የኢትዮጵያ የአካባቢና ደን ምርምር ኢንስቲትዩት
Ethiopian Environment and Forest Research Institute

PACKAGE OF PRACTICES FROM RESEARCH OUTPUTS

Volume III
2020

Transferred for use by:
Environment, Forest and Climate change Commission
Ministry of Agriculture
Ministry of Water, Irrigation and Electricity
National Meteorological Agency
Regional line Bureaus
Tree farmers and Wood based industries
Forest Product Processing Enterprises

Ethiopian Environment and Forest Research Institute
P.O.Box:24536,Code1000
Phone:+251 11 646 48 98/11 646 48 85
Fax:+251 11 646 48 82
Addis Ababa

Message from the Deputy Director General, EEFRI

Economic development is very much dependant on how the natural resources are sustainably conserved and utilized in a given country. Manufacturing industries nearby rural settings stimulate urbanization and also take off much of the load and burden from overpopulated rural lands. Mountainous areas usually have aquifers for year round flow of white water, if well vegetated with perennial woody vegetation and of course covered with grasses for rain water infiltration during heavy rains.

Cognizant of this fact, Ethiopia launched green legacy plantation campaign through its premier since 2019 with over 4 billion seedlings planted in urban and rural areas. This campaign in the current year also has plans to take over 6 billion tree seedlings with the motto "Let's cover Ethiopia with green vegetation". Emphasis is given for agroforestry fruit bearing trees to improve rural livelihoods and produce surplus for the market and processing agro-industries. The Environment, Forest and Climate Change Commission (EFCCC) of the Federal Government of Ethiopia, assessing the resulting progress in forest cover and the curtailed deforestation of the natural forest, has reports, however subject to verification that the forest cover has climbed up to 17.5 per cent with deforestation per annum slowing down to 32,000ha per year from 92,000 ha per year it has been over previous years.

Despite all these efforts, challenges are ahead to cover the over arching bare mountains and degraded and denuded sites out-of-the-way for transporting seedlings and planting campaigns. Sources of the Abbay River and many more catchments of the tributaries of this major river remain deforested in quest for cultivable land to feed the growing population. Poverty in these sensitive watersheds needs to be addressed with alternative job and income opportunities in our rural growth strategies. In support of the government development and green legacy initiative, Ethiopian Environment and Forest Research Institute (EEFRI) has initiated greening of the Abbay gorge in between Gohatsion and Dejen with lowland bamboo. The species is well adapted to the area and found in patches indicating its native presence. Covering the gorge in both sides would enable to stabilize the landscape, reduce rain water runoff and prevent silt transport to the river. The initiative is in collaboration with EFCCC, Salale and Debre Markos Universities. Bamboo due to its nature, requires yearly harvesting of the fourth year culms to provide space for new culm re-growth, would provide continues

supply of bamboo culm for charcoaling, manufacturing goods and leaves for feeding livestock all the year.

Ethiopian Environment and Forest Research Institute in its third volume of package of practices, has presented technologies and information from selected research outputs to support the all out activities of the regional and federal governments in the environment management, forest development and climate change adaptation and mitigation. The packages are also intended for users in the private tree farming, small scale forest based industries and agroforestry development.

I congratulate EEFRI researchers who prepared these packages from their partly and fully completed research outputs under very constrained research infrastructure and logistic supply.

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

Reviewers listed are acknowledged for their inputs put forward to make the contents easily understandable and readable to users.

Agena Anjulo (PhD, Agroforestry), Associate Professor/Senior Researcher
Deputy Director General
Ethiopian Environment and Forest Research Institute
Addis Ababa, Ethiopia
May, 2021

Reviewed and edited by:

Zenebe Mekonnen

Daniel Gebeyehu

Miftah Fekadu

Abayneh Derero

Alemayehu Esayas

Biruk Gobena

Getachew Desalegn

Agena Angulo

Teshome Tesema

Tatek Dejene

Contents

List of Figures

List of Tables

Part I: Packages of Technologies

Post-harvest handling techniques of *Ziziphus mauritiana* wild edible fruits

Responsible Researchers: Abrham Dilnesa, Fikiremariam Haile,Tewabech Alemu, Mahelete Tsegaye, Tegene Tantu, Yihun Bekalu

Brief description of the technology

Wild edible vegetables contribute to the major portion of the human diet that provides the essential bio-chemicals like carbohydrate, protein and lipids. These wild edibles not only contribute to the essential biochemical and energy requirement of human beings but also act as supplementary sources of vitamins and minerals that are indispensable for maintaining the proper physiological homeostasis of the body. The present study focused on identifying suitable packages, both from a technical and economic point of view for handling and transportation of matured and immature fresh *Ziziphus mauritiana* fruits (Kurkura) collected from Kobo Woreda in Amhara region of Ethiopia. Sorting and grading of fruits were carried out after the harvesters of the fruits wear cotton gloves and trimmed their fingernails to reduce mechanical damage while harvesting. The homogenous samples of uniform, similar size and equal weight of fully ripe and good appearance fresh fruits were placed into the nestable plastic crate, wooden box, and cooled box, and then immediately transported to Forest Products Innovation and Research Centre laboratory, Addis Ababa. Suitability of each package types to transport *Z. mauritiana* fruits from farm area to Addis Ababa was tested. The fruits were packed in a cooled box had lesser bruising damage, weight loss and had better keeping quality in terms of physical injuries, weight loss, and decay as compared to those packed in wooden boxes and nestable plastic crates. However, nestable plastic crates are suitable for transportation due to their lesser cost and availability.

Suitability

- These postharvest handling technologies (cooled box and plastic crate) have tremendous effects on the transportation of the fruits; however, plastic crate is preferable in terms of

cost and availability. These technologies help to minimize physical injuries, weight loose, and decay of *Ziziphus* fruits.

Requirements

- To implement these postharvest handling techniques the pre-requisites are
    a) Raw material: *Z. mauritiana* fruit
    b) Safety materials: gloves, mask and safety shoes
    c) Materials for harvesting: rope, ladder, cutter and basket for fruit collection
    d) Material for transportation: packaging materials (High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE), cooled box and nestable plastic crates
    e) Working manual and training of producers

Practice

- To implement these post-harvest handling techniques, the fruit harvesters need to wear cotton gloves and trim their fingernails in advance to reduce mechanical damage while harvesting.
- Sorting and grading of fruits carried out.
- Matured (fully ripe) and undamaged (have good appearance) fresh fruits of *Z. mauritiana* harvested.
- The collected fresh samples of *Z. mauritiana* fruits packed by cooled box and nestable plastic crates, then the packed fruits transported and put into a refrigerator until processing and utilization.
- Finally, effects of post-harvest handling techniques on the nutritional, anti-nutritional, and mineral composition of *Z. mauritiana* determined.

Management

- Appropriate management required for harvesting and transporting.
- The fruits should be kept in the refrigerator until use.

Comparative advantage/yield

- Fruits packed in a cooled box had lesser bruising damage, weight loss, and had better keeping quality in terms of physical injuries, weight loss, and decay as compared to those packed in nestable plastic and wooden boxes crates.
- Cooled storage transportation is the one widely practiced method for bulk handling of the perishable goods between production, processing and marketing.
- Cold storage transportation is one of the methods of preserving perishable commodities in fresh and wholesome state for a longer period by controlling temperature and humidity within the storage system; however, plastic crate is preferable in-terms of cost and availability.

Cost-effectiveness

- No financial analysis done.

Risk and uncertainty

- There are several challenges and barriers (e.g. drought and insect damage) that create risk and uncertainty for the advancement of the fruit production sector.

Purpose

- Post-harvest handling techniques create an opportunity for employment, income generation for farmers; help to decrease food scarcity in urban and rural areas, contribute to the conservation of forest resources, and to protect environmental pollution.

End-user

- Beneficiaries of this technology will be farmers, tree growers, small and medium scale enterprises, investors, food and beverage factories (industries), hotels and restaurants.

Performance of used motor oil as control measure against subterranean termites and fungal damage on lumber species

Responsible Researchers: Getachew Desalegn, Gemechu Kaba, Tsegaye Wubshet, Saifu Amanuel, Tesfanesh Ababu

Brief description of the technology

Damages caused by bio-deteriorating agents (Termites, fungus, beetles and marine borers) on forest products being utilized by construction and wood industries are serious problems that led to destruction of valuable indigenous lumber species such as *Juniperus procera*, *Hagenia abyssinica*, *Cordia africana*, *Podocarpus falcatus* and *Pouteria adolfi-friederici*. Bio deteriorating damage is among the overlooked major causes of the destruction of forest products in the country. Subterranean termites (Macro-and-microtermitinae) have been considered as the major causes for the damage of wooden houses and other constructions in Ethiopia, which led to partial or complete rebuilding in 3-5 years' time. However, destruction of wood and bamboo-culms based constructions with soil and moisture contact applications have been occurred, even within 1-2 years short time, which has been caused by subterranean termites and/or fungal mutual attack.

Controlling measures on forest products against termite and fungal damage is to increase service life and maintain their aesthetic values. Research was conducted during the years 2012-2014 on natural durability of *Eucalyptus pilularis*, *Eucalyptus viminalis* and *Trichilia dregeana* lumber species and effectiveness of control measures against subterranean termites and fungal damage. A total of 165 lumber samples (stakes) having dimensions of 2 x 5 x 50 cm were treated using used motor oil with non-pressure treatment application methods namely hot and cold dipping and brushing. Stakes of *T. dregeana* lumber were treated with its own sawdust extract using hot and cold dipping method. Treated stakes were taken and installed at Bako, Adami Tulu and Meisso grave-yards research stations. The subterranean termites at Bako station were Microterms and *Pseudacanthoterms militarious* while that of Adami Tulu, having the same agroecology as that of Zeway was dominated by subterranean and mound building termite species, *Marcoterms bellicosus*. The subterranean termites at Meissio station were Microterms. Damage of subterranean termites and fungi varies with lumber species, control measures, graveyard stations

and length of exposure years to biodegrading agents. Results indicated that mean subterranean termites and fungal damage varies with lumber species, control measure treatments, graveyard stations and length of exposure years to biodegrading agents. Mean termites and fungal damage on stakes of *E. pilulalris* treated with used motor oil using hot and cold dipping method was 48% while that of fungi was 20.5% at five and half years. *E viminalis* stakes treated with used motor oil were damaged 55% by termites and 80% by fungi. Brushing with used motor oil and hot and cold dipping with sawdust extract from the *T. dregeana* was not better than the untreated control. *E viminalis* control stakes were more damaged (62.5%) by termites than *E. pilularis* (55%) and *T. dregeana* (60%) stakes. *E. viminalis* stakes were more damaged by fungi while *E. pilularis* and *T. dregeana* damaged by termites. In general, the non-pressure method using used motor oil treatments increase service life of lumber stakes up to four times compared to the untreated lumber stakes.

Suitability

- The controlling measures and technologies applied against subterranean termites and fungal damage are simple, less expensive compared to commercial preservatives such as Tanalith. It is also affordable and recommended to small scale construction sectors and enterprises.
- The technology of hot and cold dipping of lumber stakes with used motor oil more effective in controlling termite and fungal damage compared to brushing treatment and untreated lumber.
- The lumber species **(***E. pilularis, E. viminalis* and *T. dregeana***)** have different potential end-use applications for different industry and construction sectors.

Requirements

- Lumber, sawmill, radial arm saw, jointer, planer and circular saw, electric power, sensitive balances, meter, digital calliper, oven drying machine, used motor oil, fire wood, match box (lighter).
- Non-pressure treatment facilities, hot and cold dipping tank and brushing tools
- Skilled professionals.
- Written manual as a guideline to apply the treatments.

Practice

Harvesting, log sawing and lumber stakes preparation for laboratory and field tests

- The trees to be harvested should be mature with mean diameter at breast height (DBH) of 30 cm and minimum top diameter of 20 cm. Felled trees should be bucked into appropriate log lengths (3-5 m preferable) but it depends on the transporting truck size, final purpose of the products and dimension of treatment plant.
- The matured sample trees of *E. pilularis, E. viminalis* and *T. dregeana* should be selected. Logs with merchantable height with good morphological quality, straight and cylindrical stem, relatively free from visible defects should be selected from different sites.
- Harvested logs while green (≤ 30 % moisture content) without access of direct sunlight have to be transported to processing industry. This is to prevent excessive end splits and checks**.**
- The logs have to be sawn through and through (flat sawing method) 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.
- Stakes for grave-yard tests or for construction applications from representative boards and free from visible defects should be prepared. Lumber at least 15 per species having dimensions of 2 x 5 x 50 cm for treatments and graveyards stations have to be prepared.

Non-pressure treatments of lumber stakes with control measures against bio-degraders

Hot and cold dipping of lumber stakes

- For the treatment of lumber stakes with oil-borne type preventive measures namely used motor oil with a mixture of Shell Rimula diesel oil 40 and Helix Ultra 40 engine oil with equal ratio (1:1) can be used.
- The stakes can be treated using the hot-and-cold dipping open tank method or thermal process.
- The stakes have to be submerged in a dipping tank containing 25 litre of cold used motor oil.
- The fire has to be burned under the dipping tank and the oil have to be heated gradually to about 90°C to reduce viscosity of the oil and maintained for four hours.

- The treated stakes have to be withdrawn from the dipping tank after 24 hours cooling, as the stakes cool down, absorb the preservative.
- Finally, the stakes can be cleaned from surplus oil using cloth rags and air seasoned for a week before field (here after grave-yard stations) installation.

Brushing of lumber stakes with used motor oil

- Brushing is one of the non-pressure treatment methods and applied using a standard size brush.
- Used motor oil can be applied to half size of the stake having a dimension of 2 x 5 x 50 cm.
- The treated stakes have to be left in the air for a week to dry.

Density of Lumber species

- Density of *E. pilulalris* (780 kg/m^3) (650-800 kg/m^3) and that of *E. viminalis* (810 kg/m^3) at 12% moisture content classified as very heavy (650-800 kg/m^3).
- Density of *T. dregeana* (530 kg/m^3) at the same 12% moisture content classified as light density (300-450 kg/m^3) lumber species.

Management

- To control bio-deteriorating agents' damage applying of effective control measures and technologies needed
- Used motor oil treatments have to be carried out properly and very carefully
- Lumber of species have to be dried ≤ 20% moisture content before treatments
- Construction sectors and marketing enterprises need to follow the research results and methodologies of treatments as guideline

Comparative advantage/yield

- Used motor oil treatments can increase the service life of the lumber in construction up to four times compared to the untreated lumber.

Cost effectiveness

- Cost effectiveness analysis not studied. However, from experience, the hot and cold dipping technology with used motor oil is found to be simple, less expensive, and affordable and recommended to small scale forest products processing industries, construction sectors and marketing enterprises.

Risk and uncertainty

- During application of hot and cold dipping technology few risks of chemicals and fire during treating will be occurred.
- Lumber handling with ground and moisture contact may lead to bio-deterioration damage.

End users

- Beneficiaries include urban communities, small-scale construction sectors, investors, civil engineers, vocational training colleges, higher learning institutions, development partners/actors and other stakeholders.

Seasoning characteristics of *Acacia melanoxylon* lumber

Responsible Researcher: Mahadi Mussa

Brief description of the technology

Seasoning is one of the major factors that determine the quality, utilization and service life of wood as round and sawn lumber. Lumber drying (hereafter, seasoning) aims to dry lumber uniformly with minimum defects in the shortest possible time to a moisture level similar to the surrounding air (equilibrium moisture content). It is done using air, and artificial methods such as, air seasoning, solar, kiln, humid, and other seasoning techniques. For this study, air and kiln seasoning technologies were used. In air seasoning lumber has to be dried by exposing to natural atmospheric conditions under shed. Drying times and degradation can be minimized by correct stacking of freshly sawn lumber. Kiln seasoning done in closed chamber in which air temperature, relative humidity and airflow can be controlled and drying lumber to specified moisture content, in such a way that minimization of drying time and seasoning defects could be achieved. Therefore, research has been undertaken on seasoning characteristics and density along with the tree height of *Acacia melanoxylon*, with the objective of generating appropriate seasoning technologies and information.

A. melanoxylon was one of the species introduced to Ethiopia to be used as an alternative source of raw material to meet the ever-increasing demand for different forest products. *A. melanoxylon* belongs to the family Leguminosae and the subfamily Mimosoideae. It is a fast-growing species with a tall and straight trunk/bole, commonly called Australian Blackwood and locally known as Omedla in Ethiopia. *A. melanoxylon* is underutilized tree species due to lack of information/technology on the wood properties of the species.

A total of ten trees of 30 years old *A. melanoxylon* were randomly selected and harvested from the Chencha woreda community forest. The selected sample trees are straight trunks, normal branching and had no disease or pest symptoms. The height and diameter at breast height (DBH) of the trees were ranging from 17 to 20 m and 21 to 26 cm, respectively. Each sample tree was

cross-cut into three 2.5 m logs which represent the bottom, middle and top of the tree height. Sample boards were prepared for determination of seasoning characteristics and density along with the tree height. The basic density and tangential, radial and volumetric shrinkages were affected by tree height, and the highest values were observed at the base and lowest at the top of tree height. The mean values of the basic density were 0.57 g/cm^3. The mean values of the tangential, radial and volumetric shrinkage from green to 12% moisture content (MC) were 3.8%, 1.97%, and 6.19%, respectively and longitudinal shrinkage was negligible. The mean initial and final MC for air and kiln seasoning stacks were 67.36% and 14% and 66.19% and 12.03%, respectively. Air seasoning time to reach 14% MC took 42 days, while kiln seasoning to reach 12.03% MC took 7 days. The species showed low shrinkage and less seasoning defects both on air and kiln seasoned boards. The lumber of *A. melanoxylon* can be classified as very rapid seasoning rate for both air and kiln seasoning technology.

Suitability

- The air seasoning technology requires foundation and shed. It is comparatively affordable and recommended to small scale forest products processing industries, construction sectors and enterprises.
- The kiln seasoning technology is expensive because it needs drying machine and electric power. This technology is recommended to medium and large scale forest products processing industries, construction sectors and enterprises.
- *A. melanoxylon* lumber can be used for cabinet and furniture making, highly suitable for veneers, turnery, panelling, carving, flooring, boat building, gunstocks, musical instruments, plywood, tennis racquets, knobs and pulp and paper.

Requirements

- Sawmill chainsaw, wood working machines, dry kiln machine, air-seasoning, shed/yard electric power, drying/micro-oven machine, diameter tape and caliper, sensitive balance, moister meter.
- Skilled kiln operator.
- Relative humidity and wood equilibrium moisture content charts.

Practice

Harvesting of trees

- Trees to be harvested should be matured with straight cylindrical bole, normal branch and no disease or pest symptoms.
- Trees harvested at stump height of 30 to 40 cm above the ground.
- The ends of the logs sealed/painted with dyes as soon as the logs cut to avoid end split.
- Felled trees cross-cut into three 2.5-3.5 m logs which represents bottom, middle and top of the tree height.

Log Sawing and Sample preparation

- The sample logs are sawn tangentially (through and through) using circular sawmill into uniform length of 2.5 m and thickness of 3 cm.
- Fifteen representative defect free sawn boards which represent bottom, middle and top portions are selected for both air and kiln seasoning.
- From each selected boards, 10-12 representative sample boards with a dimension of 100 cm in length, 3 cm thickness and width equal to log diameter are prepared (figures 1 and 2).

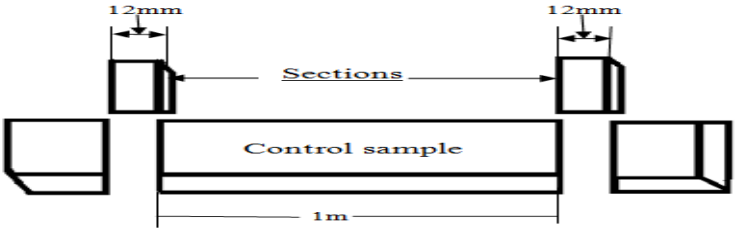

Figure 1: Sample preparation for determination of seasoning characteristics

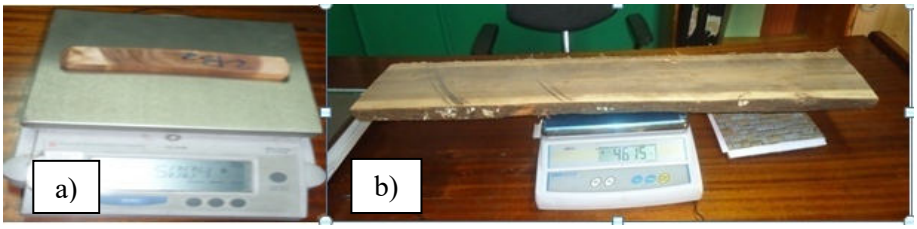

Figure 2: Initial moisture content sample weighing (a) and control sample board weighing (b)

Sample preparation for shrinkages and basic density

Specimens free from visible defects having cross-section (20 x 20 mm) and length 30 mm at green state should prepared from bottom, middle and top portions of the tree species.

Stacking sawn boards for air and kiln seasoning

- Immediately after sawing, boards are transported to the air seasoning yard and compartment kiln-seasoning chamber areas (Figure 3).
- Lumber stacking procedures are similar for both air and kiln seasoning technologies.
- Boards are stacked horizontally in vertical alignments at 3 cm spacing between successive boards to facilitate circulation of air and separated by well-seasoned, squared and standard stickers.
- Two types of stickers are used: long stickers with a dimension (width, thickness and length) of 2.5 x 2.5 x 180 cm, respectively used to separate boards, whereas the short stickers with dimension of 2.5 x 2.5 x 20 cm are put on the long stickers to easily access the control sample boards for the follow up of the drying process.
- The stickers have to place at uniform interval and are aligned one on top of the other in each stack.
- Loading should be applied on the top of stacking (Figures 3a & 3b) to offset/minimize warping. Based on the availability of the materials and nature of each test, in air and kiln seasoning, concrete slabs/heavy stones weighing about 50 kg/m^2 loaded. In all cases, the loads on the stacks using the stickers are used at a spacing of 0.5 m.
- The ends of boards are should be stacked equal in both directions.
- The control sample boards are distributed in each stack to represent the lumber in the sack and the seasoning process at different positions (top- bottom, left right and vice-versa).
- Weighing and put back the control sample boards into the stack are done repeatedly until the moisture content reached the desired amount.
- The control sample boards are used to follow-up the progress of seasoning (moisture content reduction rate) and final moisture content.

Figure 3: Stacked lumber of *A. melanoxylon* for air seasoning (a) and for kiln seasoning (b)

Air Seasoning

- Boards for air seasoning were stacked in air seasoning yard on firm foundations having 45 cm clearance above the ground and a dimension of 1.8 x 0.45 x 4 m.
- Boards for air seasoning stacked under shed without direct interference of moisture, rainfall and sunshine.
- Green weights of all air seasoning samples boards were measured immediately after plaining and crosscutting using sensitive balance.
- Weighing of initial MC samples at 4 hours interval should be carried out until the difference between two successive weights of each specimen is between 0.1-0.2 g and the final weight is taken as the oven-dry weight.
- The control sample boards are weighed and re-placed into the stacks and re-weighed at one week interval.
- The process is continued until the average final MC of the stack reached about 15-12%, which is the equilibrium moisture content (EMC) for in and outdoor purposes.

Kiln Seasoning

- Board for kiln seasoning are stacked outside of the kiln on the transfer carriage having a dimension of 2.7 x 1.6 x 0.30 m and placed in the kiln-seasoning chamber.
- The conventional type of artificial kiln seasoning machine is used in this study. The machine has about 2.5 m^3 wood loading capacity room or chamber.
- The air circulation, temperature and humidity which can be adjusted based on the initial moisture content of the species using psychrometers (dry bulb and wet bulb thermometers).

- The kiln has been equipped with fans to force air circulation and air outlet at a temperature range of 40 -70ºC.
- Kiln schedule Ethiopia number three (Eth. no. 3) a hardwood type schedules is used (Table 1).
- Kiln seasoning test sample boards are weighed, moisture content calculated, psycrometrs regulated, steam spray done, and the direction of the fan changed at 8 hours interval (three times in 24 hours) to allow uniform air circulation, control the seasoning process and quality of the seasoned wood.
- The process continues until the required final 12% MC level is reached.
- Kiln seasoning boards can be air seasoned first (up to fiber saturation point, 30% MC) before stacking and starting the regular kiln seasoning processes. This saves on drying costs through kiln seasoning.

Table 1: Kiln Schedule for three hardwoods of Ethiopia

Initial MC (%)	Temperature (°C)		Relative humidity (%)
	Dry-bulb	Wet-bulb	
100-70	38	35	80
70-60	42	37	70
60-50	44	39	65
50-40	50	40	60
40-30	53	42	55
30-20	55	43	50
20-10	60	45	40

Moisture content determination

- The oven-dry weight method of MC determination has to be applied.
- Initial and final moisture content has to be determined for both air and kiln seasoning stacks.
- For this work, the average moisture content of the two sections (Heartwood and sap wood) is determined using the specimens prepared

- The weight of each sample at the time of cutting is used to estimate the analytically determined oven-dry weight of the stack samples at 12% MC. The moisture content was calculated as follows:

Moisture content (%) = (IW-OD/OD) x100 = (IW/OD-1) X100 = (W/OD) x100

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 (from green to about 12% MC) for the lumber species are determined from the initial MC of the sampled species.

Shrinkage determination

- Twelve green samples of lumber of size 2 x 2 x 3 cm, width, thickness and length, respectively, were taken. The prepared specimen blocks are soaked in distilled water for 72 hour to ensure that their moisture content is above the fiber saturation point (FSP).
- In this water saturated condition, the radial, tangential, longitudinal and volumetric dimensions are marked and measured to the nearest 0.01 mm using a digital caliper.
- The blocks are then oven dried at 105°C for 24 hours and the oven-dried blocks are then weighed and the dimensions are measured again along the points marked earlier using the same dial caliper.
- Green to 12% MC shrinkage in tangential, radial, longitudinal and volumetric shrinkages are determined, expressed as a percentage of the saturated dimension to its 12% MC dimension.

Shrinkage (%) = Decrease in dimension (mm)/green dimension (mm) x100

Basic density determination

- The same specimens' of shrinkage used for this basic density determination.

- Then the dimensions in all three principal directions (tangential, radial and longitudinal) were measured with a digital caliper to the nearest 0.01 mm and their weights were taken with nearest to 0.01g for green weight.
- The green volume is calculated based on these green dimensions measurements.
- Finally, the specimens are oven-dried at 105^0C and relative humidity 65% for 24 hour and again the dimensions and weights measurement are taken.
- This is continued until constant weights are obtained.
- Basic density is determined on a green volume, oven dry weight basis. The formula used to calculate the basic density is:

Basic density = Sample oven dry weight (g)/Sample green volume (mm^3)

Seasoning defects determination

- Sample boards from each air and kiln seasoned randomly selected and defects are separately measured
- Warp which include (cup, crook, bow and twist), and as well as surface splits, end-splits, surface checks and end-checks are measured and determined on a flat surface using different measurement tools (caliper, ruler ,measuring tape, spacer etc.).
- An identification mark at either end/sides of the measured boards shall be placed.

Management

- Trees and logs should be properly harvested, sawn and the log ends well sealed/painted.
- Seasoning boards properly stacked by using dry standardized sticker and top loading
- The stickers and top loading should be placed in uniform intervals
- Lumbers should be seasoned to less than fiber saturation point (< 20% moisture content)
- Seasoned lumber of the study species have to be properly stacked one over the other without stickers and handled without direct access of moisture and bio-deteriorating agents.

Comparative advantage/yield

- Seasoning increases strength, reduces susceptibility to fungal decay, increases the effectiveness of preservative treatments, and seasoned lumber effectively fastens with glues, paint, stain, polish, and planines better than unseasoned/green lumber.
- Seasoned lumbers are largely eliminating warping, splitting, checking, and other defects.
- Kiln seasoning technology is better than air seasoning in terms of seasoning rate, lumber quality, low shrinkage and seasoning defects. This is because of the controlled temperature, ventilation and air circulation.

Cost effectiveness

A cost-benefit analysis is not done.

Risk and uncertainty

- During and after air seasoning bio-deteriorating agents (borer/beetle, wood decay fungi and termite) may attack the lumbers.
- When technologies are applied by processing industries and kiln operators, risk of fire during kiln seasoning may occur. Thus, care should be taken.
- Using air seasoning technology to dry until the desired moisture content is difficult because it depends on the surrounding environment such as: temperature, relative humidity, rain, wind and sunlight.

End users

The end users of this technology are wood industries, forest enterprises, construction sectors, investors, government and non-governmental organizations, research and academic institutions, scientific communities, forest industries, furniture manufacturing industries, urban communities and other stakeholders.

Part II: Packages of Information

Effects of *Acacia seyal* on soil properties, growth and yield of sorghum

Responsible Researchers: Alayu Haile, Kidane Giday and Yemane G/Egziabher

Brief description of the information

Acacia seyal is one of the multipurpose parkland agroforestry tree species found in most eastern and southern African countries. It is a common on-farm tree in the rift valley of Ethiopia, but information is limited on its effect on soil property and sorghum growth and yield. The study was conducted to evaluate effects of *A. seyal* on selected soil properties, sorghum growth and yield at Guba-Lafto district of northern Ethiopia. Six isolated and closely comparable *A. seyal* trees growing on sorghum farms were purposely selected and plots were marked under the canopy of trees with three radial distance (0-2 m, 2-4 m and 4-6 m) and one outside of the tree canopy (10 meters away from a tree trunk). Soil samples were taken at two soil depths of 0-20 cm and 20-40 cm along each distance zone. Four quadrates with 1m x 1m at each distance zone in four directions were laid for sorghum growth and yield attribute valuation. Results showed only total nitrogen (TN) was significantly higher at subsoil layer under the canopy compared to an open area but other selected soil parameters were found not affected by the tree species. Sorghum biomass yield and grain yield were significantly lower under the canopy of the tree than in the open area. Large-scale biophysical and socioeconomic survey is recommended to evaluate the overall effects of farmland trees with competitive effects to inform policy and practice.

Introduction

Maintenance and improving existing practices by incorporating multipurpose tree species preferably nitrogen-fixing legume tree species on farms are recognized as critical interventions to increase agricultural productivity sustainably. *A. seyal* has a typical drought avoidance strategy and is adaptable to water stress conditions. The farming communities allow *A. seyal* to grow in

their farmlands and sorghum is the common companion crop integrated with it. However, its integrating advantage to soil fertility improvement and sorghum productivity enhancement was not studied before. Therefore, this study was designed to investigate the effect of *A. seyal* on selected soil properties and sorghum growth and yield attributes on farmland during the main rainy season in Guba-Lafto district, North Wollo Zone.

Brief methodology

Sorghum (var *Jamyo*) farmlands with similar crop history and management were systematically selected from *A. seyal* dominated parkland farming system at selected site. Then, six comparatively similar on farm *A. seyal* trees were selected via systematic random sampling technique. Soil sampling and sorghum growth and yield measurements were taken under three concentric radial distances (subplot) of the selected *A. seyal* and one from open area. Soil samples were taken at two soil depths of 0-20 cm and 20-40 cm along each distance zone. A total of 48 composite soil samples were taken and analysed for selected soil properties following appropriate lab procedures. Growth and yield parameters of sorghum were collected and estimated from each subplot of 1 m x 1 m basis.

Major findings

Available nitrogen under subsoil condition found significantly higher near tree bole of the species compare to open area. Other soil properties namely electrical conductivity (EC), soil organic carbon (SOC), soil pH, cation exchange capacity (CEC), available phosphorus (P), moisture content (MC), bulk density (BD) and texture didn't significantly affected by the species. Even though, sorghum growth parameters was not significantly influenced; biomass and grain yield found negatively affected by the presence of the species. So, the result indicated less importance of the species in integrating into the farm system.

Recommendations

- Because *A seyal* has a competitive effect on crop production, it is to grow it as a plantation for wood production.
- The environmental and socioeconomic effects of competitive trees such as *A. seyal* on agricultural systems should be investigated at a larger scale considering different contexts to make conclusive remarks that shape and influence policy and practice.

Potential users of the information

Potential users will be agricultural experts, researchers and farmers.

Reliability of information

The information is extracted from original research report which was done following the standard research methods where representative sampling size and design were taken.

The contribution of *Acacia decurrens* for food security and land reclamation

Responsible Researchers: Demelash Alem, Sintayehu Esehtu and Yeshifana Alemneh

Brief description of the information

A study was conducted in Fagita Lekoma *woreda* (district), Awi Zone of the Amahra National Regional State to characterize *Acacia .decurrens* plantation practice. Field observation, focused group discussion (FGD), and questionnaire was used to collect relevant information. A total of 150 farmers were interviewed. Most of the farmers allocated over 80% of their land to *A. decurrens* plantation. The average annual income per household from *A. decurrens* was about 30,000 ETB (about 1000 USD), and the practice created job opportunities for many people. It was perceived that the plant had also improved the soil tremendously and increased crop production and land productivity. However, there were some problems from production up to marketing. The seedlings produced were not of good quality and not planted with proper spacing and most of the seedlings were planted without removing plastic bags. The charcoal production was also traditional and emitted excessive smoke to the surrounding. Disease and pest were also observed. Producers were not reaping the full benefits that can accrue from the product because of so many brokers along the value chain. The species was also used only for charcoal production despite its potential to provide other uses and services. Therefore, improving the practice ranging from seedling production to marketing is necessary to tap the full production potential and environmental services of the species and scaling up the practice to other areas of similar agroecology.

Introduction

In Amhara National Regional State (ANRS), smallholder tree plantation activities have become an important emerging livelihood approach. One of these best practices is *Acacia decurrens* plantation development in Fagita Lekoma *woreda* (district), Awi Zone of the ANRS. A study was conducted with the main objective of characterizing the farmers' practice and providing

information that would help to optimize and scale up the practice to other potential areas of the country. The specific objectives were to 1) characterize the economical, ecological and social aspects of the practice; and 2) identify the major strengths and weakness of the practice. The research output is believed to provide relevant information for the wider application of the practice in other areas of the country with similar agroeclogical settings and contribute for food security, land rehabilitation and narrowing the fuel wood (energy) demand and supply gap.

Brief methodology

Fagita Lakoma woreda was selected because of the wide practice of *A. decurrens* plantations in the area. Then three *kebeles* (smallest administrative units in Ethiopia), namely Gulanaazemach, Gafera, and Endewuha, were selected randomly from the 27 kebeles available in the woreda. Proportional random sampling method was used to determine the number of respondents in each selected *kebele*. The total sample size was determined by taking 5% of the total households of the three selected *kebeles* resulting in a total of 150 respondents. Data were collected through questionnaire and focus groups discussion. The parameters analyzed were planting size, number of seedlings planted, proportion and size of land allocated to *A. decurrens* plantation. The relation between these parameters and household socio-economic characteristics such as age, educational status, landholding size and others was also analyzed.

Major findings

- Planting and management of *A. decurrens* plantation in the district was started in 1996 and currently planted at a wider scale in all of the 27 *kebeles* found in the *woreda*
- Now, the plantation is expanding and fully established and managed by the farmers without any external support. The practice is expanding to neighbouring *woredas* such as Sekela woreda of West Gojjam
- About 41,914 ha of *A. decurrens* plantation is found in the *woreda* and is mainly planted for charcoal production
- Short term economic benefits, adaptability and fast growth nature of the plant are the main driving factors for its expansion

- Major problems and challenges in developing and expanding the practice include land shortage, labour shortage, bureaucratic hurdles, free grazing, and water shortage for seedling production as well as well as damages by disease and pest
- Even though the primary objective of plantation is for charcoal production (98.7%), people are also getting other benefits such as fuelwood (85.3%) and construction materials (62%)
- The plantation is established in Taungya mixed mainly with annual crops
- Most of the respondents (61%) use a planting spacing of 0.5 m x 0.5 m
- Only 17% of the respondents use a spacing of less than 0.5 m and the smallest spacing used is 0.25 m. Only 20% of the respondents use planting spacing of more than 0.5 m to 1 m
- About 71% of farmlands are used for growing *A. decurrens* during the study year
- The percentage of land holding average land size allocated for planting *A. decurrens* ranged 14% to 100%
- About 65% of the respondents allocated >50% of their farmland
- Even some of the respondents converted their total land including homesteads and irrigable lands to the plantation
- Some lease land for *A. decurrens* plantation
- The rotation age of *A. decurrens* plantation for charcoal production ranges from 5 to 6 years
- The trees are cut at the ground level, even a little bit lower to remove the stump for easy ploughing
- Charcoal production per ha is about 3000 sacks and the average price of one sack of charcoal is about 80 ETB
- Therefore, from a hectare of *A. deccurens* plantation, one can get about 240,000 ETB. The average price of one ha *A. decurrens* stand is 128,000.00 ETB
- Stands were sold at an average price of nearly 32,000 per a quarter ha (128,000 ETB/ha)
- More than 80% of the respondents replied that planting *A. decurrens* was twice more profitable (in monetary value) than crop production
- The plantation reclaimed salt affected (and degraded) land

- *A. decurrens* improved the livelihood of the local community and created job opportunities

Recommendations

- Modernization of all activities ranging from seedling production, charcoal making and marketing is of a paramount importance to use the full production potential and environmental services of the species
- Tree growers and charcoal producers' association should be established to maximize the profit of the practice for the farmers
- It is of a paramount importance to diversify the products and means of livelihood of the local community as well as diversify products and services from the species. The species can be used for dye, gum production and other uses and services
- Balancing the plantation development and crop production is essential. Otherwise, the farmers will face critical food shortages in case price is lowered and something bad such as large-scale disease and pest damage occurs on their plantations
- Research should be conducted to select appropriate spacing which minimizes cost and maximizes productivity/production
- The observed diseases and pests on *A. decurrens* plantation should be further studied and the respective proper controlling mechanism should be devised

Potential users

Farmers in similar agroecologies of the country, district office of agriculture, Bureaus of Agricultural and natural resource offices, policy makers, zonal department of agriculture, higher learning institutions, students, investors, tree growers, policy makers

Reliability of information

This information is reliable as it is based on primary and original data collected directly from farmers.

Effect of storage conditions on nutritional and anti-nutritional composition of *Zizyphus mauritiana* wild edible fruit

Responsible researchers: Fikremariam Haile, Abraham Dilnesa, Berhane Kidane, Tigabu Redae, Tegene Tantu, Tewabech Alemu, Amsalu Tolossa, Buzayehu Desisa and Mahelete Tsegaye

Brief description of the information

Fruit quality is affected by different factors such as packaging technology, shelf life, and storage condition. Fruit quality of *Zizyphus mauritiana* depends on the postharvest handling techniques. The aim of this study was to identify suitable packages for handling and transportation, and to characterize the mineral, nutritional and anti-nutritional composition of matured and immature fresh *Z. mauritiana* fruit collected from Kobo, North Wollo, Ethiopia. *Z. mauritiana* fruits were packed in three types of packages (nestable plastic crate, cold box, and wooden boxes) and transported over a distance of 500 km by road. The fruits packed in a cold box had lesser bruising damage, weight loss, and had better quality in terms of physical injuries, weight loss, and decay as compared to those packed in wooden boxes and a nestable plastic crate. On the other hand, the phytochemical analysis of *Z. mauritiana* showed that it contains acceptable amounts of moisture content (5.72%), ash (6.15-6.23%), protein (8.75-9.35%), fiber (1.63-1.74%), fat (5.45-5.7%), phytate (310-321 mg/g) and tannin value (11251-11478 mg/gm). The analysis of minerals for *Z. mauritiana* fruits showed that it has an acceptable amount of potassium (226.7 mg/100g), calcium (1.98 mg/100g), sodium (0.35 mg/100g), magnesium (0.22 mg/100g), iron (0.04 mg/100g) and zinc (0.02 mg/100g). Therefore, *Z. mauritiana* wiled edible fruit can be used as a good source of food.

Introduction

There are hundreds of indigenous fruits trees (IFT) species in Sub-Saharan Africa. However, unlike exotic species, indigenous wild edible fruits are relatively unknown in global markets, and most species remain undomesticated. Africa has an abundant plant species which are known to be rich in health-promoting compounds and minerals (protein, fiber, fat, potassium, calcium, sodium, magnesium, iron and zinc etc.), many of which remain undiscovered or unused. Ethiopia

has different less utilized or unutilized non timber forest products (NTFPs) of which *Z. mauritiana* is one of the main wild edible fruits (WEFs). It is a multipurpose species, which has an economic importance in the Sahel region and which can serve as candidate species for agroforestry. *Z. mauritiana* fruits were grown naturally at farmlands, home gardens, and farm boundaries and also in the natural forests. In developing countries, where there is a profound lack of infrastructural and marketing facilities, post-harvest losses of fresh products varies from 25-50% of the total production, depending on the commodity. Hence, it is important to introduce suitable packaging techniques for the handling and preservation of fresh fruits. The objective of this study was to identify suitable packages for handling and transportation, and to characterize the mineral, nutritional and anti-nutritional composition of matured and immature fresh *Z. mauritiana* fruit. Therefore, there is a need to assess post-harvest handling; fruits preservation and processing techniques to recommend for current and future utilization the species.

Brief methodology

- Mature (fully ripe) and undamaged (have good appearance) fresh fruit of *Z. mauritiana* were harvested from Kobo woreda, Amhara Region
- The collected fresh *Z. mauritiana* fruits were placed into a cooled icebox, then immediately transported to the Forest Products Innovation Research Center laboratory
- Sorting was done by hand, and any mouldy fruits, insect damage or mechanical injury and other impurities were removed
- The fruits were washed with potable water, and then dried for two hours under shade at an average temperature of 29^0C
- Then, the fruits were placed in the two selected packing materials (high or low density polyethylene bags) and transferred into a refrigerator; for further nutritional and anti-nutritional analysis
- Data were analysed by using the Statistical Analysis System (SAS) software

Major findings

- The fruits packed in a cooled box had lesser bruising damage, weight loss, and had better quality in terms of physical injuries, weight loss, and decay as compared to those packed in wooden boxes and a nestable plastic crate
- The phytochemical analysis of *Z. mauritiana* stored in cooled box showed acceptable amounts of moisture content (5.72%), ash (6.15-6.23%), protein (8.75-9.35%), fiber (1.63-1.74%), fat (5.45-5.7%), phytate (310-321 mg/100g) and tannin value (11251-11478 mg/100g). The analysis of minerals for *Z. mauritiana* fruits showed that it has an acceptable amount of potassium (226.7 mg/100g), calcium (1.98 mg/100g), sodium (0.35 mg/100g), magnesium (0.22 mg/100g), iron (0.04 mg/100g) and zinc (0.02 mg/100g)
- Tannin and Phytate contents of *Z. mauritiana* fruits increase with the increase of the temperature at which the fruits were stored.
- The results indicated that placing of the fruits in the two selected packing materials (high or low density polyethylene bags) and storing into refrigerator can preserve the fruit up to 45 days.

Recommendations

Fruits should be stored in a cooled box since cold storage transportation is one of the methods of preserving perishable commodities in fresh and wholesome state for a longer period of time by controlling temperature and humidity within the storage system.

The potential user of the information

The beneficiaries of the research output are local community, individual farmers, development partners, and industries that can produce jam, juice, and different beverages.

Reliability of information

The information packed is the original work of the specified authors and all the results are reliable.

Population status, distribution, phenological characteristics and yield potential of *Dobera glabra* fruit trees in dry lands of Ethiopia

Responsible Researchers: Zewdu Yilma, Dereje Gashaye, Kibruyesefa Sisay, Wubalem Tadesse, and Elsabet Befekadu

Brief description of the information

One of the major and socio-economically important lowland fruit tree species in Ethiopia is *Dobera glabra* which is distributed in the lowland dry land agro ecology of the north eastern and south eastern part of Ethiopia. It naturally grows in woodland and cultivated lands and produces edible fruits and its seed is considered as typical 'famine-food'. Although the importance of *D. glabra* is highly appreciated as a food source and livestock feed and its adaptability to the area, there are some critical problems facing the species. Among the many problems the main one as stated by the local people is lack of new regenerations.

Despites its benefits as food and a wide range of adaptation from arid to semi-arid climates with a prospect to be grown in a wide range of land use classes, information on its distribution and fruit yield is limited. Therefore, designing of different options for development, production, improvement, value addition and promotion of high value Non-timber Forest Products are the most important as it can easily generate income for the household and the nation while improving environmental wellbeing. Based on its socio-economic importance, *D. glabra* fruits were considered for this study.

For this specific survey, potentially better growing areas of Amibara and Awash Fentale woredas of Afar region, Karat woreda of Southern Nation Nationalities Peoples Region (SNNPR), and Yabelo woreda of Oromia region were selected.

A total of 120 sample plots were established with minimum of thirty sample plots in each land cover types were laid along transect lines. Also twenty five representative *D. glabra* fruit trees were selected and marked and were used to determine the fruit yield potential of the tree under

different diameter classes. In addition to the fruits yield, phenological characteristics study of *D. glabra* was conducted to determine the flowering and fruiting time.

The survey revealed that the number of trees per hectare varies along different land cover types; i.e. 347, 14, 421, and 44 trees/ha in dense shrub land, open wood land (Afar), open wood land (Yabelo) and in cultivated land (Konso), respectively.

The vertical and horizontal structure (DBH and Height) class distribution was seemed as an inverted J-shape which implied that *D. glabra* population status in Yabello had good reproduction and recruitment as well as regeneration status. Whereas the *D. glabra* DBH and height class distribution on cultivated land in Konso showed irregular nearly bell-shape distribution and this distribution implies poor reproductive and recruitment status.

The same DBH and height class structure distribution was observed in Afar region both on dens shrub land and open wood land which had poor recruitment and reproduction potential of the targeted species. The fruit yield difference was observed between Amibara and Konso (Karat) woredas. The fruit yield from each 25 *D. glabra* trees per each study site was about 160.36 and 135.02 kg, respectively.

Introduction

Wild edible plants (WEPs) have been used as source of food since ancient times. In Ethiopia, the rural populations have a wider knowledge, tradition and opportunity of using wild edible plants despite the variation in age, sex, time and season.

WEPs have always been used as an emergency, supplementary or seasonal food sources during periods of crop failure, drought and famine to avert food insecurity in rural households of Ethiopia. WEPs have also been used as food source diversification since they are rich in nutrients that are absent or limited in locally cultivated crops. However, the consumption pattern of WEPs depends on the availability of normal foods. WEPs are consumed as supplementary food in normal periods, as food when the volumes of normal household foods start to become insufficient and wild plants alone used for food only when food reserves or other assets are no longer available.

Despite this fact the role of wild edible plants in developing countries has been ignored and under-estimated for many years. A study conducted in southern Ethiopia and in Afar Region indicated that strong traditions, beliefs and religious taboos still limit people's psychological and mental willingness to domesticate and cultivate wild food plants.

Wild edible fruits are an integral part of the diet of many rural communities and hence have diverse contributions in various ways. They are relevant to household food security and dietary diversification as well as income generation in some rural areas, particularly in the dry lands, to supplement the staple food, to fill the gap of seasonal food shortages and as emergency food during famine, prolonged drought or social unrest. The rich biodiversity enables the country to harbor many WEPs that have always been used as an emergency, supplementary or seasonal food sources during periods of crop failure, drought and famine to avert food insecurity in rural households of Ethiopia. WEPs have also been used as food source diversification since they are rich in nutrients that are absent or limited in locally cultivated crops. However, the consumption pattern of WEPs depends on the availability of normal foods. WEPs are consumed as supplementary food in normal periods, as food when the volumes of normal household foods start to become insufficient and wild plants alone used for food only when food reserves or other assets are no longer available.

One of the major low land fruit tree species in Ethiopia is *D. glabrea* which was targeted for the present study. *D. glabrea* is distributed in India, Kenya, Saudi Arabia, Sudan, Tanzania, Ethiopia, Djibouti, Uganda and Yemen. It is an ever-green tree with alternate thick skinny leaves. The flowers are white and the fruits are ovate purple when ripe. Among the wild food plants found in the Afar Region (Ethiopia) is *D. glabra*, locally known as *'Garsa'*. The plant grows in dry areas, on saline, heavy, or calcareous loam soils and on rocky hillsides. It grows abundantly in dry and moist lowland areas (400-1300 m above sea level). *D. glabra* produces edible fruits and the seed is considered a typical 'famine-food'. Despites its benefits as food and a wide range of adaptation from arid to semi-arid climates with a prospect to be grown in a wide range of land use classes, information on its distribution and fruit yield is limited.

Therefore, designing of different options for development, production, improvement, value addition and promotion of high value Non-timber Forest Products are the most important as it can easily generate income for the household and the nation while improving environmental wellbeing. Based on its socio-economic importance, *D. glabra* fruit tree was considered for this study. The current study was conducted with the objectives of (1) examining the current population status and distribution of *D. glabra* in its natural habitat and farm lands in Amibara, Awah-Fentale, Yabelo and Karat woredas, (2) to study the phenological characteristics such as flowering and fruiting period and (3) to measure the fruit yield potential of *D. glabra.*

Major findings

- Our survey revealed that the number of trees per hectare varies along different land cover types; i.e. 347, 14, 421, and 44 trees/ha in dense shrub land, open wood land (Afar), open wood land (Yabelo) and in cultivated land (Konso), respectively.
- The vertical and horizontal structure (DBH and Height) class distribution was seemed as an inverted J-shape which implied that *D. glabra* population status in Yabello had good reproduction and recruitment as well as regeneration status. Whereas the *D. glabra* DBH and height class distribution on cultivated land in Konso showed irregular nearly bell-shape distribution and this distribution implies poor reproductive and recruitment status.

Recommendations

- The local community awareness should be improved on the sustainable development and utilization of *D. glabra* fruit trees
- Proper management strategies like shifting grazing should be considered to give chance for seedlings and saplings to perform well; otherwise the trees will be endangered
- *D. glabra* wild edible fruit trees should be incorporated in agroforestry farming system

Potential users of the information

Local communities (Pastoralists, Farmers, Agro-pastoralists); environment and forestry sectors; higher learning and academic institutions

Reliability of information

The information packed is the original work of the specified authors and all the results are reliable.

Effect of spacing on growth performance and leaf biomass yield of *Moringa stenopetala* plantation

Responsible Researchers: Zewdu Yilma, Abeje Eshete, Dereje Gashaye and Mulugeta Geremew

Brief description of the information

Ethiopia is endowed with diverse wild edible plants (WEPs) that vary by geographic location and food preferences by the diverse cultural groups that are endowed with diverse indigenous knowledge. Very few researches documented the ethno-botanical information of WEPs. WEPs have always been used as an emergency, supplementary or seasonal food sources during periods of crop failure, drought and famine to avert food insecurity in rural households of Ethiopia. *Moringa stenopetala* is one of the edible plants and a multipurpose tree in southern Ethiopia, which has been domesticated as a 'cabbage tree' by Konso people from their territory lowland dry forests. Almost every household of the Konso, Gamo and Gofa people grow the tree in their homesteads and farmlands for food, fodder, shade, windbreak and medicinal value. The tree has vital nutritional, industrial, and medicinal applications and thus good for large scale and/or commercial plantation. However, it is being cultivated traditionally without any technical and technological supports.

Therefore, studies on silvicultural practices are essential to provide technologies to boost its growth and leaf biomass yield. This study was conducted at the surrounding district of Arba Minch town to determine the effect of plant spacing on growth parameters and leaf biomass production. Three planting spacing (0.5 x 0.5 m; 1 x 1 m and 2 x 2 m) were arranged in a randomized complete block design and the treatments were replicated three times. Survival, root-collar diameter, height and stem diameter of the trees in each plot were recorded at three months interval from the 3rd to 15th months. Data for leaf biomass was collected at the age of 27, 32 and 48 months. Individual Moringa trees showed better growth performance at wider spacing of 2 x 2 m. The mean root collar diameter, plant height and stem diameter were 7.45 ± 0.20 cm, 1.69 ± 0.06 m and 3.19 + 0.11 cm for the wider spacing while 3.12 ± 0.16 cm, 1.02 ± 0.07 m and 2.12 ± 0.14 cm for the narrow spacing at the age of 15 months. The wider spacing produced the largest quantity of dry leaf biomass (119.28 ± 9.02, 143.85 ± 10.29 and 249.8± 24.220 g/tree and 298.20 ± 22.54, 359.62 ± 25.73 and 624.49± 60.59 kg/ha) while the narrow spacing produced the

smallest quantity (48.36 ± 5.10, 44.74 ± 3.19 and 88.15 ± 30.28 g/tree and 1934.40 ± 203.89, 1789.56 ± 127.78 and 3526.01± 1211.2 kg/ha) at the first, second and third harvest, respectively. This indicated that an increase in the plant spacing led to elevated dry leaf biomass production of the individual trees, but the lesser the yields per hectare. The performance of *M. stenopetala* is promising and hence it can be considered for large scale and commercial plantation at narrow spacing.

Introduction

Ethiopia has diverse geographic features and a very high variation in macro and micro-climatic conditions that contributed for the formation of diverse ecosystems inhabited with a great diversity of life forms of both animals and plants. Such diverse ecological conditions enabled the country to inhabit > 6000 higher plants of which about 10% are endemic. The country is also known as Vavilov centre of origin and diversification for many food plants and their wild relatives. Despite this rich natural resources and being an agrarian country with over 80% of its population is rural people, more than 35% of Ethiopian people are food insecure. The most commonly mentioned responsible factors for the food insecurity of the country are the ever increasing population along with recurrent drought, war and poor agricultural practices with low productivity.

The rich biodiversity enables the country to harbor many wild edible plants (WEPs) that have always been used as an emergency, supplementary or seasonal food sources during periods of crop failure, drought and famine to avert food insecurity in rural households of Ethiopia. WEPs have also been used as food source diversification since they are rich in nutrients that are absent or limited in locally cultivated crops. However, the consumption pattern of WEPs depends on the availability of normal foods. WEPs are consumed as supplementary food in normal periods, as food when the volumes of normal household foods start to become insufficient and wild plants alone used for food only when food reserves or other assets are no longer available.

Ethno-botanical information have been documented on 413 WEPs that are found from about 5% of the 494 Ethiopian districts indicating that more WEPs are believed to exist in Ethiopia given the high diverse systems in terms of geography, ethnic and culture. *M. stenopetala* is one of the edible plants in southern Ethiopia which has been domesticated as a ‘cabbage tree’ by Konso

people. It is distributed in the lowland dry ecology of the southern part of Ethiopia and cultivated for food, fodder, shade, windbreak and medicinal value around homesteads and in farmlands. It has various local names: Shiferaw in Amharic, Haleko in Gofa areas, Shelagda in Konso. *M. stenopetala* is a multipurpose tree with vital nutritional, industrial, and medicinal applications. The tree is also a drought resistance that provides shade in arid and semi-arid areas, provide nectars for honeybees, serve as a live fence and ornamental plant and conserve agricultural soils when intercropped in farmlands.

Despites its multitude benefits and a wide range of adaptation from arid to humid climates with a prospect to be grown in a wide range of land use classes, its distribution is limited to mainly southern Ethiopia and its potential has not been taped. Recently, the production and marketing of the leaves and seeds of *M. stenopetala* has increased in other parts of the country owing to its perceived medicinal and nutritional values and the tree is now being growing in most lowland and midland parts of the country. The production is expanding and new businesses are flourishing from time to time where women and youth are benefiting from the growing businesses, creating new jobs and employments, which are believed to reduce poverty. *M. stenopetala* can attract more unemployed youth and women to involve in income generating activities through growing, processing and marketing of the tree and its products. Recently investors have also showed interest in establishment of plantation from *M. stenopetala* for massive production of leaves and seeds and in establishing value-added products. Even though the tree has such high value for food security at smallholder farmers' level and industrial value at national and international level, the tree is being cultivated traditionally without any technical and technological support. Previous studies focused on documenting the use of different plant parts, estimating number of trees per household per hectare, nutritional contentment of the tree. Generally there is limited scientific information on the effect of different silvicultural practices on growth performance and leaf biomass yield of *M. stenopetala*. Such scientific studies are important to determine the productivity levels of *M. stenopetala* as a cabbage tree for its leaf biomass in the arid and semi-arid areas of Ethiopia. This study was thus initiated to determine the optimum spacing for better growth performance and leafy biomass yield of *M. stenopetala*. The study was conducted at Arbaminch Woreda, Gamo Zone, Southern Nation Nationalities and Peoples Region, Ethiopia.

Major findings

Survival

The overall mean survival rate of *M. stenopetala* averaged 94%, 89.6%, 88.7%, 87% and 87% at the age of 3, 6, 9, 12 and 15 months after planting. The tree has shown relatively better mean survival rate in the narrow spacing than the medium and wider spacing at the 3, 6, 9, 12 and 15 months after planting. The mean survival rate in fact has decreased with time until the 12th month for the narrow and wider spacing while until the 9th month for the wider spacing and was constant then after.

Root collar diameter, plant height and stem diameter growth

- The mean root-collar diameter increment in wider spacing (7.45 ± 0.20 cm) was significantly higher than the narrow (3.12 ± 0.16 cm) and medium spacing (6.14 ± 0.24 cm) at the 15th months after planting. Similarly, the mean root-collar diameter increment in medium spacing was significantly higher than the narrow spacing at the 15th months after planting.

- The medium (1.36 ± 0.06; 1.54 ± 0.07; 1.72 ± 0.08 m) and wider spacing (1.28 ± 0.05; 1.48 ± 0.06; 1.69 ± 0.06 m) showed significantly higher mean height growth than the narrow spacing (0.81 ± 0.05; 0.88 ± 0.06; 1.02 ± 0.07 m) at the 9, 12 and 15th months after planting, respectively.

- Mean stem diameters averaged 1.42 m, 2.0 m, and 1.96 m at 9 months for narrow, medium and wider spacing, respectively; 1.84 m, 2.7 m, and 2.99 m at 12 months for narrow, medium and wider spacing, respectively; and 2.12 m, 2.96 m, and 3.19 m at 15 months for narrow, medium and wider spacing, respectively. The medium and wide spacing (1 x 1 and 2 x 2 m) had significantly larger stem diameter than the narrow spacing in the 9, 12 and 15th months after planting.

Leaf biomass production

- The dry leaf biomass on individual tree level across the densities ranged from 7.8 to 530.4 g/tree, from 9.36 to 608.4 g/tree and from 6.24 to 1684.8 g/tree for the 1st, 2nd and

3rd harvests, respectively. A significant difference in the dry leaf biomass production on individual tree level was observed depending on the studied factor: spacing. The increase in planting spacing led to the increase in dry leaf biomass at the three harvest seasons. At the first harvest the wide spacing (2 x 2 m) showed significantly higher dry leaf biomass than the medium and narrow spacing and the medium spacing (1 x 1 m) showed significantly higher dry leaf biomass than the narrow spacing. A similar significant difference in the dry leaf biomass production was observed across spacing levels at the second and third harvest.

- The dry leaf biomass on hectare bases across the spacing levels ranged from 31.2 to 8112.0 kg/ha, from 23.4 to 8736 kg/ha, and from 15.6 to 67392 kg/ha, for the 1st, 2nd and 3rd harvests, respectively. A significant difference in the dry leaf biomass production on hectare bases was observed depending on the studied factors. The increase in planting spacing led to the increase in dry leaf biomass at the three harvest seasons. At the first harvest the wide spacing (2x 2 m) showed significantly higher dry leaf biomass than the medium and narrow spacing and the medium spacing (1 x 1 m) showed significantly higher dry leaf biomass than the narrow spacing. A similar significant difference in the dry leaf biomass production was observed across spacing levels at the second harvest. At the third harvest, the wide spacing showed a significant higher dry leaf biomass than the medium and narrow spacing but there was no significant difference between the medium and narrow spacing in dry leaf biomass production.

Recommendations

- Planting Moringa at a relatively wider spacing is very helpful for individual farmers at their farmlands and homesteads since it significantly increased leaf biomass production of individual trees.
- Planting Moringa at relatively narrow spacing is highly recommended for commercial plantation since it is found to be capable of producing a good leaf biomass and seed yield at a relatively high density of plants on hectare bases.
- Large scale of Moringa plantations can contribute to CRGE of the country and decrease the rate of unemployment.

Potential users of the information

- Local communities (Farmers, Agro-pastoralists, Women and youths)
- Investors
- Environment and forestry sectors at national, regional and district level
- Higher learning and academic institutions

Reliability of information

The information packed is the original work of the specified authors and all the results are reliable.

Within stem variation of density and mechanical properties of *Acacia melanoxylon*

Responsible Researcher: Mahadi Mussa

Brief description of the information

In Ethiopia, the higher rate of population growth and development of wood industries together with increased demand for wood has caused a dramatic decrease in forest resources. Besides, high demand for wood and deforestation rate has led to the increase in the introduction and adoption of exotic trees species. *Acacia melanoxylon* was introduced to Ethiopia from Australia and the species has been underutilized in the country. This is due to lack of information and/or technologies on different wood properties of the species. The wood of *A. melanoxylon* is used in making cabinet, furniture, veneers, turnery, panelling, flooring, boat building, gunstocks, musical instruments, plywood, etc. The objective of this study was to investigate the variation of density and mechanical properties of *A. melanoxylon* along the stem height and radial direction. For this study, 30 years old *A. melanoxylon* trees were randomly selected and harvested from Chencha. From each tree, three sample logs of 2.5 m long were collected from the bottom, middle and top portions of the stem height. The sample logs converted into lumber, and specimens free from visible defects were prepared for determination of density and mechanical properties along the stem height and radial directions for both green and air-dry condition tests. The tests were carried out in according with International Standards Organization (ISO). The results showed that the overall mean of density (0.695 and 0.609) g/cm^3, modulus of elasticity (MOE) (9249.7 and 13671.89) N/mm^2, modulus of rupture (MOR) (69.49 and 147.98) N/mm^2, impact bending (9519.60 and 9880.81) Nm/m^2, maximum crushing strength (33.96 and 62.71) N/mm^2, and hardness in tangential (3720.64 and 5373.10) N and radial (3825.8 and 5415.40) N in green and at 12% moisture content (MC) tested specimens, respectively. The results revealed that the stem height had significant ($p<0.05$) effects on density and mechanical properties in both moisture conditions. However, significant ($p<0.05$) effects wasn't found between the heartwood and sapwood in both moisture conditions of density and mechanical properties of the tree species. The effect between tree height and heartwood-sapwood had significant effect on MOE, MCS and

impact bending in the case of both moisture conditions. In both moisture conditions, the density and mechanical properties were decreased from the base towards top of the stem height. The density and the mechanical properties of this species were classified under medium tree species. The wood properties of the species are comparable with commercially known and endanger tree species in the country. *A. melanoxylon* tree species showed potential alternative lumber species to the wood industry.

Introduction

In Ethiopia, the higher rate of population growth and development of wood industries together with increased demand for wood has caused a dramatic decrease in forest resources. Starting from the year 2013, Ethiopia consumed more than 124 million cubic meters of wood each year. With population growth and economic development projections, total wood product demand will increase by about 27% over the next 20 years, reaching an annual consumption of 158 million cubic meters by 2033. Currently, natural forests and selected tree species are being cleared in excess in the country due to the increased demand of wood, for household energy and construction materials. Conversely, there are numerous plantations and potential species whose industrial and other commercial benefits are not yet fully realized. The selective use of the species combined with an inefficient further processing and inappropriate utilization due to lack of information and technologies on different wood properties and utilization methods for the alternative lumber species.

A. melanoxylon was introduced to Ethiopia from Australia and the lumber was underutilized. The species has been planted in the country in cooler and wetter upland areas, Moist and Wet Kolla, Weyna Dega and Dega agroclimatic zones. *A. melanoxylon* is belongs to the family Leguminosae and the subfamily Mimosoideae. It is a fast growing species with a tall and straight bole. It is commonly called Ausralian Blackwood and locally known as Omedla in Ethiopia. *A. melanoxylon* is unusual among the acacias in that it is adapted to moist rather than dry areas. It grows in cool temperate rainforests, open forests of the tablelands and coastal escarpments. It performs well in altitude ranging from 1500 to 2300 meters above sea level with mean annual temperature 6 to 19 ^{0}C, mean annual rainfall is 750 to 2300 mm. *A. melanoxylon* is a valued lumber species since the physical appearance of the wood is considered attractive and has an

even texture. Its heartwood shows a rich brown colour and a high natural durability. It has good strength and machining properties which make the wood suitable for high-quality furniture, cabinet making, fancy veneer, turnery, panelling, carving, flooring, boat building, gunstocks, plywood, tennis racquets and knobs. The wood is also used for light construction, tool handles, musical instruments, fence posts, firewood and charcoal.

The use of wood is influenced by the physical and mechanical properties of the lumber such as density, moisture, MOE, MOR, impact bending, compression strength, hardness, etc. Density is an important physical property of wood and one of the first to be considered when assessing wood quality, since it correlates with most of the strength properties of wood and conversion processes, including cutting, gluing, finishing, drying and paper making. Mechanical properties of wood indicate the ability of wood to resist various types of external forces, static or dynamic, which may act on it. Mechanical properties are very much important in case of constructional and structural purposes of lumber. The information on the wood properties of this tree species grown in Ethiopia is not available. The objective of this study was to examine the variation of wood density and mechanical properties along the tree height and radial direction of *A. melanoxylon* tree grown in Chencha.

Brief methodology

Representative of *A. melanoxylon* trees were randomly selected and harvested with straight trunk, normal branching and no disease or pest symptoms from Chencha. The height and diameter at breast height (Dbh) of the trees were ranging from 15 to 20 m and 21 to 26 cm, respectively. From each selected tree, three 2.5 m long logs were taken from bottom, middle and top of the tree height. The species grows on an elevation between 1300 and 3250 m above sea level with geographical location of 6°8′0′′- 6°26′0′′N latitude and 37°22′30′′- 37°43′30′′E longitude. The mean annual precipitation and temperature of this area is about 1172 mm and 14°C, respectively.

Sample preparation

The sample logs were sawn tangentially using circular sawmill, 3 cm thick boards were produced in Forest Products Innovation Research Centre, Addis Ababa. The sawn boards were cross-cut

into a series of 1.25 m long stringers for determination of density and mechanical properties (Figure 4). These were grouped and coded into odd and even numbers for the green and air-dry test. Boards for dry tests were subjected to air seasoning yard under shade until 12% MC reached. While the green test sample boards were plained, ripped and cross-cut into a final cross-section of 2 x 2 cm and 100 cm length. Finally the heartwood and sapwood from each section separately cross-cut into standard length specimens corresponding to each wood property test. The stringers at air-dry condition after they reached 12% MC, cross-cut into standard length specimens corresponding to each wood property test.

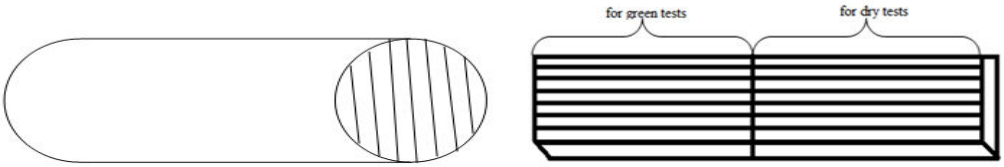

Figure 4: Sawing pattern and sample preparations from sawn lumber for density and mechanical properties test at green and air-dry conditions

Table 2: Dimensions, standards and numbers of test specimen used for density and mechanical properties test

Property	Specimen dimensions (mm)*	Standards	Number of specimens
Density	20 x 20 x 60	ISO 3131	180
Static bending	20 x 20 x 300	ISO 3133	180
Impact bending	20 x 20 x 300	ISO 3348	180
Compression// grain	20 x 20 x 60	ISO 3387	180
Hardness	20 x 20 x 45	ISO 3348	360

(Radial x tangential x longitudinal)*

Density tests

The dimension of specimens was 20 x 20 x 60 cm for the determination of density along with the three stem height (bottom, middle and top) and radial direction in both green and at 12% MC condition. The density of wood was determined on a green-mass and air-dry-mass basis. A digital caliper was used to measure the dimensions of the samples in green and air-dried to 12% MC in order to determine their volumes. The specimens were then weighed using an electronic balance. Density calculated using the following formulas:

$$\rho g = \frac{Mg}{Vg}$$

$$\rho 12 = \frac{M12}{V12}$$

Where: ρg is density at green (g/cm^3), ρ12 is density at 12% MC, Mg is mass at green, M12 is mass at 12% MC (g), Vg is volume at green (cm^3) V12 is volume at 12% MC.

Static bending

The static bending strength was determined by using the Universal Testing Machine (UTM) (Figure 5). The dimensions of the specimens were 20 x 20 mm cross-section and 300 mm length. The distance between the points of suspension was 280 mm. The load was applied to the centre of the specimen, on the radial face at a constant speed of 0.11mm/s. Load of the force plate and corresponding deflection was recorded from the dial gauge manually for each sample. Graph plotting was done for each specimen using Microsoft excel to calculate MOE and MOR. From each plotted graph, MOE and MOR were calculated as follows:

Figure 5: Mechanical properties tests using Universal Testing Machine (UTM)

$$MOE = \frac{p^1 L^3}{4d^1 bh^3}$$

$$MOR = \frac{3PL}{2bh^2}$$

Where: MOE=Modulus of elasticity (N/mm^2), MOR=Modulus of rupture (N/mm^2) P^1= Load at the limit of proportionality (N), P= Maximum Load (N) L= Span length (mm), d^1= Deflection at the limit of proportionality (mm), b= Width of specimen (mm) h= Thickness of the specimen (mm)

Impact bending

Impact bending or Specific impact resistance is the work consumed in causing total failure in impact bending. The dimensions of the specimens were 20 x 20 x 300 mm. It determined based on (ISO 3348). A pendulum hammer, type of Impact bending Testing Machine was used for this testing (Figure 5). The specimens were placed on the machine and the load was applied to the

centre and perpendicular to the radial face of the test specimen. The joule value was read from the force plate of the test machine and the strength was computed from the following formula.

$$\text{Sp.Im.Re.} = \frac{P}{bh}$$

Where: Sp.Im.Re=Specific impact resistance in (Nm/m^2), P=Joule value (Nm), b=width of the specimen (mm), h=Thickness of the specimen (mm).

Compression parallel to the grain

Compression parallel to grain test was done based on ISO 3387. The dimensions of specimens were 20 x 20 x 60 mm. Universal Testing Machine with speed of loading 0.01 mm/sec was used. The Maximum Crushing Strength (MCS) was determined from the following formula:

$$\text{MCS} = \frac{C}{bh}$$

Where: MCS=Maximum crushing strength (N/mm^2), C=Maximum load (N), b=width of the specimen (mm), h=Thickness of the specimen (mm)

Hardness test

Hardness represents the resistance of wood to indentation and marring. Hardness was comparatively measured by force required to embed 11.3 mm ball one-half its diameter into the wood. Hardness values were obtained by using Janka method (ISO 3348) by using Universal Testing Machine with the rate of loading was 0.11mm/s for both radial and tangential direction tests.

Major findings

- The overall mean values of heartwood in green and at 12% moisture contents of density (700.9 and 614.57 kg/m^3), MOE (9400.50 and 13863.17 N/mm^2), MOR (70.64 and 149.63 N/mm^2), impact bending (10071.11 and 9808.80) Nm/m^2), MCS (34.73 and 63.73 N/mm^2) and hardness (3868.12 and 5487.56 N), respectively were slightly higher than the corresponding the overall mean values of sapwood in green and at 12% MC of

density (689 and 604.87 kg/m^3), MOE (13479.62 and 9098.92 N/mm^2), MOR (68.34 and 146.78 N/mm^2), impact bending (9690.60 and 9230.80 Nm/m^2), MCS (33.26 and 62.23 N/mm^2) and hardness (3678.22 and 5301 N), respectively.

- The overall mean values of density (0.695 and 0.609) g/cm^3, MOE (9249.7 and 13671.89) N/mm^2, MOR (69.49 and 147.98) N/mm^2, impact bending (9519.60 and 9880.81) Nm/m^2, maximum crushing strength (33.96 and 62.71) N/mm^2, and hardness in tangential (3720.64 and 5373.10) N and radial (3825.8 and 5415.40) N for green and at 12% moisture content conditions, respectively.
- The result revealed that in the case of both green and air-dry to 12% moisture content conditions, the stem height had significant effects on the density, modulus of elasticity (MOE), modulus of rupture (MOR), impact bending, maximum crushing strength (MCS) and hardness in (tangential and radial). However, the heartwood and sapwood didn't shown significant effects on density, MOE, MOR, impact bending, MCS and hardness in (tangential and radial) in green and air-dry conditions. The effect between tree height and heartwood-sapwood had significant effect on MOE, MCS and impact bending in both moisture conditions.
- In both moisture conditions, the highest values of density and mechanical properties were observed at the base and the lowest at the tip of the tree. This indicated that the bottom portion had better strength than the middle and top portions of the tree.
- The variations of mechanical properties had showed similar trend to the wood density of the species. This indicated that the density of the species can predict the values of mechanical properties of the species since density highly correlated with the mechanical properties of wood.
- The variations of wood properties along the stem height might be due to maturity at the base and juvenility at the tip of the tree. Maturity decreases from the bottom to top; density and mechanical properties also decreases. On the other hand, density and mechanical properties in the juvenile wood zone is low because there are relatively few late woods/summerwood cells and a high proportion of cells have thin wall layers. This implies that the high-density and mechanical properties of wood found from the bottom logs; such wood can be used for structural purposes where high strength is required.

- The differences between the heartwood and sapwood may be extractives deposited in the heartwood. A significant amount of extractives are deposited in the heartwood, up to two or three times more than in sapwood of *A. melanoxylon* species.
- The overall mean values of mechanical properties tested at 12% moisture content were increased more than twice of in green condition tested of the tree species. This indicated that moisture contents found in lumber less than fiber saturation point is influences the density and the mechanical properties of the tree species.
- *A. melanoxylon* lumber is belongs to medium to high dense and strong wood species. It is suitable for furniture, joinery, veneer, cabinet work, musical instruments, tool handles, flooring, craft and decorative purposes, and pulp and paper.
- The density and the mechanical properties of the lumber found in this study were comparable with many commercially known home grown and exotic tree species. Therefore, *A. melanoxylon* could substitute the commercially known and endangered tree species in the country.

Recommendations

- The density and the mechanical properties of the lumber found in this study were comparable with commercially known and endangered tree species in the country. Therefore, *A. melanoxylon* tree species could become an alternative raw material to support the wood industries in the country.
- The policy maker, government and non-governmental organizations, forest sectors and local communities shall promote plantation of this species in the country.

Potential users of the information

This information is useful for forest industries, furniture manufacturing, forest enterprises, construction sectors, farmers, government and non-governmental organizations, policy makers, research institute, academic institutions and scientific communities.

Reliability of information

The information packed is the original work of the specified authors and all the results are reliable.

Successional changes of *Boswellia* dominated woodlands after shifting agriculture-related human disturbance

Responsible Researchers: Melkamu Abere, Dereje Gashaye, Abeje Eshete, Gemechu Jebeso, Abera Getahun[1], Ambachew Getenet[1], Mitiku Alemu[1], and Dagnew Yibeyin

Brief description of the information

Combretum –Terminalia woodlands are one of the dominant vegetation types that cover large parts of the lowland areas in Ethiopia. The woodlands harbour diverse tree species that are known for their valuable non-timber forest products of local, national and international significances. *Boswellia papyrifera* species are well-known and dominant species in Metema, north-western Ethiopia. However, populations of a species are disappearing rapidly due to the combined effect of conversion of forestlands into agricultural lands, fire, and grazing and intensive tapping practices. Therefore, studies of successional changes of *B. papyrifera* dominated woodlands after shifting cultivation along fallow ages using enclosures are essential to enhance and evaluate species secondary succession. Therefore, the study was intended to generate information and characterize species richness, and species composition and population structure of tree species along succession periods at Metema *woreda* (district), located in the Amhara region, northwest Ethiopia. Seven experimental plots that measure 30 x 50 m were selected and each appropriate fallow age plots delineated and fenced purposively. These enclosures were fallowed for five consecutive study years (2014-2018). The diversity, density, abundance, frequency, dominance, importance value index (IVI) and regeneration of the woody species in the study area along succession were analysed. The result showed that both species richness and density were increasing up to the third year due to site protection and a decline in the fourth year due to disturbance. However, there were no *B. papyrifera* recruitments in all the successional periods. Therefore, a multiple-approach of management like a long year and well-establishing area enclosures and introduction of well-developed seedlings and saplings will be needed to maintain *B. papyrifera* species.

Introduction

Dry tropical forests or woodlands cover over 40% of the global tropical forest areas and 14% of the total African land mass. These forests however are declining rapidly from time to time in area due to different factors like expansion of agriculture and pasture lands. About 97% of the remaining dry tropical forests are at risk of being further fragmented and degraded by fire, fuelwood collection, and grazing damage.

Boswellia dominated woodlands in Metema, north-western Ethiopia are being converted into croplands at an estimated annual rate of 0.49% (1855.3 ha) to fulfil the increasing demands to feed the ever-increasing population.

Understanding the underlying process of secondary succession in *Boswellia* dominated woodlands is critical for several reasons. First, owing to the high rates of current deforestation and other types of forest disturbance, most of the woodlands are becoming secondary forests. Second, *Boswellia* dominated woodlands are converted to an agricultural field under the slash and burn rotation system in the lowland areas of Ethiopia that generate fallow periods. Third, ecological restoration is becoming increasingly important given the urgent need to restore areas of degraded woodlands for increasing the provision forest products, for conservation purposes and improved provision of ecosystem services.

Understanding secondary vegetation development and elucidating the factors that drive the dynamics of plant communities and thus influence species diversity and abundance is fundamental to achieve restoration and management goals for such successional areas.

Major findings

Woody species composition and diversity

- A total of 13, 26, 40, 12 and 17 woody species were recorded in the five consecutive successional periods, respectively. The woody species richness was increasing until the third year when the site was protected from different disturbances but, the site was exposed to different disturbances in the fourth year and hence species richness decreased drastically. The density of woody plant species showed a similar trend, and it was 1013, 3133, 3713, 893, and 1687 per hectare along ascending successional periods.

- The Shannon-Wiener diversity index (H) along the successional periods was 1.70, 2.46, 2.98, 1.72, and 1.55, respectively, along successional periods. While their corresponding evenness values were 0.66, 0.76, 0.81, 0.69 and 0.55. The results indicate that woody species diversity increased until the third year and decreased afterwards apparently due to grazing and fire.

Dynamics of *Boswellia papyrifera* species

- The study revealed that *B. papyrifera* species dynamics decreased gradually because of the absence of regeneration in the form of seedling and sapling as well as the fall down of the adult trees by natural and anthropogenic disturbances

Density, frequency, and dominance

- Densities of woody species were 1013.35, 3133.33, 3713.33, 893.33, and 1890.66 per hectare along successional periods, respectively. In terms of species relative abundance, *Lannea fruticosa* and *Pterocarpus lucense* had the highest species density (13.83 and 9.09%; 26.12 and 17.16%) in 2018 and 2017 successional periods, respectively. Based on the field observation during the first three study years, *B. papyrifera* species were found dominantly in terms of tree density. However, in the last study years *B. papyrifera* species density declined. The primary causes of the species deterioration may be anthropogenic disturbances. This species degradation can also be due to lack of *B. papyrifera* seedlings and saplings.

- In terms of occurrence or frequency along successional periods, *B. papyrifera* and *Lanna fruticosa* had a relatively higher frequency in quadrants. *B. papyrifera*, *Lannea fruticosa*, and *Pterocarpus lucens* were the highest three ecologically important species in all consecutive successional periods.

Regeneration status of woody species along fallow ages

The woody species did not show significant variations in regeneration status along fallow ages ($p < 0.05$). The dominant species at the first regeneration time were *Acacia polyacantha, Combretum collinum, Steriospermum kuntbianum* The woody species dominancy in the 2017 successional period or study year was replaced by *Dichrostachys cinerea* and *Ziziphus abyssinica*. In final study year, all fallow ages plots were more colonized by *Dichrostachys cinerea*. The seedling and sapling woody species population difference in different years may be due to the selective browsing effect of animals and other unforeseen factors.

Recommendations

Multiple-approach of management such as long year and well-establishing area enclosures and planting of well-grown *Boswellia papyrifera* seedlings and saplings could be a solution to rehabilitate the degraded woodland.

Potential users of the information

- Local communities(Farmers, Women, and youths)
- Investors
- Environment and forestry sectors at national, regional and district level,
- Higher learning and academic institutions

Reliability of the information

The information is based on original work by EEFRI researchers, and it has been extracted from the original research report.

Carbon stocks assessment in fast growing tree plantations

Responsible Researchers: Mihert Semere, Tatek Dejene, Berhane Kidane, Tinsae Bahiru

Brief description of the information

Environmental conservation and carbon sequestration for climate change mitigation could be the fundamental reason for planting trees, however; little information is available on estimated biomass and soil carbon stock of selected fast growing species in extreme highlands of Ethiopia. This study aims to estimates the biomass and carbon stock of selected fast growing species in Diksis Woreda, Oromia region of Ethiopia. The carbon stock of selected species in the selected site, which originally was established to evaluate the performance of different species for plantations in the extreme highland areas of the country, was determined.

Introduction

Tree plantation for carbon sequestration has ecological, environmental, social and economic values and its conservation not only acts as a source of global carbon pool but also provides a wider range of services and goods to humans. Establishment of tree plantations on cleared land can reduce the rate of increase in atmospheric CO_2 and as trees grow, they sequester carbon in their tissues.

Brief methodology

This study was conducted in an experimental plantation where different tree species were planted in three blocks. The study aimed to estimate the carbon storage potential of each species found in the plantation. Data was measured in different available carbon pool (Biomass and soil organic carbon).

Major findings

- Amongst the selected species the highest mean total carbon stock was recorded for *Eucalyptus saligna* (62.5 Mg ha^{-1}) and *Eucalyptus camaldulensis* (51.2 Mg ha^{-1}) and the least was for *Eucalyptus viminalis* (35.4 Mg ha^{-1}).The highest total mean biomass carbon stock was recorded for *Eucalyptus globulus* (5.7Mg ha^{-1}) and the lower was recorded for *Eucalyptus grandis* (1.2 Mg ha^{-1}). The contribution of upper soil (0-10 cm) for the total soil organic carbon is 40% which is the highest input and the rest of the contribution was retained by second layer (10-20 cm) and the last layer (20-30 cm) 34.6% and 25.5%, respectively.
- The present study shows that plantation could store notable amount of carbon both in biomass and soil carbon pool. From selected species some shows significantly high amount of carbon thus, considering planting such species in highland areas of Ethiopia could contribute in global carbon balance and socio economic support for the local community.

Recommendations

- Carbon emission reduction strategies should give unlimited acknowledgment for plantation since it has substantial potential for climate change mitigation. In addition governmental bodies should consider carbon incentive in plantation which could offer an opportunity for sequestering a large amount of carbon while meeting other household demands.
- This study implies, practicing planting more trees could support soil conservation and enhance production for fuel wood input for local community. It also proves plantation has great potential of SOC storage, emission reduction and carbon financing scheme as climate change mitigation strategies.

Potential users of the information

This information can be used by government and non-governmental organizations, research and academic institutions and the scientific community.

Reliability of information

The findings of this work are based on original experimental research by EEFRI. The full report is included in the EEFRI's Proceedings of 2021.

Succession of plants with the recession of Lake Abijata

Responsible Researchers: Shiferaw Alem, Yared Worku, Tamiru Lemi, Genene Tesfaye

Brief description of the information

Different literatures have showed that, Lake Abijata, which is a saline alkaline Lake, is retreated. Despite this fact, knowledge on the ecological succession of woody and herbaceous plants, which are growing on the retreated part of the lake, which has a saline alkaline soil is lacking. The overall objective of the study was to assess the different woody and herbaceous plant species that grows in a saline-alkaline soil. To achieve the objective, a total of 45 sample plots with an area of 20 m x 20 m each were laid out in the different aspects of the Lake (East, West and North). In each of the plots, data on woody and herbaceous plants, and soil were collected. A total of 5 woody and 17 herbaceous plants were identified. The results indicated that the dominant tree and herbaceous species that grow in the recessed part of the Lake were *Vachellia toritilis* and *Sporobolus spicatus*, respectively. The statistical result indicated no significant differences in the diversity (H'), and number of species recorded in each aspect of the Lake while there is significant difference on the number of woody stems in the different recessed part of the Lake. Results showed that there was a significant relationship between soil pH and the number of species recorded in each plot, number of tree stems/ plot and also diversity of species/plot. Finally, it is concluded that *V. tortillis* tree and *S. spicatus* grass could be a species that can grow in the saline alkaline soils and used for a treatment of salt affected areas. .

Introduction

Lake Abijata, which is a saline-alkaline lake in Ethiopia, is shrinking from time to time, and it is estimated that greater than 100 km ^{2} of the lake is retreated so far. In the recessed part of the Lake, ecological succession takes place, however, knowledge on the tree and herbaceous plant species that are growing is lacking. Having the knowledge on the plants that are growing on the saline alkaline soil is important for the reclamation of such degraded soils. Ecological methods were applied for data collection and analysis.

Major findings

- A total of five tree species that belong to the Fabaceae family were recorded in the study area. The identified species that are succeeding the former Lake area due to its recession were *Acacia senegal*, *Vachellia sayal*, *V. tortilis*, *Pterolobium stellatum*, and *V. etbaica.*
- A total of 17 herbaceous plants were also recorded in the recessed part of the lake. The dominant grass species that was succeeding in the recessed part of the saline alkaline lake was *Sporobolus spicatus*.
- The total diversity of tree species in the recession part of the Lake H'= 0.42, while the species evenness was 0.26.
- The multiple regression analysis results indicated that the soil EC and the mean number of trees/plot, the mean number of species/plot and mean diameter DSH/plot were negatively correlated; however they did not have significant associations with the EC of the soil.
- The higher density of trees/ha of *V. toritils* in the retreated area of the saline-alkaline lake could be associated with the salt tolerance nature of the species as compared with other species. This result could also show that *V. toritilis* can grow in saline alkaline soils and the species could be used for afforestation of such area.
- Generally, the results indicated that *V. tortilis* (tree species) and *S. spicatus* (herbaceous species) are dominant species in the saline-alkaline soil and can be used for the reclamation of salt affected soil.

Recommendations

The present study showed that *V. tortilis* and S. *spicatus* can be used for the reclamation of saline-alkaline soils.

Potential users of the information

Higher learning institutions (Universities), development and research institutions, governmental and non-governmental organizations, foresters, agriculturalists and extension agents and policy Makers

Reliability of information

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

Productive and climate resilient traditional agro-forestry systems

Responsible Researchers: Mihret Semere, Marta Gebreyesus, Abirham Cherinet, Miftah Fekadu and Zenebe Mekonnen

Brief description of the information

This information characterizes the best agroforestry practices in Silete wereda of Southern Ethiopia. The best practice was selected by comparing agroforestry practices, namely, homegarden, parkland and woodlot. Data were collected by reconnaissance survey, interview of households, woody biomass inventory, and measurement of stem diameter, height and crown diameter. Farmers practiced 8 major adaptation/coping strategies/options including: livestock sale, additional off-farm activities, migration, AF products and savings. The mean total biomass carbon was 7 Mg C ha^{-1}, 3.11 Mg ha^{-1} and 2.01 Mg ha^{-1} for parkland, homegarden and woodlot agroforestry practices, respectively. Fruit trees, coffee and enset in homegarden accounted for 73%, 16% and 10.2%, of the total biomass carbon, respectively.

Introduction

Agroforestry (AF) is a spatio-temporal arrangement of plants and animals. It reduces greenhouse gas (GHGs) emission due to its ability to sequester large amounts of carbon on a relatively small land. AF is compatible with agriculture and forestry without creating leakage. Proper management of AF can play a crucial role in enhancing productivity and sustainability. Agroforestry in multiple vertical strata and canopy provides shade, reduces evaporation from the soil and shelter from wind, add mulch and nutrient from litter fall, and become carbon pools in carbon sequestration. Environmental degradation and deforestation due to improper land use system and high demand for fuelwood is the major cause for the changing climate. Farmers' perception on climate change and its impacts on production and productivity have resulted in the adoption of different adaptation strategies like adjustment of cultivation manners.

Silete Woreda in Silete zone was selected because of its diversified agroforestry systems: woodlot, homegarden and parkland. However, the system was not quantified locally. Hence, the objective of this information is to create awareness on the importance and adaptation role of the

agroforestry practices (Figure 6) in storing above and belowground biomass carbon for climate change mitigation and to select the best agroforestry practice.

Figure 6: Homegarden, woodlot and parkland agroforestry practices (left to right)

Brief methodology

Reconnaissance survey was done to identify agroforestry practices, and identified three practices, namely, homegarden, parkland and woodlot. Next, the importance and plant composition of each practice was further studied in two kebeles (Welay Sedest and Balo Keriso) by taking 125 sample households for interview to collect socio-economic data. Moreover, woody biomass inventory and measurement of diameter and height was measured in 60 plots of 20 x 20 m for homegarden; 50 x 100 m for parkland and 10 x 10 m for woodlot. Biomass carbon stock (Mg ha^{-1}) was estimated as the product of dry matter biomass and carbon content by using previously developed allometric models based on plots data of the specific site and plant species. Data were organized and analyzed using Microsoft excel and SPSS version 20 software.

Major findings

Homegarden agroforestry practice was most dominant, followed by parkland and woodlot agroforestry practices in both kebeles. Fuelwood consumption and fruit tree are the main products which contribute for most of livelihood source and household consumption in both kebeles (Figure 7).

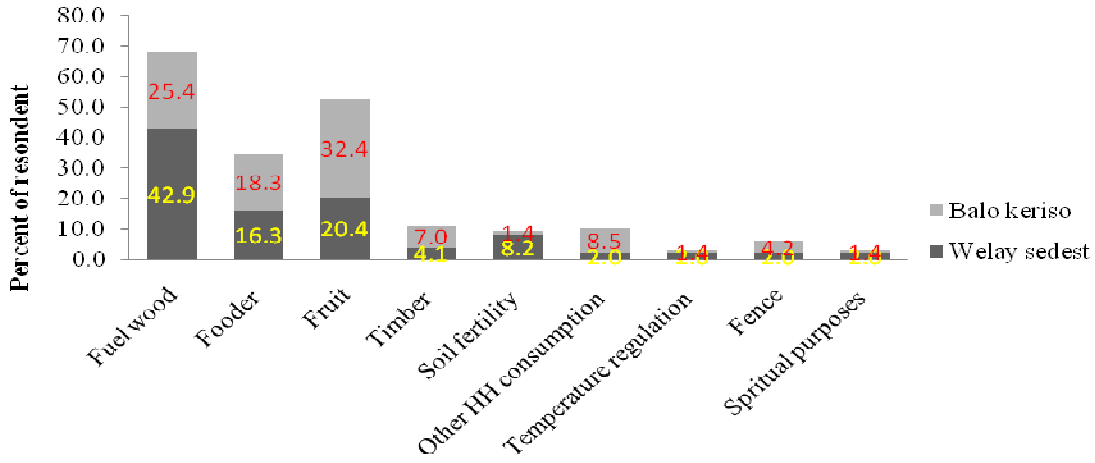

Figure 7: Usage of trees incorporated in agroforestry system for livelihood in the study areas

It was recognized that smallholder farmers sustain and expand their livelihood through different climate change adaptation strategies other than AF products. Based on their climate change experience and the nature of its impact, the farmers practiced about 8 major adaptation/coping strategies/options (Figure 8) including: livestock sale, additional off-farm activities, migration, AF products and savings.

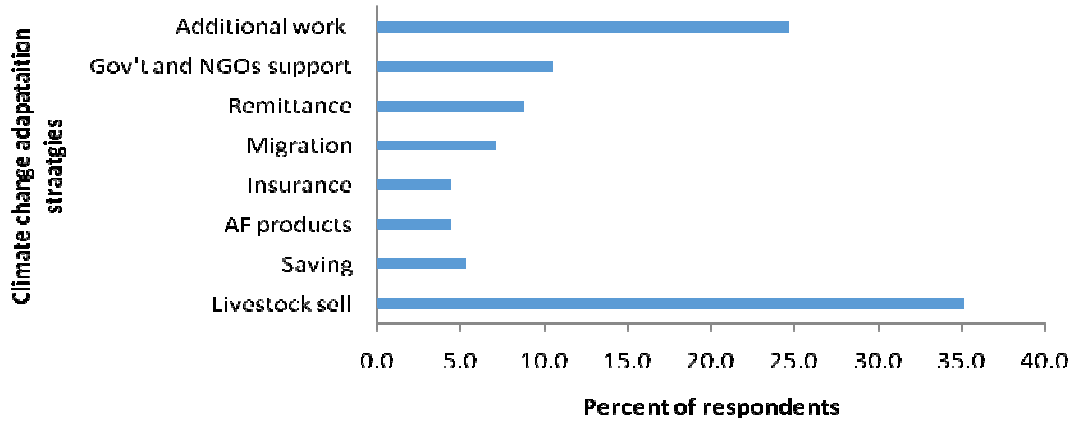

Figure 8: Climate change adaptation strategies of farmers in Silete wereda, Ethiopia

In Balo Keriso kebele the most climate variability threat was drought followed by heat wave, flood and strong wind. While the most important threat observed in Welay Sedest kebele was flood followed by drought, strong wind and heat wave.

Biomass carbon stock

The mean total biomass carbon (above and below ground) was 7 Mg C ha^{-1}, 3.11 Mg ha^{-1} and 2.01 Mg ha^{-1} for parkland, homegarden and woodlot agroforestry practices, respectively. Of which above ground biomass carbon stocks comprised 1.28, 2.14 and 5.4 Mg ha^{-1}, respectively. Fruit trees (banana, papaya, avocado and mango), coffee and enset in homegarden accounted for 73%, 16% and 10.2%, of the total biomass carbon, respectively.

Recommendations

The indigenous agroforestry systems are very important carbon sinks should be considered in the carbon credit initiatives. Incorporating trees in the cropping system support the environment by being as one means of climate change mitigation option. There is a need to advocate and upscale environmental benefit of agroforestry system by awareness creation.

Potential users of the information

The potential users of the information can be rural farmers, development agents, agricultural experts, researchers, academia, policy makers, and development practitioners.

Reliability of information

Data was collected from different profiles of the population, and from different variables by using proper sample size to produce the estimate which made the data collected representative of the population. In addition, the measurement reflects the variable of interest by which it covers the aspects of the underlying concept and was consistent with other similar measures and theories. These make the information reliable.

Climate change projections for the highlands of Omo-Gibe Basin, Ethiopia

Responsible Researchers: Moges Molla, Wondimagegn Amanuel, Zenebe Mekonnen

Brief description of the information

This climate information is envisioned to improve climate information services by providing specific point location projection using Statistical Downscaling Method (SDSM) under different representative concentration pass ways (RCPs) of climate emission scenarios for near term, midterm and end of century for upper Omo-Gibe River Basin (OGB).

Statistical downscaling technique was used to solve the scale problems of lower resolution of global circulation models (GCMs) by empirical relationships between large-scale circulation patterns and regional climate derivers. The SDSM is used to downscale present and future daily precipitation and temperature data from GCMs to the point location. Three future emission scenarios, RCP2.6 (low emission), RCP4.5 (intermediate emission) and RCP8.5 (high emission) are considered for three 20 years periods 2020-2039, 2040-2059 and 2080-2099, respectively**.** The model projected that the mean annual maximum temperature under lower and higher emission scenarios ranges from 1.01°C to 4.6°C and 2.0°C to 3.6°C, respectively. Similarly, for mean annual minimum temperature, it ranges from 1.8°C to 3.3°C and 2.3°C to 5.6°C for the periods, respectively. The ensemble models projected that annual precipitation for all RCPs will increase by 5% to 8.1% compared to the 1974–2005 baseline for highland OGB. However, in the main rainy season, the mean monthly rainfall indicates a decreasing trend in the beginning and an increasing trend towards the end of the season for all scenarios in all future time horizons.

Introduction

In recent decade, the problem of climate variability and change has come with daily bad news. Developing countries like Ethiopia are more vulnerable to the adverse impacts of climate variability and change. Due to Ethiopia's location in tropics and dependence on natural resources, the country has low adaptive capacity and is highly sensitive to climate variability,

change and associated extreme events. Sensitivity and adaptive capacity also vary between sectors and geographic locations, time and social, economic and environmental considerations within the country. Current climate variability and extreme events are already imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters.

Besides the direct effects of climate change, the necessity and opportunity to switch to a new sustainable development model is unquestionable. If Ethiopia were to pursue a conventional economic development path to achieve its ambition of reaching middle income status before 2025, the resulting GHG emissions would be more than double from 150 Mt CO_2e in 2010 to 400 Mt CO_2e in 2030. The Ethiopian government has therefore initiated the Climate-Resilient Green Economy (CRGE) to protect the country from the adverse effects of climate change and to build a green economy that will help realize its ambitious goals.

Climate change modeling should take into account the spatial and temporal variability of climate in the specific region or location attributed to various factors which include the topographic variations across the region or location and different regional and local weather systems at large and medium scale. Studies showed that there is confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and beyond due to the models' foundation on accepted physical principles and their ability to reproduce observed features of current and past climates.

Achieving CRGE goals would unquestionably require scientific information and technology regarding the characteristics of climate change in the past and future and the spatial and temporal variability of precipitation. However, large-scale trends do not necessarily reflect local conditions to fill this gap. Therefore, to improve climate information services on specific point location projection using different RCPs emission scenarios for near term, midterm and end of century is necessary.

Brief methodology

Statistical dataset of daily and monthly precipitation and temperature were obtained from National Meteorological Agency (NMA). Data covering the basin was collected for the period of 1988 to 2018. GCMs have been developed to simulate the present climate and have been used to predict future climatic change. However, GCMs are at low resolution and there is a need to downscale the results from such models to individual sites or localities for impact studies using SDSM. Atmospheric large scale variables (CanESM2 Predictors) were downloaded from IPCC's Fifth Assessment Report (AR5) CMIP5/ Coupled Model Inter-comparison Project, Phase 5 (CMIP5)/ a collaborative climate modeling process coordinated by the World Climate Research Programme (WCRP) were used for downscaling.

Major findings

- The model projected that the mean annual maximum temperature under lower and higher emission scenarios ranges from 1.01°C to 4.6°C and 2.0°C to 3.6°C, respectively. And for mean annual minimum temperature, it ranges from 1.8°C to 3.3°C and 2.3°C to 5.6°C for all time horizons.

- The projected change in annual mean maximum temperature for Wolkite shows slight difference from others under all RCPs scenarios in 2080-2099 and for Sokoru in 2040-2059.

- The ensemble models projected that annual precipitation for all RCPs will increase by 5% to 8.1% compared to the 1974–2005 baseline for highland OGB. The percentage increase was high for Sokoru under all RCP scenarios of 2080's and nearly similar under RCP4.5 and RCP8.5 scenarios for Jimma. However, in the main rainy season, the mean monthly rainfall indicates a decreasing trend in the beginning and an increasing trend towards the end of the season for all scenarios in all future time horizons.

- The projection shows slight increase in precipitation for main rain seasons (AMJ and JAS) under RCP2.6 but there was a decrease under RCP4.5 and RCP8.5 for Jimma at near term, middle term and end of century.

- The ensemble models are broadly consistent in indicating the shortening of the main rain seasons that means monomial rainfall shrinks and ranging from over eight months of rain to only three months (JAS) under all RCPs for all time horizons for Sokoru and Wolkite. The downscaled minimum temperature shows an increasing trend in all future time horizons for RCP2.6, RCP4.5 and RCP8.5 scenarios (Figure 9).

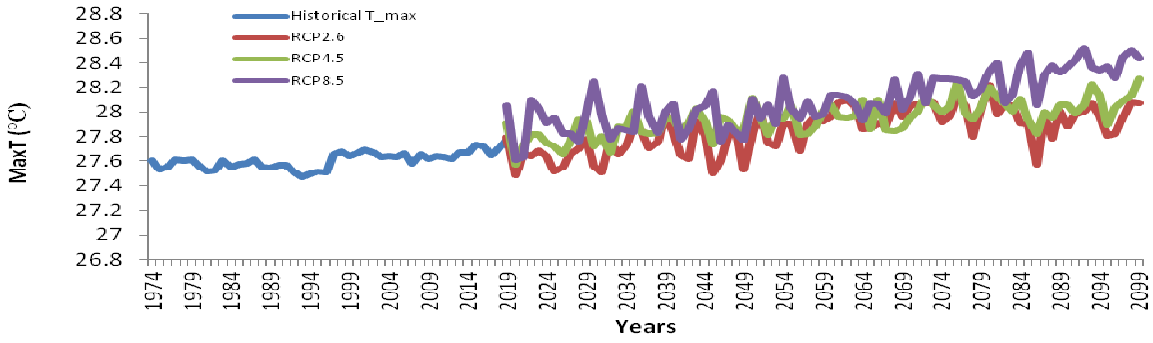

Figure 9: Projection of average maximum temperature in the highland OGB

- The average of minimum temperature increased by 1.83^{0}C, 2.95^{0}C and 3.27^{0}C, under RCP2.6 scenarios for near term, midterm and end of century, respectively. For the same time horizons under RCP4.5 scenario the minimum temperature will rise by 2.19 ^{0}C, 3.30^{0}C and 4.37^{0}C, respectively (Figure 10).

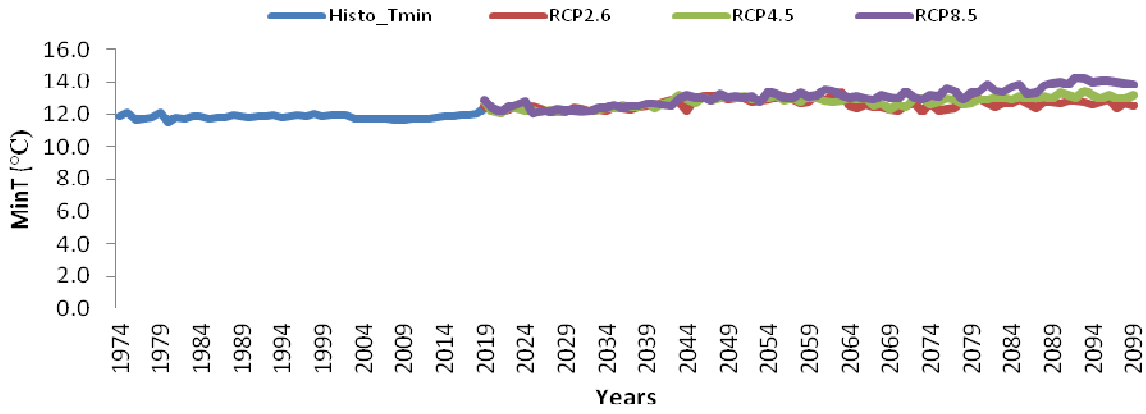

Figure 10: Projection of average minimum temperature in the highland OGB

- The climate model projection for precipitation has showed some increasing trend but with lesser degree of replication of baseline precipitation (Figure 11).

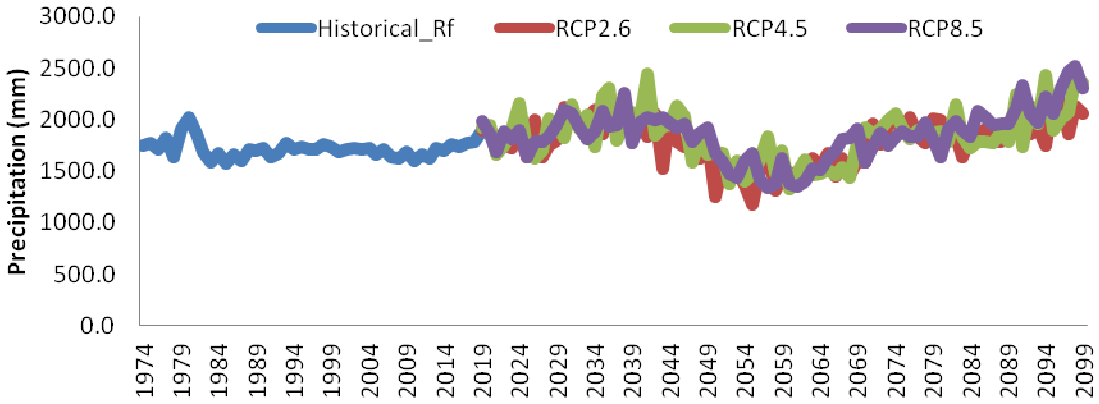

Figure 11: Projection of average precipitation in the highland OGB

Recommendations

- Developing short and long term adaptation plan
- Implementing water harvesting technologies
- Integrated of climate-risk management approaches into long-term development measures
- Forest investment around the river using different mitigation and intervention practices
- Based on the results policy makers may suggest detailed impact studies and set development plans in the future

Potential users of the information

The result of the study can be a source of material for policy makers, researchers, governmental institutions, NGOs and others.

Reliability of the information

The data was taken from NMA for multi-year recording and the analysis of the data and the results obtained were checked and validated with other similar works.

Contribution of dry forests for climate change adaptation in Tigray, Ethiopia

Responsible Researchers: Ashenafi Manaye, Berihu T/Mariam, Yirga Gufi, Zenebe Mekonnen

Brief description of the information

Despite the ecological role of dry forests, the contribution of dry forest for climate change adaptation is overlooked. Hence, the objective of this information is to show the socioeconomic contribution of dry forests and forest products to climate change adaptation in Tigray region, Ethiopia. An integrated qualitative and quantitative data analysis approach was employed. More than 94% of the total households have obtained forest products from the dry forests. Overall, dry forest contributed about 17% of the total household income. Dryland forest income reduced the area between the line of equality and the Lorenz curve, and the Gini-coefficient by 21% in dry evergreen afromontane forest users, 3% each in combretum-terminalia and acacia-commiphora woodland users. Gender, occupation, wealth status and distance of the forest from their house were variables that significantly affected the income level from combretum-terminalia woodland users. Age of a respondent in acacia-commiphora woodlands users and family sizes of the household in dry evergreen afromontane forest users have influenced dry forest income level. Therefore, dry forest income has been becoming crucial livelihood strategy in response to the changed climate in the study areas.

Introduction

Currently, climate change is one of the serious environmental, social and economic threats facing the world. Adaptation and mitigation are two broad strategies for tackling the resulting problems. In the recent international and national negotiations, sustainable forest management is one of a key strategy promoted to reduce the negative impact of climate change. Forest contributes on sustained provision of ecosystem goods and services which can help people to adapt to the local consequences of changing climate, while carbon storage on the above and belowground can contribute as climate change mitigation.

Dry forests are Africa's largest vegetation formation. They are an integral part of the ecological and social-cultural framework of smallholder farmers and pastoral societies. The role of forest

and woodlands are important in the arid dry lands than elsewhere. Ethiopia owns one of the largest dry forests in the continent, rich in biodiversity of high value tree species such as commercial gums and resins bearing species. Recent professional discourses show that, strategic integration of dry forests in Ethiopia and in the sub-Saharan Africa at large would profoundly contribute to poverty alleviation, climate change adaptation and mitigation, biodiversity conservation and combating desertification. Despite its diverse social and ecological contributions, various factors undermine mainstreaming dry forests in the dry zone development plan in Ethiopia and many other African countries. Among others, there are little empirical evidences demonstrating the actual and potential contribution of dry forests to climate change adaptation and mitigation. In spite of some efforts, there is a limited study on the role of dry forest for climate change adaptation. Therefore, this information highlighted the socio-economic contribution of dry forests and forest landscapes for climate change adaptation.

Brief methodology

Three study villages were selected from Kafta Humera, Atsibi Womberta and Raya Azebo districts of Tigray Region which are characterized by combretum-terminalia woodlands, dry evergreen afromontane forest and acacia-commiphora woodlands, respectively.

One hundred and seventy respondents, 51 from Kafta Humera, 58 from Atsibi Womberta and 61 from Raya Azebo were randomly selected from household surveys. In addition, from each district 15 key informants and one focus group were used for in-depth case study and discussion.

Major findings

The contribution of dry forest for the household income was about 24% in Atsibi Womberta, 22% in Kafta Humera and 5% in Raya Azebo (Table 3). More than 34% of the dry forest is accessed by the women to support their livelihoods. Dry forests are used for risk reduction, such as income gap, by way of diversification of income sources and assisting saving before the onset of drought. Similarly, most respondents claimed that dry forest also helps the livestock asset by being used as feed.

Table 3: Forest income of households in three districts of Tigray region, Ethiopia

Variable	**Description**	Kafta Humera	Atsibi Womberta	Raya Azebo	Total
Cash forest income	Total annual household income from sales of forest products	98	21	105	74
Subsistence forest income	Total imputed annual value of forest products used by household	1068	3954	1202	2100
Total forest income	Combination of cash and subsistence income	1166	3975	1307	2175
Share of forest income	Total forest income divided by total income	**22**	**24**	**5**	**17%**
Dry forest income	Binary indicator of forest income: 0 if forest income = 0 1 If forest income > 0	0.67	0.93	0.98	0.81

More than 51% and 35% of the respondents collected forest products from the state forest and from community forest, respectively. The majority of dry forests were used for timber and firewood production. Combretum-terminalia woodland contributed about 51% of the wall materials and 10% of the roof materials for house construction in Kafta Humera district. In Raya Azebo district, it has contributed about 73% of the wall materials and 2% of the roof materials for house construction (Figure 12).

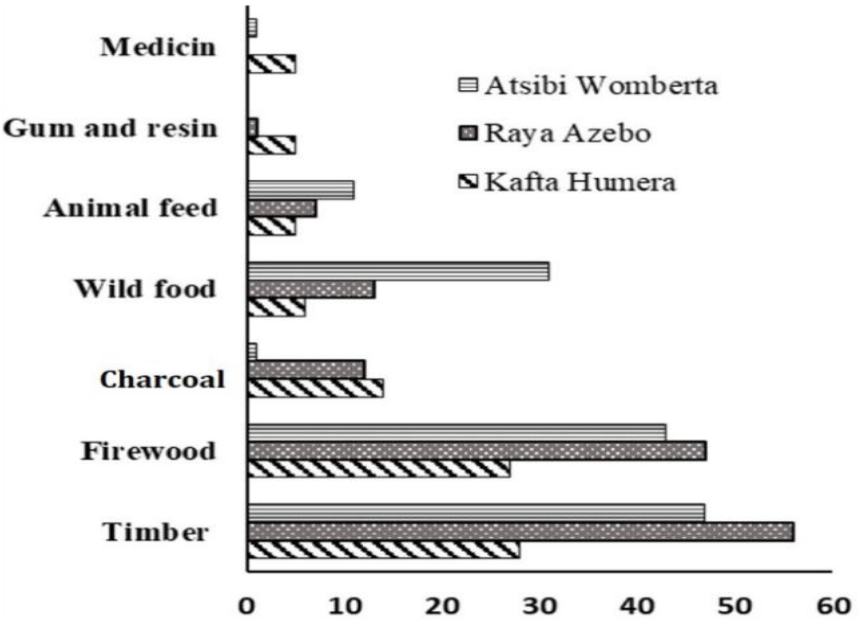

Figure 12: Proportion of respondents collecting forest products from dry forests

Dry forest income has contributed on minimizing the variation in total household incomes. It has closed the Gini-coefficient by 21%, 3% and 3% in Atsibi Wemberta, Kafta Humera and Raya Azebo, respectively.

Gender, occupation, wealth status and distance from the forest were variables that significantly affected the income level obtained from combretum-terminalia woodlands in Kafta Humera districts. Age of the respondent in Raya Azebo, and family size of a household in Atsibi Wemberta were found to influence dry forest income level significantly.

Recommendations

- Dry forest plays critical role in improving the adaptive capacity of drought prone households by contributing income and reducing the income inequality between households Therefore:
    - Dry forest income should be promoted for the target livelihood diversification on the face of climate change;
    - Advocacy should be made on the contribution of dry forest incomes and its income equalizing effect among households;

- Further studies on the impacts of climate change on selected dry land forest tree species; and how could forest income be improved to secure households' livelihood in a sustainable way, especially in food insecurity months, are needed;
- Policy makers, program managers, extension workers and the local community as well as other stakeholders should give attention on sustainable management of the dry forests and forest products for better resilience building of communities and ecosystems.

Potential users of the information

Policymakers, researchers, governmental institutions including universities and research institutes, NGOs, farmers and forest managers

Reliability of information

This information is produced from original research output that was evaluated by several professionals in the field. Information is produced from representative sample considering all possible social status of the community.

Status of emission level of cement factories in Ethiopia

Responsible Researchers: Abirham Cherint, Marta Gebreyesus, Zenebe Mekonnen, Birhanu Hailu, Moges Molla

Brief description of the information

This information provides the greenhouse gas (GHG) emission status from selected cement factories in central Ethiopia- Mugher, Derba, Habesha and Dangote cement factories. Secondary data on clinker, substituted material and energy consumption was collected from cement factories and Ministry of Industry. Since there is no country level emission factor, the analysis of the status of GHG emission was made based on the IPCC 2006 software Tire 1/default value method.

The emission level depends on amount of clinker production, efficient use of energy, use of low carbon content fuel and substituted material and use of improved technologies. Like other cement factories in the world, clinker production process and energy use are the major CO_2 emission sources from the cement factories in Ethiopia. In this regard, the highest clinker production and GHG emission was recorded in 2015. In the past five years, possible emission of 2.1 Mt CO_2e was reduced by substituting clinker by pumice, gypsum and other low carbon materials.

Introduction

Cement is an important construction ingredient around the world, and as a result, cement production is a significant source of global CO_2 emissions, making up approximately 5% of global CO_2 emissions. There are two aspects of cement production that result in emissions of CO_2. The first is the chemical reaction involved in the production of the main component of cement, clinker, as limestone are decomposed into Calcium oxide and CO_2 by the addition of heat. The second source of emissions is the combustion of fossil fuels to generate the significant energy required to heat the raw ingredients to well over 1000^oC. Cement production is a highly energy intensive production process. The energy consumption by the cement industries is estimated at about 2% of the global primary energy consumption, or almost 5% of the total

global industrial energy consumption. Due to the dominant use of carbon intensive fuels, e.g. coal, in clinker making, the cement industry is also a major emitter of CO_2.

Ethiopia's cement industry has enjoyed substantial growth in the past decade. Even if the contribution of GHG emission from the industry sector is small as compared to agriculture and forestry sectors, cement factories are the most GHG emitter from industry sectors and it will be expected to increase in the future. The baseline GHG emission for the industry sector in Ethiopia was 2.7 Mt CO_2e in 2010 and the projected GHG emission scenario to be 27 Mt CO_2e in 2015 and more than 65 Mt CO_2e in 2030. The strategy indicates that around 70% of industry abatement potential is concentrated in cement industry and this goal will be achieved through clinker substitution, use of more energy efficient technologies, usage of biomass as an energy source and so forth. Understanding the emission status from cement factories will help to highlight how the actual interventions are aligned with the country's green development goals.

Brief methodology

Secondary data for clinker production and materials used to substitute clinker were collected from cement factories and Ministry of Industry. Since there is no country level specific emission factor, IPCC default value or Tier 1 methods of data analysis were applied and IPCC 2006 inventory software was used. For those substituted materials which IPCC not incorporated on the software, we used the atomic weights of the substituted materials to calculate the possible carbon dioxide emission.

Major findings

- The cement factories had different levels of clinker production with highest in 2015 and lowest in 2014 (Figure 13).

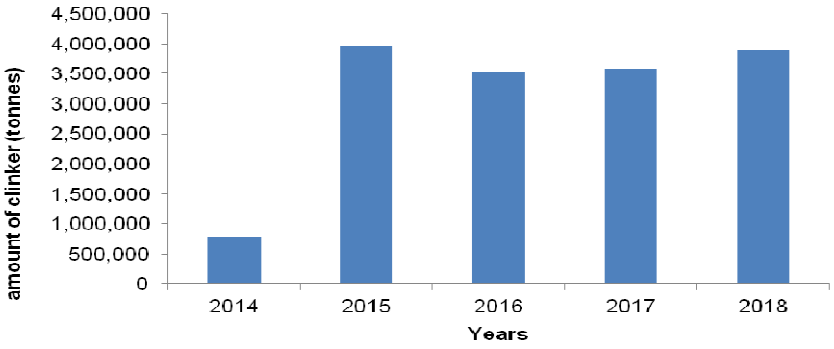

Figure 13: Amount of clinker production by cement factories (2015-2018)

- The cement factories have emitted different levels of CO_2 from pyro-processing of different raw materials for clinker production (Figure 14).

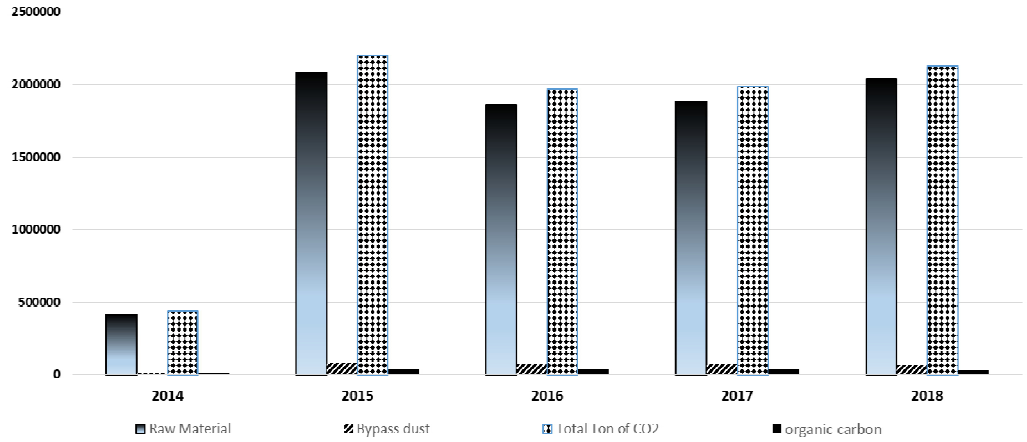

Figure 14: Carbon dioxide emission from clinker production from different raw materials

- Because the cement factories substitute high energy consumed materials such as clinker by low energy consumed materials such as pumice and gypsum, the emission trend of GHGs (CO_2, CH_4 & N_2O) from energy sources has showed a decreasing trend (Figure 15).

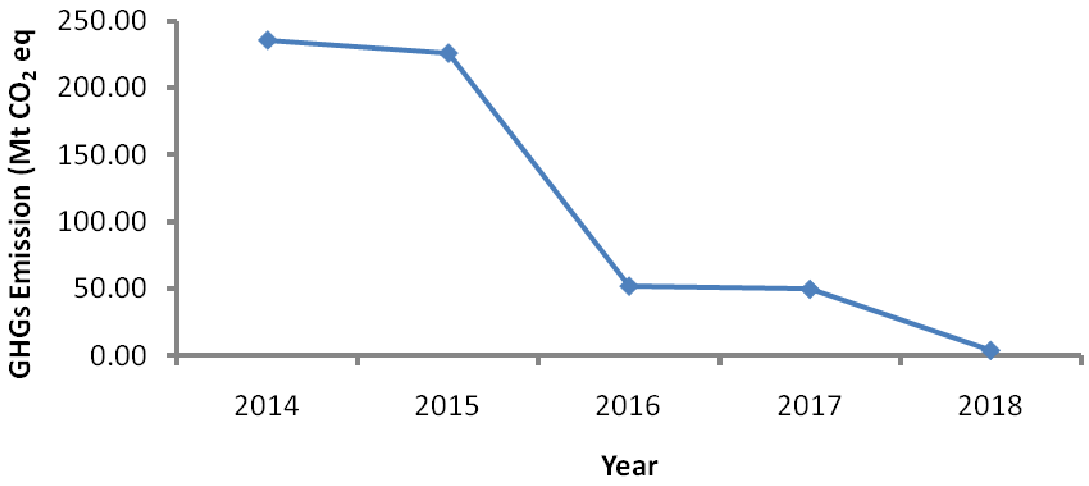

Figure 15: GHGs emission trend from energy use of cement factories

- The assessed cement factories had substituted 5.5 million tonnes of clinker by pumice, gypsum and other materials that helped to reduce about 2.1 Mt CO_2e within five production years (Figure 16).

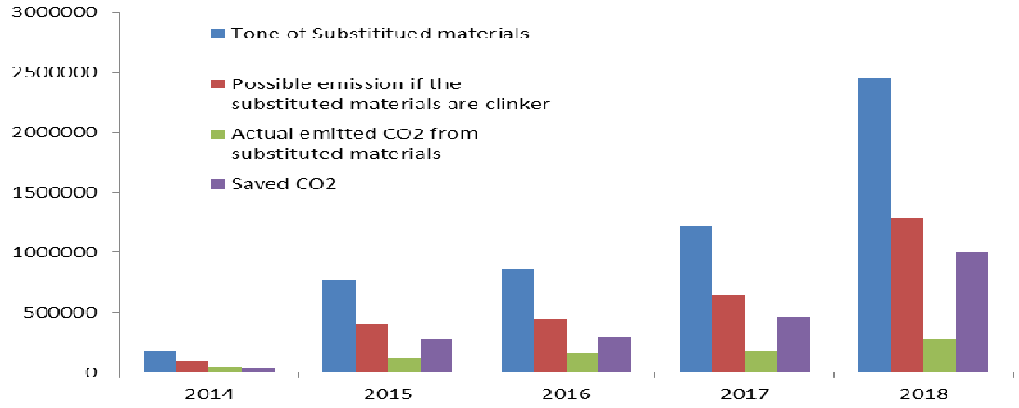

Figure 16: Potential reduction of CO_2 emission from substituted materials

Recommendations

To reduce GHG emission in cement industries it is better to:

- Improve energy efficiency
- Shifting to more energy efficient process (wet process to dry process)
- Substitute high carbon fuel by lower carbon fuel
- Shifting to lower CO_2 emitting materials
- Capture and store CO_2 from the flue gases

Potential users of the information

This finding can be a source of material for policy makers, researchers, governmental institutions, NGOs and cement industries.

Reliability of information

This information was obtained from original research work that was evaluated by several professionals who worked with the same field of study. The result obtained from the Tir1/IPCC was validated for statistical analysis and compared with other similar works.

Kitchen performance test on improved cook stoves

Responsible Researchers: Miftah Fekadu, Zenebe Mekonnen, Asenafi Manaye and Muse Tesfaye

Brief description of the information

This information is about the kitchen wood consumption of improved cookstoves in comparison to traditional cook stoves in four woredas of Ethiopia: Aseged Tsimbela in Tigray, Bure in Amhara, Amaya in Oromia and Dallocha in Southern Nations and Nationalities People (SNNP) regions. The improved stoves considered were *Mirt, Tikikil* and *Gonzie* to be compared with traditional stoves. Households were interviewed about the management and benefits of improved stoves and the amount of wood consumed in comparison to the traditional stoves. The data on the interview of the wood consumption of stove were analyzed by SPSS and the wood consumption amount by excel software developed by Shell Foundation. The information showed that using improved *Mirt*, *Gonzie* and *Tikikil* stoves shorten the time to prepare meals, save fuel, and protect the cook's hands from fire burns. Improved stoves also help to reduce the amount of CO_2 emission and indoor.

Introduction

In Ethiopia, over 90% of the total energy supply is obtained from biomass like firewood, crop residue and dung. Most of the biomass used to supply baking and cooking energy is in inefficient stoves that create wastage of energy. Improved biomass stoves were developed to improve the efficiency of the traditional stoves. Enhancing improved cookstoves reduces the amount of fuel required and can lessen the amount of time spent gathering biomass fuel, reduce forest degradation and reduce the health impact from indoor smoke pollution. Various types of improved cookstoves exist in Ethiopian rural energy workshops and market like *Awuramba*, improved *Gonzie, Tikikil, Lacketch*, *Mirt*, *Mirchaye*, etc. The desire for improved cooking stoves production and marketing across the country has been growing over time by NGOs and private traders. Cookstoves testing is crucial to evaluate the amount of wood consumption and the emission levels from household energy uses. This information was extracted from field test using kitchen performance test (KPT) with the respective stakeholders.

Brief methodology

In the selected woredas, households were interviewed to give general overview of the perception on the use, management, advantages and disadvantages of improved cookstoves. In the next step, kitchen was actually observed and firewood, sufficient to prepare three rounds of *injera* baking in improved *Mirt* or *Gonzie* stoves and three rounds in traditional open stoves, with two days' interval, was supplied to the selected households.

This information was based on the consumption of wood at measured moisture content during baking *injera* using improved *Gonzie* or *mirt* and traditional stoves. Before each baking day, the weight and moisture content of wood consumed was weighed with balance and moisture meter, respectively and recorded. And data was analyzed using excel based software developed by Shell Foundation for the purpose of energy calculation.

Major findings

In all studied woredas, it was recognized that women using improved *Mirt* and *Gonzie* stoves had shortened the time to prepare meals, improved the health condition of households by reducing smoke and protects the cook's hands from fire burns and also save fuel. In Asgede Tsimbla woreda, the improved *injera* baking *Mirt* stoves had saved wood by 34% and the improved *Tikikil* cooking stove saved wood by 18% as compared with the traditional stoves. Indeed, 37.4% and 42% wood was saved as compared with the three-stone open fire stove in Bure and Ameya woredas, respectively (Figure 17).

Figure 17: Stoves studied in Asgede Tsimbla woreda, Tigray region

In Dallocha woreda, *Gonzie* stoves saved the wood consumption by 20.2% as compared with the three stone open fire (Figure 18).

Figure 18: Traditional open stoves (left) and improved Gonzie stoves (right), Dallocha district

Despite that improved cook stoves save fuel and improve health conditions of households, there were some drawbacks on the improved *Mirt* and *Gonzie* stoves. These include size mismatch of pots/plates with improved stoves, longer time taken to set and start up fire, the stove did not heat room in cold seasons, blocked light for visibility in homes in rural areas and lack of smoke outlet or chimney.

Recommendations

To reduce emission from wood consumption and to improve the health condition of the community, the government and other stakeholders should make awareness to the community on distributing and appropriately using improved stoves with chimney. There is also a need to create market link and provision of credit for the women organized on improved cook stove production and plate size that matches with improved stoves.

Potential users of the information

The users of the information are rural farmers, development agents, agricultural or energy experts, stove designers, academia and research institutions.

Reliability of information

This information was reliable because the data was collected by the participation of local people and local experts; the information evaluated by the local energy experts at center level and at national level and relevant comments were incorporated.

Income contribution of avocado-annona based small scale agroforestry

Responsible Researchers: Lemlem Tajebe, Alemtsehay Eyasu, Diriba Abdeta, Gebeyehu Kumilacho, Dagim Amare

Brief description of the information

This study estimated and compared households' income from avocado-annona based agroforestry system and identified influencing factors for further intensification in Jimma Zone, Ethiopia. Three representative kebeles, namely, Gube Muleta, Buyo Kechema and Gibe Boso were purposively selected based on potential and accessibility of avocado and annona fruit production. The result showed that the mean gross annual income of annona practitioners from the whole produced vegetables was 7,372 ETB ha^{-1} yr^{-1} and avocado practitioners obtained 5,859 ETB ha^{-1} yr^{-1}. Gross annual income from avocado fruit was 12,284 ETB ha^{-1} $year^{-1}$ and from annona 4,017 ETB $ha^{-1}year^{-1}$. Access to extension service and total livestock holdings significantly influenced practitioners for further intensification. In avocado fruit marketing chain, producer - retailers - consumers, the retailers got the highest gross marketing margin (49%). In the producers - wholesaler - market center channel, wholesalers obtained 47.4% of the gross marketing margin.

Introduction

Fruit-tree-based agroforestry involves intentional and simultaneous association of annual or perennial crops with perennial 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 sustainable farming systems. Fruit-tree-based agroforestry has developed over long periods of time in response to interactions between agro-ecological conditions, plant diversity, and farmer resources and needs. Successful establishment of fruit-based agroforestry system can increase farm household income, enrich their diets with essential minerals, vitamins and increase varieties of fruits available in the local markets.

In the southwest part of Ethiopia, it is common to see farmers planting different varieties of tropical fruit, abundantly avocado and annona integrated with vegetables, Khat and coffee plantations in homesteads. These help farmers to get continuous income all year round, since

different products are harvested in various time. Despite the integration of common and favorable fruit trees in the area, yet knowledge on the income contributions and the various determinant factors in the management of fruits is not well identified. Thus, this information highlights the income contributions of avocado-annona based agroforestry and the major determinant factors for further intensification in Jimma Zone.

Brief methodology

The study was conducted in Gube Muleta, Buyo Kechema and Gibe Boso kebeles in Jimma zone. The kebeles were purposively selected as these areas are known with intensive avocado-annona fruit-based agroforestry production.

As observed during field visit, almost all farmers plant fruit trees in their farm land. A total of 276 (138 annona and 138 avocado practitioners) sampled household heads were purposefully selected.

Major findings

Among the total sampled household heads, 51% of avocado and 57% of annona practitioners coffee plantation was the main source of income. Farmers in the study areas plant various vegetables solely or in integration with the fruit trees and use the product for household consumption and/or as a source of income. In the homesteads, farmers plant onion, tomato, cabbage, garlic, chili, potato, Ethiopian cabbage, khat, enset and coffee in integration with fruit trees. Farmers obtained highest gross annual income from potato, Ethiopian cabbage, enset, khat and coffee as compared to other products.

The mean gross annual income of annona practitioners from the whole produced vegetables was 7,372 ETB ha^{-1} yr^{-1} and avocado practitioners was 5,859 ETB ha^{-1} yr^{-1}. Gross annual income from avocado fruit was 12,284 ETB ha^{-1} $year^{-1}$ and annona 4,017 ETB $ha^{-1}year^{-1}$ (Table 4).

Table 4: Total annual income from avocado-annona based agroforestry practitioners

	Avocado		Annona		
Vegetables	Mean annual income	n	Mean annual income	n	t-value
Onion	66	2	360	8	-1.807*
Tomato	1115	19	935	18	0.422
Cabbage	83	2	89	3	-0.064
Garlic	243	9	240	9	0.024
Chili	1953	35	1622	26	0.519
Potato	420	8	2241	15	-1.872*
Kale	1978	33	1884	30	0.179
Khat	12023	69	17379	77	-1.329
Coffee	27691	87	37850	105	-1.275
Enset	3672	31	6241	38	-1.645
Avocado-annona fruit	12284		4017		
Total	61528		72858		5.11***

Determinants of avocado-annona based agroforestry intensifications

Access to extension and total livestock holding significantly affected avocado-annona based agroforestry intensifications. Using low income category as a reference; keeping other factors constant, as access to extension service increase interest on the system increase by a factor of 1.25 for the medium income categories. As the total livestock holding increase by 1 TLU the interest of medium income categories for system intensification increase by a factor of 0.146.

Market chain analysis

Most respondents sold their fruit to retailers and wholesalers. During avocado harvesting time, traders came to farm gates to collect the fruit. Producers sold for retailers and wholesalers at farm gate with good price. The channel comparison was made based on volume that passed through each channel. The producer-wholesaler-terminal market channel took 506.42 quintal of avocado (57%) of the total volume and producer-retailers-consumers channel took a total volume of 197.87 quintal of avocado (31%) of the total marketed.

Marketing margins

Wholesalers purchased avocado fruit on an average price of 319 Birr/quintal and sold to other stakeholders on average price of 606 Birr/quintal. The gross marketing revenue of wholesaler was 287 Birr/quintal and the marketing cost was 125 birr/quintal. The net margin was 162 Birr/quintal. In the marketing chain of avocado fruit, wholesalers got 47.4% of the total margin of the marketing chain. The net profit as percentage of sale price was 27%. In gross margin of wholesaler, marketing cost contributed 44% whereas the rest 56% was the profits of wholesaler. Retailer purchased avocado fruit on average price of 425 Birr/quintal and sold to other stakeholders on average price of 837 Birr/quintal. The gross marketing margin of retailer was 412 Birr/quintal and the marketing cost was 181 Birr/quintal. The net margin was 231 Birr/quintal. In the marketing chain of avocado fruit, retailer got 49% of the total margin of the marketing chain. The net profit was 28%. In gross margin of retailer, marketing cost contributed 44% whereas the rest 56% was the profits of retailer.

Recommendations

- Provision of improved fruit tree seedlings and extension services is important to improve smallholders' fruit base agroforestry intensifications.
- Shortening the market chain and conveying an updated fruit price increases smallholders' interest for system intensification.

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.

Socio-economic impacts of community based rehabilitated degraded lands

Responsible Researchers: Weldebirhan Hailu, Eyuel Girmay, Azmera Belachew, Alemtsehay Ferede, Alemayehu Negasa and Gonche Girma

Brief description of the information

Land degradation in the Ethiopian highlands has caused occurrence of food insecurity, economic losses and various environmental hazards. To sidestep this problem, there are a number of rehabilitation efforts including exclosure. Despite the emerging, promising socio-economic intervention and ecological importance of exclosure practices in Ethiopia, very little or virtually no systematic and scientific studies were made about exclosures. Data were collected from 233 randomly selected households. This information shows the socio-economic impacts of community based rehabilitated degraded lands and their positive impacts on the livelihoods of the community.

Introduction

Land degradation is defined as a natural process or a human activity that causes the land to be unable to provide intended services for an extended time. Resources over-exploitation and inappropriate land use specifically, over-grazing, deforestation, expansion of cultivation and grazing into marginal lands, and backward agricultural practices are considered as the major causes of land degradation.

Ethiopia has been annually losing about US$ 106 million due to soil and nutrient loss through erosion, amounting to over 1.5 million tonnes per year. Generally, natural resources degradation is a leading environmental, socio-economic and policy challenge in Ethiopia.

Due to land degradation in Tigray region, the floral, faunal and microbial diversity were reduced leading to productivity decline. Rehabilitation is seen as the most worthwhile way of mitigating the effects of land degradation. In this perspective, a total of 262,000 ha have been enclosed in Tigray. This brings remarkable improvement of productivity and reduction in soil erosion. Despite the fact that exclosures have proved instrumental in the rehabilitation of degraded lands, knowledge on vegetation status and socioeconomic contribution to local people is lacking. However, lack of consistent rules and regulations, uncertainty and the lack of clarity of land tenure and public land use policy, lack of real ground community decision

making in the management and resource utilization and lack of benefit sharing from exclosures were the major problems.

This information provide the major impact of social and economic impacts of rehabilitated degraded lands and the perception of the local communities towards community based rehabilitation of degraded lands.

Brief methodology

Kola Tembien and Kilte Awulaelo woredas in Tigray region were selected purposively due to their better experience in rehabilitation of degraded lands. Then two tabia (kebeles) namely Merere, and Abreha We-Atsbeha were selected from Kola Tembien and Kilte Awulaelo woredas, respectively. In the next step, 233 households were selected using simple random sampling technique and quantitative and qualitative data were collected, analyzed and narrated.

Major findings

Farmers preferred people centered approach as it plays an important role to realize and sustainability rehabilitate degraded lands and developed considerable sense of ownership in the community, enabled them to have a common goal and relatively common understanding.

Men were active participants in area exclosure as they were involved in guarding (65%), awareness creation (41%), decision making (60%) and in coordination (51%). Passive participation of women was due to house work load and pregnancy and child care. The survey results show that most of the sample households (93.27%) from Abreha We-Atsbeha and 89.26% from Miska agreed that the practices of exclosures have enabled them to control soil erosion and /or flooding and have resulting in enhanced land value and productivity. Due to this, about 12% of the respondents from Miska and 9% from Abreha We-Atsbeha are producing vegetables and fruits two to three times per year after intervention while they were producing once in a year before the intervention.

Respondents claimed that cut-and-carry approach of using grass thatches, medicinal plants and beekeeping are activities allowed in exclosures and they benefit cash income from these (Table 5).

Table 5: Average annual household income from rehabilitated lands

	Miska	Abreha We-Atsbeha
Fodder	1405.9	1754.6
Medicinal plant	21.5	11.6
Wild fruit	413.5	353.6
Thatches	456.2	769.4
Honey	1043.9	2328.8
Farm implement	199.3	215.3
Fattening	1810	3485.4
Total	**5350.3**	**8918.7**

Farmers realize that, the rehabilitation interventions have convinced in vivid restoration changes such as reemergence of wild animals, enhance vegetation cover and water resources.

Recommendations

- To have successful rehabilitated degraded lands, particular focus should be given on empowering the women, equally and willingly in all the steps down to the project operation.
- The provision of credit for environmentally friendly activities such as beekeeping inputs, market-oriented tree seedlings, off-farm activity, alternative source of energy (cocking stoves) and training programs are recommendable. Efforts should be made by the local community, government and other stakeholders in order to clearly define and revise users' local by-laws.

Potential users of the information

Policy makers, researchers, governmental institutions, academia NGOs and communities

Reliability of information

Data was collected from different profiles of the population, and from different variables by using proper sample size to produce the estimate which made the data collected representative of the population. These make the information reliable.

Wastewater physicochemical analysis and perceived impacts of flower farms in Ethiopia

Responsible Researchers: Abera Kinfu, Biruk Gobena, Mohammed Berhanu, and Birhanu Hailu

Brief description of the information

This information illustrates the concentrations of physicochemical parameters in wastewater and the perceived impacts of five flower farms (FFs) in Ethiopia. The pH values at four flower farms were slightly acidic and below the minimum pH value (6) allowed for wastewater effluent set by the Ethiopian Environmental Protection Authority (EPA). The electrical conductivity at all FFs, sulfate and total dissolved solid at one FF, and chemical oxygen demand and phosphate at two FFs were above the provisional standard set by EPA. About 53% of respondents reported flower farms had disposed of their flower residue in the open field. It was shown that 36% of the surrounding inhabitants buy or receive empty chemical bags and containers that had been disposed of by the flower farms. Focus group discussion participants perceived the decrease in volume and quality of groundwater, a decrease in productivity, land degradation, and increased emerging diseases due to the existence of flower farms in the area. Besides, they reported abuse of employee rights, displacement of farmers from fertile land, death of cattle and fish, loss of acceptance for their agricultural and fish products.

Introduction

The demand for cut flowers in the world market has increased nowadays. Ethiopia started to enter the flower export market in the mid-1990s at a time when the EU market was much more demand-driven. Ethiopia generated over 178 million USD from flower exports. Although the contribution of the sector to GDP growth is undeniable, many scholars are doubtful about the long term impacts of this sector on the environment and welfare of the rural families.

Flower farms in Ethiopia have imported 96 types of insecticides and nematicides, and 105 types of fungicides from 2007 to 2014. Fertilizers and pesticides used extensively in the industry have been linked to negative environmental and serious health impacts. Pesticide can cause acute effects such as nerve, skin, and eye irritation and damage, headaches, dizziness,

nausea, fatigue, vomiting, abdominal pain, and systemic poisoning. It can also cause major acute effects which can cause respiratory problems, nervous system disorders, and aggravation of pre-existing conditions such as asthma.

There is very few information on the impacts of FFs on the surrounding inhabitants and environment. Therefore, this information deals on the physicochemical parameters including pH, electrical conductivity, total dissolved solids, phosphate, sulfate, and chemical oxygen demand in wastewater discharged from flower farms. Moreover, the social and environmental concerns associated with flower farms were highlighted.

Brief methodology

- Five flower farms were purposely selected (Farm 1, Farm 2, Farm 3, Farm 4, and Farm 5) in Central Ethiopia. Farm 1 and Farm 2 are found in the Southwest Shewa zone (Woliso Woreda and Bacho Woreda, respectively). Farm 3 and Farm 4 are found in the West Shewa zone (Walmera Woreda). Farm 5 is located in the East Shewa zone, Adami Tulu Jido Kombolcha Woreda.
- The cross-sectional study was conducted to assess social and environmental consequences observed by nearby inhabitants living within 2 km radius of flower farms using questionnaires, focus group discussion, and field observation from April to May 2019.
- The total sample size (n = 601) was determined using a Cochrans formula at a 95% confidence interval and 4 margin of error and the samples per study site were taken proportionally. Wastewater samples required for the determination of physico-chemical parameters such as pH, electrical conductivity, total dissolved solids, phosphate, sulfate, and chemical oxygen demand were collected from the flower farms.

Major findings

Physicochemical parameters for the wastewater

- The pH values of the four flower farms (Farm 1, Farm 2, Farm 4, and Farm 5) were slightly acidic and below the minimum pH value (6) allowed for wastewater effluent set by EPA.
- Electrical conductivity at all farms, total dissolved solid at Farm 4, chemical oxygen demand at Farm 3, and 4, sulfate at Farm 4, and phosphate at Farm 2 and 4 were above the provisional standard set by EPA.

- The wastewater sample collected from Farm 4 doesn't comply with EPA standard in all study parameters (Table 6).

Table 6: Physicochemical parameters in wastewater samples

	Mean values of parameters and EPA permissible limit					
Flower farms	**pH**	**EC(µScm^{-1})**	**TDS(mg/L)**	**COD(mg/L)**	**SO_4^{2-}(mg/L)**	**PO_4^{3-}(mg/L)**
Farm 1	5.7	3116.9	2337.7	12.8	40	2.1
Farm 2	5.8	3120	2340.3	11.2	66	11.5
Farm 3	6.5	2683.6	2012.7	339.2	125.4	7.5
Farm 4	5.9	17546.6	13160	320	716	309
Farm 5	5.4	1489.7	1117.5	16	35.1	1
EPA standard	6-9	<1000	3000	250	200	10

Waste disposal system of flower farms

- On average, 27%, 53%, and 4% of households reported that the flower farms are disposing their flower residue by burning in their compound, disposed of in an open field, and burying in their compound, respectively.
- The Anano village residents, one of Adami Tullu Jido Kombolcha district villages, use residues disposed of from flower farms to feed their cattle as an alternative feedstuff especially during the scarcity of fodder (Figure 19a).
- About 87%, 25%, 25%, and 37% of inhabitants around Farm 1, Farm 2, Farm 4, and Farm 5 have received/bought the chemical bags/containers from flower farms, respectively. They use them to fetch and store water (69.91%), for house shade (7.87%), make and store Tella and Areki (14.35%), and for sale (7.41%) (Figures 19b). The practice of cattle feeding on flower residue disposed from flower farms and the use of empty chemical containers/bags has a health risks to livestock and humans.

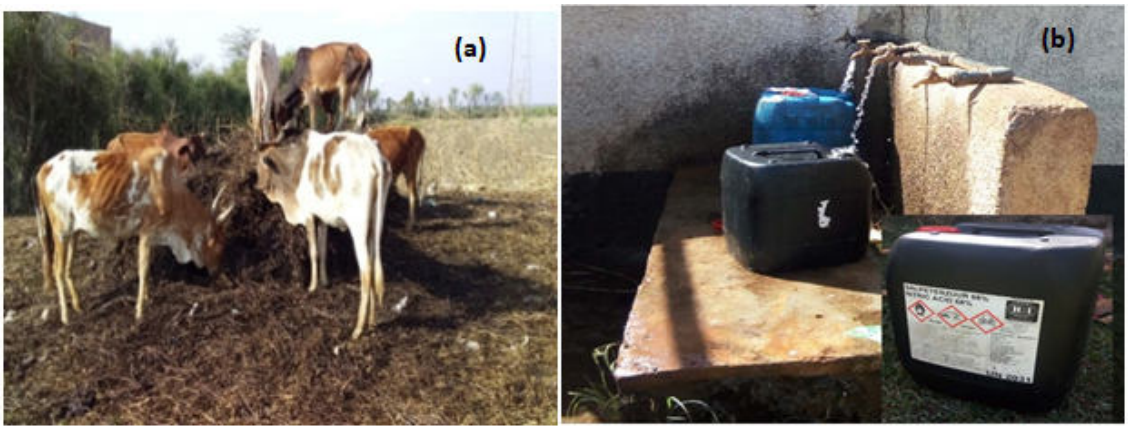

Figure 19: Cattle feeding on flower residue (a), people fetching water with jerry cans from which chemical was emptied (b)

Social complaints due to flower farms

- The majority of inhabitants around flower farms complain about high flood from the greenhouse, unfair compensation, unwillingness to implement its promises, uncontrolled water abstraction, unfair wage, chemical contamination of nearby farmland and grazing lands by flood and wind, loss of local vegetables and fish acceptability on the market, loss of farmland, decrease of crop yield, water pollution, abuse of employee rights, health problems, death of cattle and fish, funeral area demolishment, chemical odor problem and, reduced drinking water resources. Due to the above mentioned reasons almost 59% of respondents were not at all satisfied about the flower farm activity.
- However, those who gained job opportunity, drinking water provision and school service replied very satisfied and moderately satisfied.
- Respondents have perceived the increase of emerging and existing health problems and injuries due to flower farms activity in their vicinity and listed them as follows.

➢ Eye irritation	➢ Weight loss	➢ Lung disease
➢ Asthma	➢ Headache	➢ Shortness of breath
➢ Malaria	➢ Miscarriage	➢ Disability and death
➢ Convulsion	➢ Diarrhea	➢ Wounding of hands and other body parts
➢ Cough	➢ Skin lesion	

- In addition to the above findings, the common and dominant dominator views expressed by most focus group participants regarding perceived flower farms negative

impact are the decreased volume and quality of groundwater, a decrease of productivity, land degradation, loss of acceptance for their agricultural and fish product.

- FGD participants reported perceived changes in their environment attributed to flower farms such as a change in color and odor of water body, termination of springs, and decrease in fish production.

Recommendations

- The flower farms should shift to organic farming which relies on natural methods to control pests and diseases such as crop rotations, composting, encouraging the natural predators of common pests, and developing healthy flowers that have a natural resistance to pests and diseases.
- There is a need to ensure that wastewater from FFs is properly treated before it is discharged into the environment.
- Further holistic investigation should be carried out on the socio-economic and soil pollution status of the floriculture industry in Ethiopia.

Potential users of the information

Environment, forest and climate change commission, universities, policymakers, flower farming industries, consultants, and environmental auditors

Reliability of information

The information-packed are the original research works whereby the data is collected from representative samples from the surrounding communities with their participation.

Concentrations and distribution of Polychlorinated Biphenyls in soils at transformer dump site

Responsible Researchers: Sisay Abebe, Abera Kinfu and Alemaheyu Esayas

Brief description of the information

Polychlorinated Biphenyls (PCBs) are persistent toxic substances with a high potential to accumulate in soil as organic pollutant and bioaccumulate in human tissues. To assess the concentrations and distribution of PCBs, 45 composite (0-20 cm) samples were collected from 9 sampling sites that are situated in area that is being used as a maintenance workshop and dump site of transformers in Addis Ababa, Ethiopia. The extraction and cleanup of samples were done using Accelerated Solvent Extraction (ASE) with Pressurized Liquid Extraction (PLE). In addition, a checklist was used to assess existing management practice at the site. The laboratory analysis was done using GC/MS. The data were analyzed by SPSS version 20 and Origin pro 9.1. The result of the 18∑PCBs concentration is 17.16 mg kg^{-1}. The range (in dry weight) of 18∑PCBs, Dioxin-Like (DL) 12∑PCBs, and Non Dioxin-Like (NDL) 6∑PCBs, is 1.027 to 4.862, 0.561 to 1.603, and 0.166 to 4.5 $mg.kg^{-1}$, respectively. The most dominant congeners were lower chlorinated PCBs. The distribution of total PCBs concentrations was different in the entire sample tested but with a similar congener's pattern. Transformers and capacitors were dumped in open fields and directly exposed to rain and sunlight. Soil surface around the transformer area had cracks, and literally burnt which is an indication of the degree of pollution of the soil. There is poor management in handling of oil and equipment containing PCBs. It was observed that oil was leaking from transformers and barrel, and oil tankers to the open space. It is important to remediate the soil.

Introduction

Polychlorinated Biphenyls (PCBs) are chemical substances classified as Persistent Organic Pollutants (POPs) and they were first manufactured and synthesized in 1864. Out of the 209 congeners of PCBs, 197 are referred to non-dioxin-like congeners. Seven PCBs congeners are indicators of PCBs contamination in the Environment. Six of these seven are non-dioxin-like (NDL) PCBs including PCB 28, PCB 52, PCB 101, PCB 138, PCB 153 and PCB 180. Dioxin-like PCBs congeners such as PCBs 77, 81, 105, 114, 118, 123,126, 129 156, 157, 167 and 189 are also important due to their toxicological effect on humans and other living things. PCBs in general are known for their valuable properties such as fire resistance, constant

dielectric fluid, chemical stability, high thermal conductivity and electrical insulation properties. There are various sources of PCBs; however, the main source of PCBs is from capacitors that contains PCBs as an additive to transfer heat and also from transformers which contains PCBs oil. The PCBs in oil from transformers can enter the environment through poor handling of damaged electrical equipment, leakages, spillage during retro-filling and illegal dumping of waste containing PCBs. Human exposure to these chemicals is mainly through consumption of PCBs contaminated food and/ or occupational exposure. Specific adverse effects of PCBs on human beings include neurobehavioral disorders, liver damage, cancer, allergies, hypersensitivity, and birth defects.

National inventory on POPs in Ethiopia shows that there is a huge accumulation of electrical equipment known to contain PCBs in the country and these areas were designated as national PCBs hotspots. The highest number of PCBs containing transformers is found in Kotebe workshop and dump site. Generally, the area is being used as a dump site of power transformers, capacitors, and oil for over 40 years. Oil spillage from tankers and barrels is a common scene. The poor management and handling of decommissioned transformers and capacitors with long years of open storage and spillage have affected the aesthetic quality of the environment and the land in the hotspots.

Although, Kotebe workshop and dump site had achieved a PCBs hotspot status, there is no confirmatory study on both the distribution and levels of PCBs contamination. Therefore, this information highlights investigation of the concentration and distribution of PCBs based on 18 PCB congeners (6 indicators and 12 dioxins like PCBs congeners) from soil samples.

Brief methodology

- Forty-five soil samples (0-20 cm), 500 gram each, were collected using auger from nine sites at the Kotebe transformer maintenance workshop and storage site in Addis Ababa using grid sampling technique. Control soil samples were taken from the Entoto forest near the study area. The collected soil samples were thoroughly mixed to ensure a representative sample of each location and were later transferred to airtight polyethylene bag covered with aluminum sheets. To preserve sample integrity, samples were temporarily stored in an ice box. Consequently, samples were transported to laboratory and stored at $4^{o}C$.

- Analysis of all soil samples (10 grams each) was conducted at the Suzhou Hongyu Environment testing Co.LTD in China using standard laboratory protocols. The analytical method validation was performed by procedure blanks and triplicate analysis and the analysis of certified reference materials.

Major findings

- PCBs were found in all of the soil samples tested with dominance of lower chlorinated PCBs
- The range (in dry weight) of 18∑PCBs, Dioxin-Like 12∑PCBs, and Non Dioxin-Like 6∑PCBs, is 1.027 to 4.862, 0.561 to 1.603, and 0.166 to 4.5 $mg.kg^{-1}$, respectively. The concentrations of the carcinogenic dioxin-like 12 PCBs accounted for 13.74% to 43.32% of the total PCBs.
- The result obtained in this study has exceeded the Canadian soil quality guideline of residential urban areas of 1300 $\mu g.kg^{-1}$ and also above the permissible limit of screening value (0.14 $mg.kg^{-1}$) and control value (1.4 $mg.kg^{-1}$) of type I in the Chinese standard. The total concentration of indicator PCBs was more than the European Reference value for soil (20 $\mu g.kg^{-1}$) and above limit concentration of PCBs in soil that requires remediation (1000 $\mu g.kg^{-1}$)
- Currently, however, Ethiopia has no guidelines and quality standard set for PCBs in soils to compare the results.

Recommendations

- It is important that relevant authorities should design strategy of soil remediation options to lower the PCBs concentrations in the area.
- It requires safe management and disposal of PCBs containing equipment in Ethiopia.

Potential users of the information

Environment, Forest and Climate Change Commission, higher learning institutions, policy makers, Ethiopian Electric Power Utility, Ministry of Water, Irrigation and Electricity

Reliability of information

The information is based on original research design following appropriate sampling and analysis procedures.