions of vulnerability. The LVI-IPCC estimated that households in the *Abela Longena kebele* were highly vulnerable to climate variability and change compared to *Habicha Bade* and *Bosa Wanche*. Integrating rural development schemes aimed at increasing adaptive capacity and designing site-specific intervention strategies, like the CDM project, to reduce vulnerability of the communities to climate variability and change is recommended to the range of climate extremes that the community experienced.

Introduction

Humbo CDM project in Humbo district of Southern Ethiopia was initiated by World Vision Australia and World Vision Ethiopia in 2006. It has introduced a farmer-managed natural regeneration technique to restore the degraded natural forest and thereby to generate carbon credits. Consequently, the forestland that had long been an open access resource has become

enclosed and protected. Since the time of its introduction, the project managed to restore 2,728 hectares of degraded forest and thereby contributed to the reduction of greenhouse gases from the atmosphere.

In spite of the widespread debate over the potential of CDM projects to achieve their sustainable development goals, the number of A/R carbon sequestration CDM projects is rapidly increasing. The study on potential benefit of A/R carbon sequestration CDM projects in Africa indicates that, in short run, the projects are less likely to benefit local communities and may even harm them by restricting access to natural resources. In Ethiopia, studies indicated that Humbo A/R carbon sequestration CDM project has managed to restore degraded forest through strategic replanting and protection and thereby managed to generate revenues from carbon sale.

In a midterm evaluation report of the Humbo A/R carbon sequestration CDM project, the reports by World Vision Australia indicated that the project has increased the protection and enhancement of biodiversity, reduced water and wind erosion, increased water supply, and returning of wild animals as major outcomes of the project. The reports showed that the project has contributed to the establishment of local cooperatives, securing of user rights to cooperatives, and financial inflows from the sale of carbon stocks as social and economic benefits of the regeneration and protection of the degraded forest. However, the evaluation reports did not disclose how the surrounding communities cope with the loss of forest products created by the sudden restrictions imposed by the project. It neither did assess the impacts of the benefits claimed to be associated with the project on the livelihood assets of the households nor on communities participating in it. Indeed, the costs incurred or the benefits enjoyed by a given community in turn significantly influences the way that community views and manages the natural resource under consideration. Therefore, the objective of this study was to measure the vulnerability of households near and adjacent to Humbo CDM project to climate extremes

Brief methodology

Households that are legally organized as forest development cooperatives to manage the forest of interest were the focus in the survey. A two stage sampling procedure was employed to select the sample households in Humbo district. First, three representative cooperatives out of seven were purposively selected on the basis of their accessibility and representativeness: *Abela Longena*,

Hobicha Bada and *Bosa Wanche*. Secondly, proportional samples of 51, 46 and 42 households, respectively, were selected from each cooperatives using systematic random sampling technique. The livelihood vulnerability index (LVI) was calculated based on 9 major components consisting of 38 indicators in their sub-components. Each indicator value was standardized between zero and one inclusive.

First, the value of each major component was calculated by the addition of the values of the sub-components and divided by the numbers of the sub-components.
Second, the sum of the products of index for major component i by weight of major component i and then divided by the sum of the weights of the sub-components in major component i will give the livelihood vulnerability index (LVI_i) for a particular site i.

Third, the index for exposure, sensitivity and adaptive capacity for site i was calculated by the sum of the products of the indices of the major components by weight of the major components divided by the indices sum of the major components for site i for each of the three contributing factors of vulnerability.
Finally, the livelihood vulnerability index for a site based on IPCC approach was calculated as follows:
$LVI\text{-}IPPC_i = (E_i - AC_i) * S_i$
$LVI\text{-}IPCC_i$ (-1 to 1 inclusive) livelihood vulnerability index for site i; Ei is exposure index for site i; AC_i is adaptive capacity index for site i; and S_i is sensitivity index for site i.

Major findings

- The household vulnerability index ranged from -0.373 to 0.402. The overall LVI-IPCC scores indicated that households in *Bosa Wanche* were comparatively less vulnerable compared to others because of their better adaptive capacity and less exposure. The LVI-IPCC showed that the households in *Abela Longena kebele* were more vulnerable to climate change compared to *Habicha Bade* and *Bosa Wanche* (Figure 14).

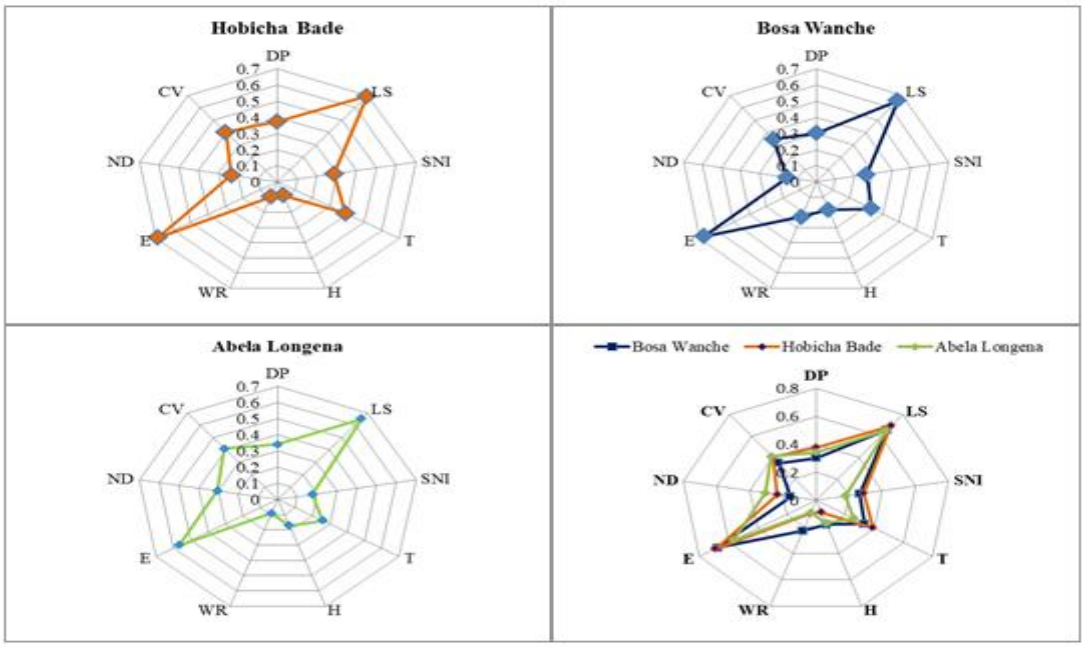


Figure 14 Vulnerability spider diagram of major components of LVI

Note: DP, demographic profile; LS, livelihood strategies; SNI, social network and infrastructure; T, technology; H, health; WR, water resources; E, ecosystem; ND, natural disaster; CV, climate variability. The scale represents 0 for least vulnerable and 0.8 for most vulnerable.

- The overall LVI-IPCC indicated that 16.1% of the households in the communities were highly vulnerable to climate change and variability that need urgent intervention. On the other hand, 54% and 30% of the respondents were less and moderately vulnerable to climate extremes, respectively. And when the results are disaggregated to different *kebeles*, the following results were obtained.
    - ☛ 25.5% of the respondents in *Abela Longena* were highly vulnerable to climate change and variability that need urgent intervention. The rest, 29.4% and 45.1% of the respondents were less and moderately vulnerable to climate extremes.
    - ☛ Moreover, nearly 11% of the respondents in *Hobicha Bada* were highly vulnerable to climate extremes. In this regard, 65.2% and 23.9% of the respondents were categorized into less and moderate level of vulnerability to climate variability.
    - ☛ Only 4% of the respondents in *Bosa Wanche* were highly vulnerable while 72.5% and 17.5% of the respondents, respectively, were less and moderately vulnerable to climate change and variability.

- On average the adaptive capacity component has contributed 38.5% followed by exposure 31% and sensitivity 30.5% to overall household vulnerability index.
    - ☛ Adaptive capacity score contributed 41.7% to household vulnerability index in *Habicha Bade*,
    - ☛ Sensitivity score contributed 35.7% to household vulnerability index in *Bosa Wanche*,
    - ☛ And exposure score contributed 35.7% to household vulnerability index in *Abela Longena.*

Key Policy Recommendations

- The LVI-IPCC indicated that livelihood strategies, ecosystem management and climate change/variability impacts are the most important factors to affect households' vulnerability with some variations from *kebele* to *kebele*. Indeed, undertaking intervention on these issues like the CDM project that recovers some of the ecosystem of the area, are key policy arena for community development and building resilience.
- The vulnerability analyses provide insight to devise coping strategies for indigenous communities and incorporate them in the climate change policies. Overall, it is hoped that the LVI will provide a useful tool for development planners to evaluate livelihood vulnerability to climate change impacts in the communities in which they work and to develop programs to strengthen the most vulnerable sectors to build resilience and enhance livelihoods.

Potential users of the information

Policymakers, research institutes, universities, governmental and non-governmental organizations, environmental and humanitarian advocators and practitioners and others.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Wondimagegn A., Musse T., Adefiris W., and Zenebe M. "Livelihood Vulnerability to Climate Extremes at Humbo CDM Project area" (unpublished report).

Traditional Weather Forecast for Climate Change Adaptation

Responsible Researchers: Zenebe Mekonnen, Martha Kidemu, Marta Gebreyesus, Mihret Semere, Habtamu Abebe, Musse Tesfaye, Adefires Worku

Brief description

Traditional knowledge is an indigenous or local community knowledge accumulated over generations in a particular environment. It is getting more consideration in the context of climate change adaptation by gaining as a knowledge system that has much to contribute to climate change research and political initiatives. Traditional knowledge or indigenous knowledge is framed on observation, culture and experiences. It is increasingly recognized as valuable for adaptation to climate change, bringing scientists and indigenous people to collaborate and exchange knowledge, focus on social context of exchange, benefits through mutual learning and mutual generation of knowledge. Giving less recognition to this knowledge are implications of multiple mutual, cultural, legal, risk-benefits and governance contexts. The combined use of traditional and scientific knowledge will enhance to build knowledge co-production which is the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems oriented understanding of the problem. This in turn is important to make effective adaptation to climate change and variability impacts. In this regard, farmers are using different rainfall prediction indicators such as moon position and size, animal behavior, wind direction and speed, etc. so as to manage their day-to-day agricultural and natural resource management activities.

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 knowledge 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 traditional knowledge system into conventional climate change adaptation and mitigation interventions planning. The marginalization of the traditional knowledge system has resulted in the increase of the vulnerability of society and their ecosystems in various ways. Cognizant of this, and mainly

since the Rio Declaration, there are some developments to acknowledge the diverse roles of traditional knowledge system, mainly in areas of natural resource management, climate change adaptation and mitigation, biodiversity conservation, weather forecast, peace building and conflict resolution.

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 package was developed based on the study conducted in the Central Rift Valley of the country where vulnerability to climate change and variability and landscape degradation has become severe challenge. This package of information is framed on how traditional knowledge system is applied in rainfall forecast and planning and implementation of climate change adaptation practices by smallholders.

Brief Methodology

Data was collected on the overall environmental and livelihood problems and driving factors, on 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 collection methods such as key informant interviews, focus group discussion and field level observation 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 in the study area;
- Indigenous knowledge has played important role in managing those risks in the day-to-day agricultural activities of farmers even in the absence of formal weather information;
- Communities use various indicators such as animal behavior, wind circulation, cloud cover and movement, water bodies, plant characteristics etc. (Table 1) to predict the onset and ending of rainfall and to make informed decisions on needed interventions (Indigenous early warning system);

Phenomenon	Indication	Responses	Related with scientific indicators
Red sky at sunrise	Rain is expected	Start to cultivate land	Yes
Temperature of the day become hotter	It is going to rain soon	Go to home sooner	Yes
'Harbu' tree started to flushing leaves	Coming of rainfall in a few days	Start to cultivate land	Yes
Colour of lake become black	It will be good season	Plan to do more agricultural activities	Need study
Rain started on women 'Ayana' day	It will be good season		
Rain started on horse 'Ayana' day	It will rain erratically	Plan to store grain to next season and use some available irrigations	Need study
Rain started on elephant 'Ayana' day	Heavy rain is expected	Plan to prepare for flood diversion and control	Need study
Rain started on the day of 'Ayana korma'	Drought is expected	Prepare grass for livestock and store grain for next season, harvest water	Need study
Children unusually cry for food	The coming season will be bad	Pray God to liberation	Need study
Bulls capering in the field	Rain to come soon	Land preparation when it is during may or crop harvesting when it is during November	Need study
Hyenas screaming in low tone			
Roaming of red ants around home			
Bee migration to lowland	Better rainfall at lowland	Hung beehives and prepare farm land	Need study
Change in the direction of cloud movements from normal	Expectation of the absence of rainfall (i.e. drought)	Store fodder for livestock and grain for humans for the coming drought year	Yes

- Due to cultural degradation, indigenous 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 weather forecast and have resulted in mismanagement of agricultural and natural resources 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, climate forecast thereby plays greater role in enhancing socio-ecological adaptive capacity and resilience.

Policy Recommendations

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

research showed exclusion of these systems facilitates 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.

Potential users of the information

Policymakers for integration in policy formulation, meteorologists for further research, extension agents for use in early warning system, NGOs and farmers for development intervention, etc.

Reliability of the information

- The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Zenebe M., Martha K., Marta G., Mihret S., Habtamu A., Musse T. and Adefires W. " Traditional Weather Forecast for Climate Change Adaptation" (unpublished report).

Traditional Agroforestry System for Climate Change Resilience in Tigray Region, Northern Ethiopia

Resiponsible Researcher: Ashenafi Manaye, Berihu Tesfamariam, , Musie Tesfaye, Adefires Worku , Haftu Abraha, Yirga Gufi

Brief description of the information

Agroforestry is a win-win solution to address the food security of small-scale farmers and synergies between climate change adaptation and mitigations. Despite the knowledge of this importance, there is still limitation of which traditional agroforestry (TAF) system is resilient to changing climate, which system better works where, for whom and under which conditions. This study was aimed at evaluating the TAF practices on the face of climate resilience in different agroecological parts of Tigray region, Ethiopia. Agro-silvopastoral TAF system was the dominant system in all agro-ecologies. Parkland AF practices in the midland and lowland, rotational woodlot in the highland have also considerable proportion. Overall, agroforestry contributed about 40% of the livelihood products. A total of 59 species, belonging to 48 genera and 32 families were recorded. Shannon diversity index (H') of highland agroecology was higher in homegarden AF, whereas in the midland and lowland the higher H' were recorded in parkland agroforestry. The mean total ecosystem carbon stocks of the TAF system was 103 ± 39 t C ha^{-1}. The difference in biomass carbon stock was significant between each agroforestry practice. Thus, our study revealed that the TAF practices have co-benefits on diversifying the livelihood strategy of farmers in the face of climate change and contribute to the adaptation and mitigation of climate change strategies.

Introduction

Nowadays, the negative impacts of climate change and variability are of great concern to the world in general, and to developing countries in particular. These impacts affect directly or indirectly agricultural production as well as the ability of ecosystem to provide goods and services. Ethiopia is among the highly vulnerable countries to climate change and vulnerability because majority of the population is poor and depends on agriculture, which is highly sensitive to the rainfall variability. The majority of the communities remain chronically food insecure, and Ethiopia continues to be seen as a country that is still unable to feed itself. Tigray region is one of the highly vulnerable areas to climate change. As a result, to secure food and income, the rural

communities remain disturbing the existing natural forest and have been moving to marginal and fragile areas which are already susceptible to land degradation, drought, pest and disease outbreak. The TAF system could be a solution to address the impact of climate change by improving the livelihood of the community.

Currently, the government of Ethiopia promoted agroforestry to improve local livelihood by diversifying income generation, reduce GHG emissions and enhance carbon sequestration. Despite the significant contribution of agro-forestry systems in climate adaptation and mitigation, it doesn't mean that all agro-forestry systems are effective and can be applied everywhere. Scholars argue that there is still limitation on knowledge, for instance, which agro-forestry system is more resilient to changing climate, which system better works where, for whom and under which conditions. This study was aimed at evaluating the contribution of TAF practices for climate resilience in the different agroecological part of Tigray region, Ethiopia.

Brief methodology

A preliminary survey was done to identify the different characteristics of agroforestry types (spatial distribution, their function and structure) and specific sites having an agroforestry practices across different agro-ecologies. A multistage sampling technique was employed to collect the data. From Tigray Regional state, three districts (*Endamehoni*, *Tanqua Abergele* and *Klite Awlalo* districts) from highland, lowland and midland agroecology were purposively selected, respectively. Systematic random sampling was used to select a total of 197 households from each respective village administration. From each household, socioeconomic and inventory data were taken. The plot size, established randomly for inventory data, was with size of 20 m x 20 m for home garden agroforestry, 50 m x 100 m for parkland agroforestry, 10 m x 10 m for woodlot agroforestry and 10 m x 50 m for boundary plantations. Then, aboveground and belowground biomass were estimated using the general allometric equation of Kuyah, developed for agro-forestry species of Kenya, which is similar to the study area agro-ecologies. Tree biomass was converted into carbon by multiplying the aboveground biomass by 0.5 (50 % of the dry mass). Finally, data were analyzed using both descriptive and inferential statistics.

Major findings

Characterization of the TAF practices

- The TAF practices of all agro-ecologies was dominated by agro-silvopasture system. This was due to farmers' interest to obtain diversified benefits from the different agroforestry systems of a given land. Farmers retain or fodder trees on the farmland and use them as a feed for their livestock in a controlled way. In the highland, (*Maychew* district), the dominant TAF practice was woodlot (59%) followed by homegarden (38%) and boundary plantation (3%). In the midland, about 90% of the TAF practices was dominated by parkland agroforestry followed by woodlot (7%) and homegarden agroforestry (3%).

Contribution of TAF practices for species diversity and climate change mitigation

- A total of 59 useful agroforestry tree species, belonging to 48 genera and 32 families were recorded. Shannon diversity index (H') in the highland was higher in homegarden AF, whereas in the midland and lowland the higher H' were recorded in parkland agroforestry. The basal areas of the different agroforestry practices were 44.3 m^2 ha^{-1} in the woodlot of midland and 1.3 m^2 ha^{-1} in the parkland agroforestry of the lowland area.
- The mean aboveground and belowground biomass of TAF system stored 22.38 t C ha^{-1}. Woodlot agroforestry practice contributed about 83 % and 73 % of the total biomass carbon sock of highland and midland agro-ecologies, respectively. Whereas, in the lowland, 100% of the biomass carbon stocks were recorded on the parkland agroforestry practices. With total mean of 103 ± 39 t C ha^{-1}, the total ecosystem carbon stock showed significant difference between the AF types (Figure 15).

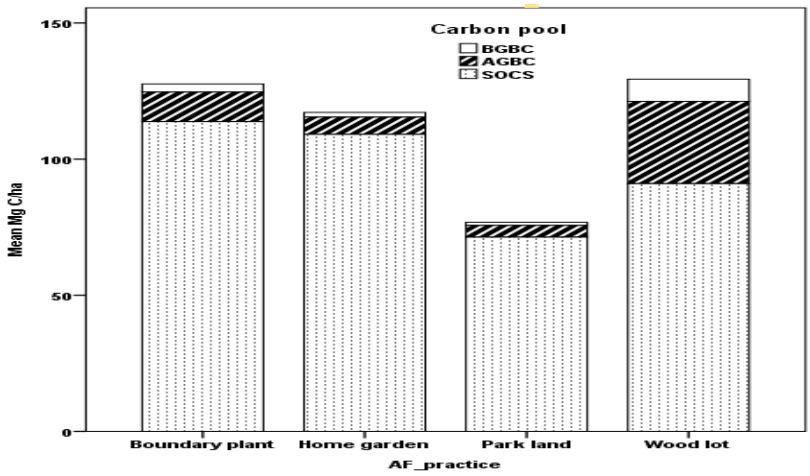


Figure 15 Ecosystem carbon stock potential of different TAF practices

Contribution of TAF practices for livelihood diversification and adaptation to climate change

- Overall, agroforestry contributed about 40% of the livelihood products in the study area. The contributions of traditional agroforestry to livelihood production for the households were about 52%, 37% and 70%, respectively, in the highland, lowland and midland agro-ecologies. In general, timber and access to fuelwood were the most important wood products obtained from agroforestry practices. However, in the midland, the prime needs of tree on farm were access for fodder (65%) to feed their livestock. In the face of climate change, farm households could obtain diversified income and increased crop production from AF (Table 11).

Table 11 Income generating (ETB) from AF product of Tigray regional state

No	AF product	Highland	Lowland	Midland
1	Fruit	1.17	481.25*	809.70**
2	Timber	2789.38	1522.88	333.83
3	Fuel wood	1339.66	521.91	136.17
4	Crops	10645.94	9961.03	6314.53
5	Fodder	42.97	1203.31’	940.63’’

**Ziziphus spina-christ* ** dominated by *Malus domestica*, *Psidium guajava*, *Mangifera indica*‘dominated *Acacia* Sps., *Leucaena leucocephala*’’, Faidherbia albida

- Respondents claimed that crops such as maize and sorghum, livestock of large ruminant i.e. cattle and fruit trees, e.g. avocado, were highly susceptible to climate variabilities. In contrast, goat and camel (livestock), from crops (e.g. teff) and from trees (all acacia species) were resilient to climate variabilities. The majority of the local communities responded that the prime option of adaptation strategies was selling their livestock followed by support from government and NGOs, savings from off-farm employment and then AF practices.

Key policy recommendations

- For the highland agroecology, multipurpose high valued tree species should be introduced to build resilience to climate change shock.
- A model of tree crop interaction on the existing and future climate change scenarios should be developed.
- Agrosilovopastoral agroforestry system should be promoted to obtain diversified benefits from the given parcel of land.

Potential users of the information

This information can be used by policymakers, farmers, researchers, governmental institutions, NGOs, etc.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Ashenafi M., Berihu T., Musie T., Adefires W. , Haftu A. and Yirga G. "Traditional Agroforestry System for Climate Change Resilience in Tigray Region, Northern Ethiopia" (unpublished report).

Regeneration in Natural Gaps of *Kafa* Afromontane Forest, South western Ethiopia

Responsible Researchers: Hailu Belay, Tesfaye Bekele, Mehari Alebachew, Tensay Teshome, and Urge Cheru

Brief description of the information

Gaps in the forest canopy are important for the regeneration of forest species and represent a different microenvironment compared to the forest understory. Gaps favor seedlings of shade-intolerant species to establish from soil seed bank and for rapid growth of shade tolerant seedlings from seedling banks. Some of the newly regenerating and growing seedlings may reach to the canopy layer in these gaps. Natural disturbance are among the major phenomenon that result in canopy gaps formation. This study was conducted at *Kafa* afromontane forest, located in *Gimbo* and *Gawata* districts of *Kafa* Zone at 450 km west of the capital Addis Ababa. Three sites (*Yeyibto*, *Achewa* and *Saja*) within the forest system were selected and a plot size of 4 ha (200 m x 200 m) was selected and established systematically inside each of the three sites. Similar size and number of plots were established in dense forest where there is no gap. Gap size, gap forming species, causes of gap stand number of regenerating woody species were recorded in all plots. The results revealed that the naturally created gaps have mean gap size of 223.31m^2 with standard deviation of 152.14 m^2. Most of the gaps were caused by snapping off (43%) followed by broken branches (29%). About 57% of the gaps were categorized as smaller gaps (< 200 m^2). Gaps had higher species richness (36), species diversity (2.64) and stem density (11,273 ha^{-1}) than plots in control or dense forest. Within these gaps, 36 woody species seedlings were recorded. However, population structure of woody species was healthy and stable in both gap and dense forest system. We concluded that gaps are important sites to initiate regeneration of species that need canopy openings. Thus, deliberate gap formation through de-branching of big branches or cutting of trees with dense canopy cover is recommended to enhance regeneration of native tree species with limited number of seedlings for sustainable management of such forest systems

Introduction

Afromontane forests are subject to a wide range of disturbances of variable duration, intensity, and frequency. Gap formation depends on several physical and biological factors involving

canopy closure, intensive growth of advanced regenerations and species colonization. The incidence contributes in altering light availability, to enhance seedling and sapling establishment among species, which otherwise blocks most light from reaching the forest interior. Gaps help to maintain the tree diversity, density and niche partitioning. The colonization of gaps by species of different categories or successional groups is influenced by eco-physiological responses of species in the area by the seed bank and by seedlings and/or remnant individuals, as well as by post-disturbance migrant species via dispersal processes. Thus, regeneration processes are associated with gap building phase. Understanding the dynamics of gaps in natural forests is paramount for forest restoration, sustainable management and conservation of forest remnants. This study aims to identify richness and the potential of natural regeneration of tree species in a natural gap represented by gaps of different sizes found in *Kafa* afromontane forest, south western Ethiopia.

Major findings

Gap sizes

The size and frequency of gaps are important parameters that vary by location and nature of gap maker trees. The areas of the gaps were calculated by using the ellipse formula. Thus, the result showed gap sizes ranged from 75 to 555 m^2 with the mean gap size of 223.31m^2 with standard deviation of 152.14 m^2 (Table 12). Most of the gaps had an area that falls < 200 m^2 (57.1%, n = 8) of the gaps. While four gaps (28.6%) were grouped as in gap size class, 200-400 m^2. On the other hand, gap size which has an area of > 400 m^2 was the least encountered (14.3%, n = 2) in each gap size class in the forest. Generally, the size distributions of the gaps showed sleekness to the left. Therefore, this study provides some of the firsthand information on gap dynamics of the *Bonga* forest where such data can be used in planning sustainable management of the forest.

Table 12Area of different gaps and their relative frequencies

Category	Mean Area (m^2)	Number of gaps	Percentage (%)
Small (< 200 m^2)	117 ± 42	8	57.1
Medium (200-400 m^2)	289 ± 61	4	28.6
Large (> 400 m^2)	513 ± 59	2	14.3
Total	223 ± 152		

Gap maker species

Gap makers are the trees that initially fell to create gaps. These species were identified during field collection by looking at the intact leaves when available and recognized by remnants. Hence, gap maker species includes *Olea welwitschii, Ehreta abyssinica, Polyscus fulva, Prunus africana, Syzigium guinensi, Schefleria scimperina and Elaeodendron buchananil*. The largest proportion (36%) of gaps were created by *Olea welwitschii* (Table 13). This species is also the most dominant tree species in the forest area.

Table 13Gap former tree species in Kafa moist afromontane forest and number of gaps

Gap maker tree species	Average dbh (cm)	Average height (m)	Percentage (%)
Olea welwitschii	47.12	29.9	35.71
Prunus Africana	55.00	28.0	14.29
Shefleria schimperina	77.50	29.5	14.29
Syzigium gueneensi	32.00	21.0	14.29
Ehretia abyssinica	24.00	35.0	7.14
Elaeodendron buchananail Loes.	74.00	26.0	7.14
Polyscias fulva	24.00	35.0	7.14

Causes for Gap formation

The major causes of gap formation in the study area were caused due to four reasons: which include snapping off, uprooting, broken branches and standing dead. Among these snapping of accounts (43%, n = 6) of the causes of gap formation. There were 36 species of woody seedlings belonging to 21 families recorded in 14 gaps and at three sites (Table 14). The number of tree species recorded in control plots was about 30 species. The gap area had higher density of 11,274 stems per hectare as compared to 7,974 in control plots. There is also more species richness (36) in canopy gaps than species in control plots (30). Evenness of the area was found to be 0.390 and 0.448 for gaps and control plots, respectively. Shannon diversity was 2.643 for gaps and 2.599 for control plots. Simpson index was 0.879 for gaps and 0.873 for control plots.

Table 14 Comparison of diversities of Kafa afromontane forest in gaps and control plots

Parameter	Gap	Control	p-value
Number of species	36	30	0.001
Number of seedlings	11,274	7,974	0.000
Dominance	0.121	0.127	0.034
Shannon H	2.643	2.599	0.012
Evenness e^H/S	0.390	0.448	0.001
Simpson index	0.879	0.873	0.034

Key policy recommendations

- The study of gap dynamics was not carried out in this forest before. The current study of gap dynamics could provide some information on aspects of gap regeneration in the forest. Therefore, this study provides some of the firsthand information on gap dynamics of *Kafa* afromontane forest where such data can be used in planning sustainable management of the forest.
- The study in gap dynamics in *Kafa* afromontane forest revealed that natural gaps caused by single tree or multiple trees fall are essential for maintaining the diversity of woody species in the forest. The mode of mortality was mainly related to snapping off the canopy trees.
- Variations in the gap sizes were observed due to factors such as mode of death of the canopy trees. Regeneration in the forest is low in closed forest as compared to the gaps.
- Precaution is needed in protecting illegal settlement and herbivores following gap formation.

Potential users of the information

- Forest managers and public forest enterprises,
- Governmental organizations,
- NGOs,
- Higher learning institutions,
- Regional environment and forest authorities
- Environment , Forest and Climate Change Commission

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Hailu B., Tesfaye B., Mehari A., Tensay T. and Urge C. “Regeneration in Natural Gaps of Kafa Afromontane Forest, South western Ethiopia” (unpublished report).

Phenology of Selected Indigenous Tree Species in *Gera* Natural Forest, South Western Ethiopia

Responsible Researchers: Hailu Belay, Tesfaye Bekele, Mehari Alebachew, Tensay Teshome, and Urge Cheru

Brief description of the information

Phenological events include flowering, leaf unfolding (or budburst), seed set and dispersal, and leaf fall. Phenological studies of four indigenous tree species: *Cordia africana, Pouteria altisima, Podocarpus falcatus and Hagenia abyssinica* were studied at *Gera* natural forest south western Ethiopia. A total of 40 mature trees (10 individuals from each species) were selected and marked. Phenological data of these species which includes flowering and fruiting were taken twice a month from May 2014 to June 2017. Based on the phenological data collected, the phenological calendars of the tree species were prepared. Among the tree species under consideration, *Podocarpus falcatus* flowers were not visible or observed during the times of data collection, and thus it was excluded from analysis of the information. *Hagenia abyssinica* and *Pouteria altisima* were found to be evergreen that exhibit leaves during the data collection period, while *Cordia africana* was found to be deciduous that exhibited leaves from September to August during the study period of field data collection. *Hagenia abyssinica* flowering took place from October to December and the fruiting period extended from January to February. *Pouteria altisima* gives flowers from April to May and bears fruits from June to August. *Cordia africana* gives flowers from June to September and bears fruits from November to December. Such phenological information are important for collection of quality seeds and forest interventions to enhance natural regeneration.

Introduction

The interest in phenology arose in the 19th century; where people had paid close attention to the seasonal timing of natural events. The tree species in this information included are *Cordia africana, Pouteria altisima, Podocarpus falcatus and Hagenia abyssinica*. *Cordia africana* occurs at medium to low altitudes, in woodland, savannah and bush, in warm and moist areas, often along river banks. It grows in drier conditions but thrives in good rainfall areas and is scattered in occurrence. It occurs in afromontane rainforest and undifferentiated afromontane

forest mixed with Podocarpus forest, usually along margins and in clearings. *Hagenia abyssinica* was first described in Ethiopia and also found in East Africa, and often dominant in the woodland zone just above the mountain bamboo. *Hagenia abyssinica* and *Podocarpus* forest can exist mixed with *Juniperus procera* forests. The phenological studies of these species are important from the point of view of the conservation of tree genetic resources and forestry management as well as for a better understanding of the ecological adaptations of plant species. The precise timing of events in the natural cycle of the seasons often determines the success or failure of individuals. But in Ethiopia there is a shortage of information concerning the phenological characteristics of most tree species.

Major findings

Seasonal patterns of flowering and fruiting were clearly observed for the three studied species: *Cordia africana, Pouteria altisima* and *Hagenia abyssinica* (Figure 16). Individual trees of this species flowered only once per year. *Pouteria altisima* and *Hagenia abyssinica* were found to be evergreen that maintain their green leaves throughout the years, while *Cordia africana* was found to be deciduous that shed its leaves during dry season. This is because the study area experienced a relatively higher temperature of about 21°C – 28 ^{o}C from January to March, and having a minimum temperature of 10 ^{o}C - 12 ^{o}C during the months of October to December (Figure 16).

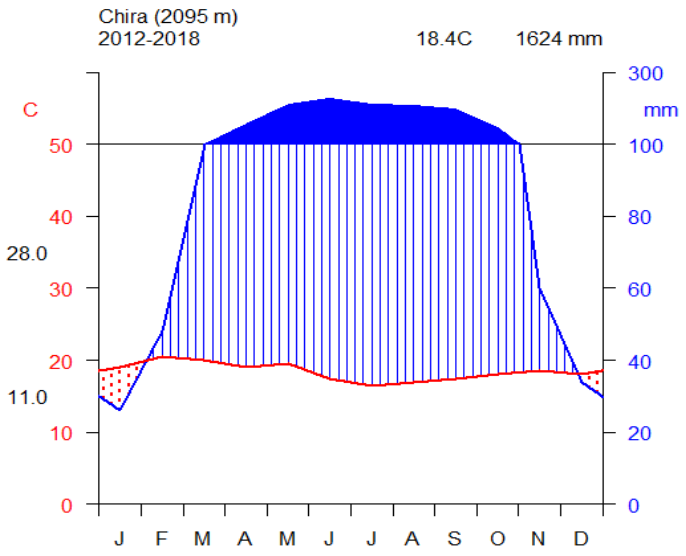


Figure 16 Climadiagram of Chira station from 2012-2018 (NMSA, 2018)

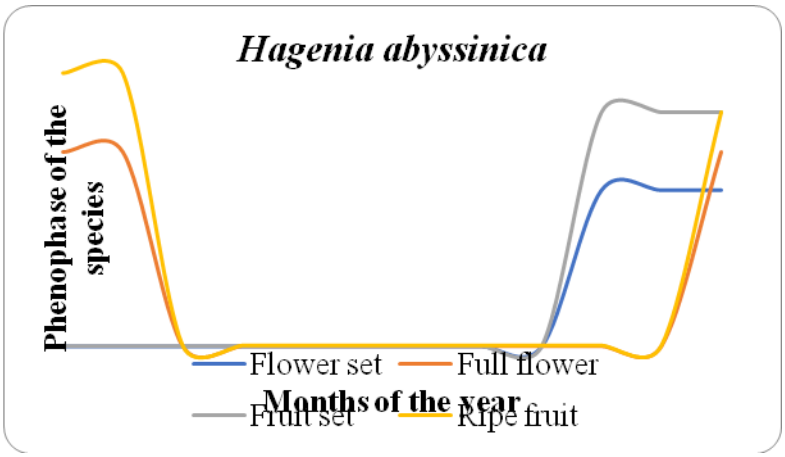


Figure 17 Phenophase of Hagenia abyssinca at Gera forest, southwest Ethiopia

Hagenia abyssinica exhibit leaves during the periods of the experiment. The observed data indicated that the flowering seasons take place from October to December and the fruit setting was extended from January to February.

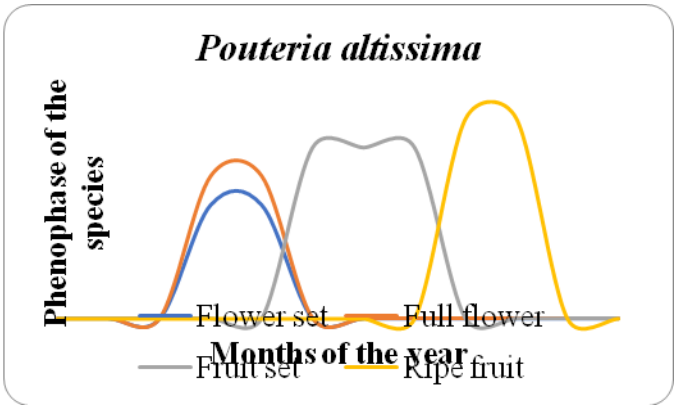


Figure 18 Phenophase of Pouteria altisima at Gera forest, south western Ethiopia

Pouteria altisima exhibited leaves during the periods of field data collection. The data revealed that the species can give flowers from April to May which is less conspicuous and also bears fruits from June to August.

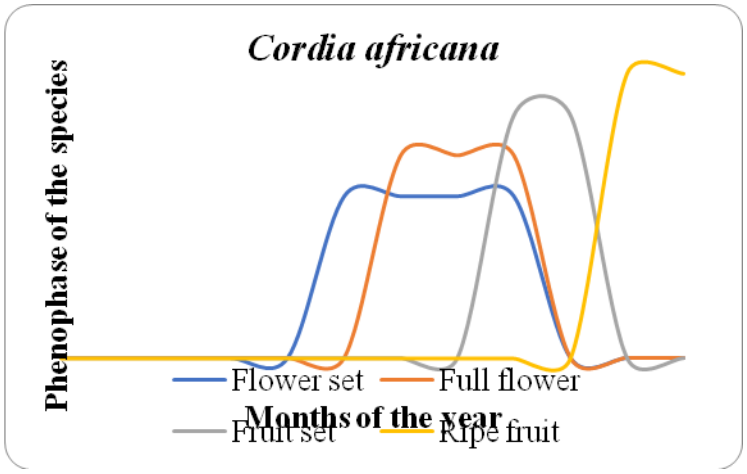


Figure 19 Phenophase of Cordia africana at Gera forest, south western Ethiopia

Cordia africana exhibited leaves from September to August during the periods of field data collection and gives flowers from January to September. It bears fruits from November to December.

Key policy recommendations

- Actors that involve in seed collection should make use of the output of this study to collect matured and quality seed of study species specifically in *Gera* natural forest.
- Appropriate silvicultural practices need to be implemented following seed dispersal to enhance natural regeneration of study species

Potential users of the information

- Forest managers and public forest enterprises,
- Forest seed enterprises,
- Governmental organizations,
- NGOs,
- Higher learning institutions,

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Hailu B., Tesfaye B., Mehari A., Tensay T. and Urge C. "Phenology of Selected Indigenous Tree Species in Gera Natural Forest, South Western Ethiopia" (unpublished report).

Social and Economic Importance of *Ghibe* Valley National Park Woodland for Local Community, South Western Ethiopia

Responsible researchers: Nesru Hassen, Shiferaw Alem and Tamiru Lemi

Brief description of the information:

Woodland forests are home to wealth of diverse and unique fauna and flora and provide various goods and services which are important for livelihood options. The study was carried out in *Ghibe* Valley, *Gurage* zone in Southern Nations, Nationalities and People's Region. *Gibe* Valley is geographically located at E 037° 15'- 037° 40' and N 08° 00'-08° 30'. It is about 174 kilometers away from the south western part of Addis Ababa, Ethiopia. *Gibe* Valley is recently established as regional national park due to its high endemism and biodiversity conservation importance and home for numerous migratory and endemic bird species. It covers 360 km^2 and it is dissected by deep gorges of the *Gilgel Gibe* and *Wabe* rivers. The *Gibe* Valley is found in three administrative districts, namely *Abeshgae*, *Cheha* and *Enemorina* Eaner. The park has an altitudinal range between 1050 to 1600 meter above sea level. The mean annual temperature (MAT) of the valley ranges from 18.5 °C - 25 °C. And its annual rainfall is 1000 mm where the highest is in July. It is categorized as hot to warm sub-humid agroecological zone. Currently, the woodland is in a recovering process even though it is facing a number of anthropogenic pressures from local communities that live in and around the park. Clear displacement of people in the park needs enough compensation for their resources. Therefore, the explicit description of the current benefits of local people gaining from the woodland would indicate future comparable incentives given to local community after total redisplacement of the people found in the park compound. The objective of this paper was to describe and quantify the socio-economic contribution of the woodland vegetation in *Gibe* Valley national park to the surrounding community.

Important socio-economic data were collected using a structured interview, from a total of 130 households, residing in three adjacent selected districts. The result of the study revealed that local people used the woodland resource for various purposes like fuelwood collection, construction wood collection, grazing and collecting other non-timber forest products. The commonest wild fruit producing tree species in the study area was *Ximenia americana* followed by *Tamarindes indica*. About 47.7% of the respondents knew the presence of gum and resin

bearing species, and about 20% of them were collecting it for household consumption. The major forest products collected from the woodland vegetation by the respondents were fuelwood, farming utensils, construction woods, wild fruits and fodder for their grazing animals. About 62% of the study participants stated that the size of the woodland is decreasing from time to time due to a number of factors. Only 20% of the sampled population collect and use traditional medicinal plants in the study area, while 75.4% of the sampled population preferred the modern medicine to cure their illness. The reason for preferring modern medicine by majority of the sampled population were due to appropriate dosage and better access to get it. Almost all (93%) of the respondents agreed that traditional healers were not willing to share their knowledge to the other members of the community. The results further indicated that crop production ranked as the primary household livelihood option and income source for local people. Livestock constituted 75.4% of their income as secondary source. The main grazing land for their livestock was the woodland. The average annual income of the local people from crop, livestock, agro forestry, plantation forestry and woodland were 17,112, 8,180, 4,528, 3,128 and 1,667 Birr, respectively. It is thus highly recommended to take action that reduces deforestation of the woodland, and enhancing its non-timber forest products through sustainable forest management.

Introduction

Woodlands are vegetation types dominated by woody plant species predominantly covered by trees and shrubs with canopy cover more than 10% and have growing period of only 179 days. These types of vegetation are habitat of a number of economical important plant species that are source of livelihood for about one quarter of the earth's population. These are also supporting the livelihood of over 2 billion or 1/3 of the world's population.

Woodlands in Africa are comprised of woodlands, bushland, shrubland and thicket and in some cases wooded grassland. The woodlands are source of highly nutritious foods (both insect wild foods and plants) that fill the gap of nutritional requirements of people. Exportable non-wood forest products of woodlands in Africa play an important role as a source of income at national and international market and creating employment opportunity for a number of women in Africa.

Woodland cover in Ethiopia is estimated to be more than 50% of the total area of the land. These woodlands are home to a number of economically important plant species: gum and resin bearing species, edible plant species, lowland bamboo, etc. The woodlands contribute significant

household income to local community that amounts from 21.4% to 67% of the total annual income

Combretum-Terminalia is the largest woodland vegetation in lowland dry land parts of Ethiopia. Local people living in such lowland dry areas are dependent on the vegetation for their livelihood. On the other hand, these forests are endowed with nationally and internationally marketable forest products that include natural gums and honey.

Therefore, studying the socio-economic aspect of lowland woodlands is important to know its socio-economic contribution at local and/or national level. But, such information in the study area were scarce and inadequate. Therefore, the current study focuses on identifying the forest products and quantifying the socio-economic contribution of the woodland vegetation to the surrounding community.

Major findings

Socio economic characteristics of the study area

The life style of people in the *Guragae* zone in general, and at studied districts in particular, is a sedentary with agriculture. *Ensete ventricosum* is the staple food crop grown in their homestead agroforestry system. Cereal crops like *Zea mays* (Maize), *Sorghum bicolor* (sorghum), and *Eragrostis tef* (teff) are widely cultivated crops. Cash crops like coffee and *Khat* are also grown in the study area in agroforestry combination. In addition to these crops, *Capsicum annum* (hot pepper), *Sesamum orientale* (Selit) and *Guizotia abyssinica* (Nug) are produced as cash crop in the study area. Animal husbandry is widely practiced. Currently, eucalyptus plantation is aggressively growing in the study area in order to maximize the local people's household income.

Social characteristics

More than 78% (98) of the respondents in the study area lived for greater than twenty years. Therefore, it is believed that almost all of the interviewee have detailed knowledge about the surrounding woodland.

Livelihood options

The six dominant livelihood options for local people were crop production, livestock rearing, agroforestry practice, plantation forestry and income from the woodland. Crop production was

their primary source of livelihood option and income source. Livestock production was the second livelihood option for the local community. About 76.1 % of the respondents in the study area were rearing livestock as major livelihood support. The main grazing land for their livestock was the woodland vegetation. This showed how the woodland vegetation supports the livelihood options of the local people.

All livelihood options illustrated in the current study had interrelations among each other. For instance, the livestock rearing, honey production, crop production and traditional medicine are dependent on the existing woodland vegetation. Honey production linearly decreased from time to time due to the entrance of bee colonies into the hollowed concreted electric pole (according to respondents). Therefore, the economic contribution of the woodland can also be reflected on the other livelihood options of the people. Respondents from *Cheha* district did not depend on the woodland for their livelihood.

Income

The average annual income of the local people from crop, livestock, agroforestry, plantation forestry and woodland were 17112, 8180, 4528, 3128 and 1667 Birr, respectively.

Forest products

More than 30% of the people in the study area collected various forest products from the nearby woodland vegetation like fuel wood, charcoal, construction wood, traditional medicines, gum and resins, farming utensils, handicrafts and grazing. Among these forest products, three of them namely fuelwood, construction wood and farming utensils had taken the larger shares of the forest products that the local people collected from the woodland vegetation.

About 49.2% of the respondents were collecting wild fruits from woodland, where as 50% of the respondents were not collecting wild fruits. The collection of wild edible plants from the woodland vegetation was not significantly varied with sex, age and family size, but it significantly varied with educational level.

The woodland vegetation inhabited a number of fruit producing tree species. The common wild fruit producing tree species in the study area were *Ximenia americana* followed by *Tamarindes indica*. The local people eat the fruits for various purposes, like for the intention of medicinal

value, mental satisfaction, for marketing, and to relieve hunger. But 31.5% of the interviewee kept silent about the purpose of eating wild fruits in the study area. 47.7% of the respondents had knowledge about the presence of gum and resin bearing tree species, and 20% of them were collecting it for household consumption. Some of the reasons why they did not collect and sell the product in the market include inaccessibility (23%), lack of knowledge (53.8%), and lack of permission to enter into the park.

Threats

It is known that deforestation, specifically in dryland woodlands of Ethiopia is a serious and devastating phenomenon. More than 62% the interviewees replied that the size of the woodland is decreasing from time to time due to a number of factors that include investment, fire, charcoal production, agricultural expansion, overgrazing and settlement.

Key policy Recommendations

- Creating awareness about the economic importance of the woodland vegetation for local people and development agents has substantial usage for accounting economic value of the woodland vegetation.
- The livelihood contribution of the woodland vegetation is interlinked with different livelihood options like livestock, honey production, input for agriculture, and the like.
- Provision of training and awareness creation for the local people about the production and use of gum and resin product diversifies forest products and maximize their economy.
- Improving and diversifying agroforestry system for *Abeshgae* and *Enemorina Eaner* districts can minimize deforestation of the woodland vegetation.

Potential users of the information

- ✓ Environment and forestry sectors at national, regional and district level,
- ✓ Local communities of the districts bordering the studied forests,
- ✓ *Gibe* Valley National Park.

Reliability of the information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Nesru H., Shiferaw A. and Tamiru L. "Social and Economic Importance of Ghibe Valley National Park Woodland for Local Community, South Western Ethiopia" (unpublished report).

Diversity, Population Structure and Regeneration Status of Woody Species at *Yerer* Mountain in Central Ethiopia

Responsible Researchers: Nesibu Yahya, Belay Gebre, Genene Tesfaye

Brief description of the information:

Ethiopia has diverse environmental and climatic conditions that have contributed to the formation of various ecosystems. However, large areas of naturally forested ecosystem were changing to other land-use type in the country. As a result, biodiversity resources are rapidly disappearing. Therefore, continuous studies on diversity and structure are essential to provide baseline information in monitoring plant resources. *Yerer* mountain forest is one of the remnant dry-evergreen montane forest, where unregulated extraction of wood and non-wood forest products is widespread. However, knowledge on the diversity, population structure and regeneration of woody species is still lacking on the forest of *Yerer* Mountain. The study was, therefore, intended to generate information on species richness, diversity, population structure and status of regeneration of woody species. The study was carried out on the *Yerer* Mountain, located in Oromiya Regional State, East Shewa Zone, near Addis Ababa. Thirty-six plots (400 m^2) were laid out to collect data from vegetation along three altitudinal and disturbance gradients. The diversity, structure (density, abundance, frequency, dominance/basal area, important value index and population structure) and regeneration status of the woody species of the study area were analyzed. The result showed that thirty-one indigenous woody species that belong to 23 families were recorded. Higher woody species diversity were obtained in the lower altitude (Shannon-Wiener diversity indices = 2.38) followed by middle (Shannon-Wiener diversity indices = 2.14) and higher altitude (Shannon-Wiener diversity indices = 2). The density of seedling, sapling, shrubs and trees were 6383, 1022, 481and 115 ha^{-1}, respectively. Although only a few tree species dominated the forest of the study area, *Juniperus procera* is the most dominating one. The structural analyses of the whole community of the study area shows larger number of seedlings and saplings compared to matured individuals, which indicate healthy regeneration status of woody species. However, the population structure of *Juniperus procera* exhibited poor regeneration status. In general, the study concluded that the forest is dominated by small-sized tree/shrub species, which show the forest is under early stage of succession after disturbance. Therefore, sustainable forest management practices such as enrichment planting of

other native woody and adequate protection from illegal encroachment is highly recommended to enhance the development and biodiversity of the forest systems.

Introduction

Ethiopia has a great diversity of environmental and climatic conditions that have contributed to the formation of diverse ecosystems. The country is considered as one of the most important habitats for many endemic plants and animals in tropical Africa. The geographical and ecological diversity of the country plays crucial role to cover diverse vegetation types involving forest ecosystem.

However, woody species in forest ecosystem are being destroyed at an alarming rate because of farmland expansion, illegal wood harvest, and excessive free grazing.

Historical document shows that forest and woodlands once covered over 40 % of the total area of the country. However, devastative deforestation and forest degradation has occurred for satisfying the demands of an ever-increasing human population. Increasing agricultural expansion, overgrazing, extraction of woody species for energy source and construction materials are the main drivers of deforestation and forest degradation. Over the last few decades, large areas of naturally forested land were changing to other land use type in the country. Due to loss of forest ecosystem, biodiversity resources along with their habitats are rapidly disappearing in the country.

Therefore, continuous studies on diversity and structure are essential to provide baseline information. Understanding of diversity and structure of the forest are useful in identifying ecologically and economically important plants species and their diversities, which ultimately need to protect threatened species among them. In addition, information on population structure can provide an insight whether a particular population in the forest has a stable distribution or not. This information contributes much in the promotion of sustainable management, utilization and conservation.

Yerer Mountain forest is one of the ruminant dry-evergreen montane forest ecosystems. The ecosystem in general experienced unregulated extraction of wood and non-wood forest products at the national context. The challenge is also serious in the *Yerer* forest community as it is near to the capital Addis Ababa. Ultimately, such unregulated extraction will affect the existing plant

diversity and leads to floral species loss. This being the situation, very little is known about *Yerer* Mountain forest in general, and its floral diversity, in particular. In this study, therefore, woody species richness, diversity, evenness, population structure and regeneration status were studied in the forest of *Yerer* Mountain.

Major findings

Woody species composition and diversity

Thirty-one indigenous woody species representing 23 families were recorded from *Yerer* Mountain. The most diverse families were Anacardiaceae, Celastraceae, Euphorbiaceae, Lamiaceae, Myrsinaceae, Rosaceae and Sapindaceae with 6.5 % each of the total number of species. In terms of habit, from all recorded woody species 22.6 % were trees and the remaining 77.4 % were shrubs.

The woody species diversity encountered in the study sites were 2.0, 2.1 and 2.4 in the higher, middle and lower altitude range, respectively; while their corresponding evenness values were 0.67, 0.74 and 0.81. Woody species diversity decreased along altitude. This might be due to edaphic factors like high soil organic matter and nutrient availability and warmer temperature at the lower altitude than the higher altitude. Moreover, the occurrence of rock in the highest altitude might contribute for the lower value of woody species diversity.

Density, frequency and dominance

The total densities of all woody species, including shrubs, in the study area were 595 stems ha^{-1} at *Yerer* Mountain. The six densest species were *Juniperus procera* (111 stems ha^{-1}), *Carissa edulis* (84 stems ha^{-1}), *Erica arborea* (81 stems ha^{-1}), *Myrsine africana* (55 stems ha^{-1}), *Dodonaea angustifolia* (49 stems ha^{-1}), *Maytenus undata* (47 stems ha^{-1}). The six most frequently occurred species were *Juniperus procera* (11.8%), *Carissa edulis* (10.5%), *Myrsine africana* (8.6%), *Rubus volkensii* (8.6%), *Maytenus undata* (8.2%), *Osyris quadripartite* (7.7%). The dominance of woody species at *Yerer*, expressed in terms of basal area of woody species, was 0.56 m^2 ha^{-1}. *Juniperus procera* dominated the forest system with the basal area of 0.54 m^2 ha^{-1}.

Important value index (IVI)

Importance Value Index (IVI) is an essential parameter in vegetation ecology that indicates the ecological significance of species in the forest. Accordingly, *Juniperus procera* (126),

Pittosporum abyssinicum (7), *Rhus retinorrhoea* (6), *Buddleja polystachya* (5), *Croton macrostachys* (2), *Prunus africana* (1) and *Acacia bussei* (0.6) exhibited the highest important value index in the study area.

The diameter at breast height (DBH) class distribution of all woody species from the forest of *Yerer* demonstrated a higher number of individuals in the lower diameter class with a decreasing trend as the diameter of individual increases. Such distribution pattern shows a stable or healthy structure in terms of size. However, the diameter class distribution of the most dominant tree species, *Juniperus procera*, shows a very few individuals in the first lower classes with increasing trend as diameter of individuals increases. Such distribution shows an unhealthy pattern. The total density of seedling, sapling, shrub and trees in the study area were 6383, 1022, 481 and 115 ha^{-1}, respectively. The distribution of seedling populations is greater than that of sapling, shrub and mature trees. Such pattern of natural regeneration implies that the distribution of woody species at seedling and sapling level has healthy undergrowth. In general, the combined result of structure and regeneration status indicated that the forest lies relatively under a young succession after disturbance.

Key policy Recommendations

- Promising intervention of sustainable forest management such as enrichment planting shall be introduced to increase the diversity and enhance natural regeneration of poorly represented species.

Potential users of the information

- Environment and forestry sectors at national, regional and district level,
- Higher learning and academic institutions
- Local communities of the districts bordering the studied forests,

Reliability of Information

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Nesibu Y., Belay G. and Genene T. “Diversity, Population Structure and Regeneration Status of Woody Species at *Yerer* Mountain in Central Ethiopia” (unpublished report).

Woody Species Diversity, Regeneration Status and Carbon Stock of Dry Afromontane Forest in Central Highlands of Ethiopia

Responsible Researchers: Mindaye Teshome, NesibuYahya, and Mehari Alebachew

Brief description of the information

Arba Gugu forest is one of the remnants of dry Afromontane forest ecosystem found in the Central Highlands of Ethiopia, which is composed of broadleaved and coniferous forest. However, studies about species composition, diversity, status of regeneration and carbon stock were not yet investigated. This study, therefore, aimed to generate information on species composition, diversity, status of regeneration and carbon stock of *Arba Gugu* forest. A total of 35 sample plots of 20 m x 20 m (400 m^2) each were established in the natural forest. In addition, three subplots were laid out inside main plots for saplings, shrubs and seedlings data collection. Species composition, diversity, regeneration status and carbon stock were analyzed using appropriate equations. 42 woody species (27 trees and 15 shrubs) belonging to 27 families were recorded. The total density of mature trees/shrubs, saplings and seedlings were 130, 149 and 964 individuals ha^{-1}, respectively. The total basal area of mature trees/shrubs was 32.9 m^2 ha^{-1}. The Shannon-Weiner diversity and evenness index value was 2.12 and 0.70, respectively. Among the studied tree and/or shrub species, 4 species exhibited good regeneration (GR); 13 species had fair regeneration (FR); 13 species showed poor regeneration (PR) and12 species had no regeneration (NR). The mean total carbon stock was 238.4 t C ha^{-1} (aboveground = 198.7 and belowground = 39.7). Overall, *Arba Gugu* forest has relatively lower number of species but the existing tree/shrub species in the *Arba Gugu* forest has the potential to store large proportion of carbon. Species with no or limited regeneration require urgent conservation measures that include protecting and applying appropriate silvicultural practices that enhance the regeneration of species.

Introduction

Forest provides several goods such as wood and non-wood forest products and ecosystem services such as biodiversity protection, fresh water supply, soil protection and climate regulation. These all are important for the well-being of people at local, national and global levels. In addition, forests mitigate atmospheric CO_2 as sinks in its carbon pools. For example,

tropical humid and dry forests cover over 2.1 billion hectares of land, stores 180 Gt of carbon stock in its biomass and have turnover of 915 Gt of carbon each year.

Plant diversity is influenced by species composition and their abundance. Natural regeneration is a central component of tropical forest ecosystem dynamics and is essential for preservation and maintenance of biological diversity in the forest. A successful regeneration is indicated by the presence of a sufficient number of seedlings, saplings and young trees in a given population. The number of seedlings of any species can be considered as the regeneration potential of that species. Studies on population density are important to understand the regeneration status, management history and ecology of specific forest. Hence, analyses of the status of naturally regenerated woody species can provide basic information in sustainable management, utilization, and conservation.

Ethiopia is endowed with various types of natural forest ecosystem. The dry Afromontane forests are either mixed *Juniperus* - *Podocarpus* forests or predominantly *Podocarpus* forests, both with an element of broad-leaved species. They occur in both north western and south eastern highlands, especially on the plateau of Oromia, Tigray, Amhara and Southern Nations, Nationalities and People's Regional (SNNPR) states at altitudes from 1500 - 2700m. Over two - thirds of these types of forests are heavily disturbed forest and needs appropriate forest management. However, information on species diversity, composition, regeneration and carbon stock are scanty in the study area. On the contrary, sustainable forest management is possible if adequate information is available in these regards. Therefore, the existing ecological knowledge related to *Arba Gugu* forest is outdated and insufficient to make conclusions on the status of the forest. The objective of this study was, therefore, to generate information on the woody species composition, diversity, regeneration status of woody species as well as to quantify the carbon stock (aboveground and belowground) in the *Arba Gugu* forest. This information will help to complement the ongoing efforts to develop decision support tools that guide the sustainable management and utilization of dry Afromontane forests in Ethiopia.

Major findings

Woody species composition and diversity

- A total of 42 woody species (27 trees and 15 shrubs) belonging to 27 families were recorded. The richest family was *Araliaceae*, followed by *Euphorbaceae*, *Rosaceae* and *Asteraceae*. The remaining families were represented by one tree species only.
- The total density of mature trees/shrubs was 130 individuals ha^{-1}. *Podocarpus falcatus* (62 individual's ha^{-1}), *Juniperus procera* (17 individual's ha^{-1}), *Schefflera volkensii* (9 individual's ha^{-1}), *Croton macrostachys* (6 individual's ha^{-1}) and *Maesa lanceolate* (4 individuals ha^{-1}) exhibited the highest density, all together accounted about 76 % of the total density of mature trees/shrubs.
- The total basal area of mature trees/shrubs was 32.9 m^2 ha^{-1}. *Podocarpus falcatus* was the dominant species comprising 43% of the total basal area followed by *Juniperus procera* (34 %), *Schefflera volkensii* (9 %), *Schefflera abysinica* (4 %) and *Croton macrostachys* (2 %).
- The Shannon - Weiner diversity and evenness index value of tree/shrub species was 2.12 and 0.70, respectively.

Regeneration status of tree and shrub species

- The tree/shrub species showed a significant variation in regeneration status. Among the tree and/or shrub species, 4 species (*Calpurnia aurea*, *Canthium oligocarpum*, *Doviyalis verrucosa*, and *Lepidotrichilia volkensii*) exhibited good regeneration with both the ratio of seedling to sapling and sapling to mature trees was greater than or equal to 1. The 13 species (*Bersama abysinica*, *Brucea antidysenterica*, *Carissa spinarum*, *Diqal abuna*, *Ekbergia capensis*, Embus, *Olinia rochetiana*, *Osyris quadripartite*, *Pittosporum viridiflorum*, *Tecleanobilis*, *Vernonia myriantha*, Akoma and *Zanhago lungensis*) exhibited poor regeneration. On the contrary, 12 tree species (*Clutia abysinica*, *Euphorbia amplophylla*, *Ficus sur*, *Hagenea abyssinica*, Mukedimu, *Nuxia congesta*, *Polycias fulva*, *Rhus glutinosa*, *Salix mucronata*, *Schefflera abysinica*, *Schefflera volkensii*, and *Vernonia amygdalina*) had no seedlings and saplings and only represented by mature trees.

- Seedlings were represented by 32 species belonging to 30 genera and 26 families. The total seedling density was 964 individuals ha^{-1}. The sapling stage was composed of 33 species representing 30 genera and 22 families covering 53.2% of the tree/shrub species. The total sapling density was 149 individuals ha^{-1}.

Aboveground and belowground carbon stock

The aboveground and belowground biomass of trees/shrubs ranged from 19.9 to 1972.7 t ha^{-1}. There is high variability among the study plots.The total carbon stock ranged from10 to 986.4 t C ha^{-1}. The mean aboveground carbon stock was 198.7 t C ha^{-1}, while the corresponding mean belowground carbon stock was 39.7 t C ha^{-1}. Among the tree species, *Podocarpus falcatus*, *Juniperus procera*, *Schefflera volkensii*, *Schefflera abysinica*, and *Pouteria adolf-friederichi* contributed 93.7 % of the total aboveground biomass and carbon stock.

Key policy Recommendations

- Intervention is crucial to enhance the natural regeneration of poorly represented species through enrichment planting techniques,
- The *Arba Gugu* forest offers excellent opportunities for active management of existing carbon stocks and enhancing its stocks through $REDD^+$ is important. Based on this baseline study, we recommend the area as a possible pilot for $REDD^+$ of the country.

Potential users of the information

- ✓ Environment and forestry sectors at national, regional and district level,
- ✓ National and international higher learning and research institutions,
- ✓ Local communities of the districts bordering the studied forests,
- ✓ NGOs, Government and Private forest enterprises

Reliability of the Information:

The information is based on an original work by EEFRI researchers, and it has been extracted from original research report by Mindaye T., NesibuY. and Mehari A. “Woody Species Diversity, Regeneration Status and Carbon Stock of Dry Afromontane Forest in Central Highlands of Ethiopia” (unpublished report).