

Potential Difference of Tree Species on Carbon Sequestration Performance and Role of Forest Based Industry to the Environment (Case of Arsi Forest Enterprise Gambo District)

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Abstract

This study attempt that to evaluate the potential difference of trees species in carbon sequestration performance. This study has been carried out through biomass estimation and quantification in Gambo district. Identification to species level, and their diameter at breast height (DBH) and height are recorded using ground measurements. The study finding shows that *G. robusta*, *P. radiata*, *C. lusitanica*, *P. patulla* and *E. grandis* were ranked 1st, 2nd, 3rd, 4th and 5th in carbon sequestration performance in the same condition respectively. Tree plantation, harvesting it and reforesting that same land has importance in socioeconomic appraisal and environmental values if and only if the forest product is used for last long products, but more than 50% of forest enterprise product after sawmill process is used for fuel wood or leftover in and around the industries. Therefore, local sawmill has to be upgraded and has to reduce the by-products or has to use it for further processing. Government and NGO have to work in the area in providing green energies. In Adama city the concern given to tree species is less than 45% rather more attention is given for shrubs, grass and selection of species is only based on the survival capacity of the species. So this study highlighted the role of each tree species in carbon sequestration and emphasize the need for greater attention to be paid to the selection of trees species in cities to have an appropriate mix of trees species that supports maximum biodiversity and maximizes environmental services.

Keywords: Biomass; Carbon offsets; Carbon sequestration; Climate change; Greenhouse gas; Carbon credit

Introduction

Background

Global emissions of carbon have been increasing for about 140 years since the beginning of the Industrial Revolution. The sharpest increase is observed during the most recent 50 years [1], principally from accelerated use of fossil fuels. Concentration of carbon dioxide (CO₂) in the atmosphere has increased by about 25% from pre-industrial levels and will approach 360 ppm by the end of year 2000. It is estimated that future doubling of atmospheric CO₂ concentration to about 700 ppm will risk an accompanying greenhouse rise of approximately 1.5-4.0°C in mean global surface temperature [2]. Ethiopia is one of the fast growing countries in which following agriculture lead to industrial economic strategies'. One of the recent foundations of industrial park in the country aims to support agricultural sector in the long run to take over the role of agriculture. Therefore, with the industrial development the effect of environmental pollution in general has to get attention and mitigation methods have to be developed. Urban greenery is supposed to get attention in the entire the country in general and specifically in the city proposed for establishments of industrial parks. Accordingly, Adama is one among those cities and also due to geographical location need to develop mitigation methods since the city is one which is fastest growing even among some Ethiopian cities. In this regard, this study made an assessment on main tree species in a plantation in the entire city and mainly five species are dominating. This tree species are; *Cupressus lusitanica*, *Grevillea robusta*, *Pinus radiata*, *Eucalyptus grandis* and *Pinus patulla*. Forest based carbon offset projects have the potential to act as both a climate change mitigation tool and a means of fostering sustainable forest conservation and preservation. While modeling has provided positive assessments of the potential for our forests to sequester large amounts of carbon, the lack of localized field studies has limited the feasibility of initiating biotic carbon emissions

offset projects in many of the countries threatened forests. This study provides an analysis of carbon storage and the potential difference for selected species to increase carbon stocks in our forest. Such an assessment is required by Ethiopia's commitments under the United Nations Framework Convention on Climate Change and as a baseline for participation in the Clean Development Mechanism of the Kyoto Protocol to the convention. Scientific concerns about the issue of anthropogenic driven global warming and global deforestation trends have driven efforts to better quantify the role of forests and tropical forests in particular, in the global carbon cycle [3]. As forests are converted to less carbon rich land cover types, such as agricultural fields or urban areas, much of the carbon stored in forest biomass is released into the atmosphere. An estimated 13 million hectares of tropical forest is lost each year to deforestation [4] emitting between 5.6 and 8.6 Gt of carbon [5]. Atmospheric carbon dioxide concentrations are increasing, a trend believed to impact the earth's climate, and it is thought that land-use change is responsible for 20-30% of the net increase over the last 20 years [6]. However, the quantification of carbon storage in tropical forests is far from complete. While many studies have aimed to establish carbon storage densities in Neotropical rainforests, estimates still vary by a factor of two [7]. Furthermore, there have been relatively few in depth carbon analyses of Sub-Saharan African forests, which may account for

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one fifth of global net primary production, [8]. Quantification of carbon storage in African forests is primarily based on extrapolation from only a few forest surveys and inventory data from the United Nations Food and Agricultural Organization [8,9]. Accurate estimation of carbon storage in tropical forests is challenging, but further refinement of current estimates is crucial to understanding how land-cover change alters the global carbon cycle and how maintaining or enhancing forest cover could be used to mitigate predicted climate change. International efforts to limit net carbon emissions have resulted in the emergence of a global market for carbon credits earned through activities that offset or reduce emissions. Indeed, over 100 countries have ratified the Kyoto Protocol of the UN Framework Convention on Climate Change, which permits developed nations to obtain carbon reduction credits through investment in emissions reduction or offset projects in developing nations, a system known as the Clean Development Mechanism (CDM). Afforestation, reforestation, and deforestation prevention have been recognized as possible means of offsetting anthropogenic carbon emissions and, as a result, national utilities, private companies, and international consortiums have begun to invest in forestry based carbon offset projects with over 150 bilateral projects having been developed by 2000 [10-13].

However, while carbon trading can be a means of supplying developing nations with financial assistance and financial incentive to maintain forests, there is concern that it could shift aid away from Africa in favor of the well-studied forests of the Neotropics [14,15] and move the focus of forestry towards plantations rather than indigenous forest protection [16]. Therefore, this study will add resources for further study in the area and will be a good start by providing best tree species in carbon storage performance within specified climatic and silvicultural condition. Model-based assessments of carbon storage in Africa's forests suggest great potential to increase carbon stocks in the region as much of the area that could support carbon rich tropical forests is currently degraded and deforested land [3,9]. Brown et al. [3] suggest that Kenya and Ethiopia, amongst other African nations, could almost double their aboveground biomass. However, while general models can identify lands that are 'technically suitable' for carbon sequestration, there is little information indicating which areas are 'actually available' for such efforts [17]. In addition to this identification of species in carbon sequestration performance is not far developed in most case. Detailed local assessments of socioeconomic, political, and cultural factors may be needed to ensure potential carbon storage increases can be achieved in a sustainable manner. Carbon sequestration through forestry and agroforestry can help mitigate global warming. For Africa, carbon sequestration also represents an opportunity to fund sustainable development through financial inflows. However, with a low share of global carbon trade, there are strong concerns that African countries are losing out on this valuable opportunity through a comprehensive review of 23 carbon sequestration projects across 14 countries [18]. These projects are expected to sequester 26.85 million t of CO₂ beyond the baseline situation. Within the continent, East Africa is the preferred destination for carbon investors. Most projects are non-Kyoto compliant and represent voluntary emission reductions. While project benefits such as increased local incomes and improved natural resources are promising, there are concerns that conversion of grasslands into tree plantations can harm local ecosystems. To attract more projects, African governments will need to build their capacity to identify relevant opportunities. This and other studies in this area are expected in order to fill the gap in this regards and also one of the step to foster such an important project all around. The long-term effectiveness of carbon sequestration depends in part on the end-uses of the wood produced through project activities.

The more durable the wood product, the greater the project's carbon storage effect in the medium and long term. However, carbon stored in wood is obviously not stored permanently; organic compounds eventually decay and some will ultimately reappear as greenhouse gases. The impacts of carbon sinks-sources are directly proportional to the "ton-years" of storage (that is, tons of carbon multiplied by the number of years for which the carbon is stored). Accordingly, this study has the following four Specific objectives. They are; to evaluate total carbon sequestration potential difference of selected species, to identify species with most carbon sinker species and considerable growth, to assess environmental value of the forest enterprise in carbon sequestration and impact of product type and to recommend a species with high potential for carbon offset for the concerned body.

Materials and Methods

Description of the study area

Location: The study was conducted at Arsi Nagelle forest enterprise of Gambo district which is under the Oromia Forest and Wildlife Enterprise (OFWE), Arsi branch in Oromia Regional State. The district is located at the eastern escarpment of the Central Ethiopian at about 240 km South of Addis Ababa, located at 6°50"-7°38"N latitude and 380' 30"-390' 06"E longitude, along the eastern escarpment of the rift valley. The total concession area of the enterprise (former) is estimated to be 21,384 ha of which 6230 ha is plantation forest and the rest (15,154 ha) is natural forest. The entire forest area is divided into four districts based on their location, they are Arbagugu, Dagaga (munessa), Gambo and sole (Shashemene). The study was conducted mainly at Gambo District. The altitude of the study sites ranges from 2100 m-2450 m ASL [19]. It is a dry Afromontane forest and extends over an altitudinal range from 2100 to 2700 m ASL.

Sampling and determination of sampling site

As per the preliminary field study made prior to the data collection, the sampling site has been determined by using stratified random probability sampling technic for each plantation of selected species. The stratification of sampling is made based on age of tree, altitude of tree, soil type, slope of plantation site and so on. The total size of the forest, the current condition of woody plant species in the area and year of establishment. There are many tools that are available for identifying and delineating project boundaries such as aerial photos, global positioning system (GPS), topographic maps, land records and others. However, for this study GPS was used for boundary delineation of the study site. Accordingly, five site for each species (total 20) of 10 × 10 m plot of uniform aged site for all four selected species is made at a time.

Types of data

The primary and secondary data were used in order to collect the important data to meet the objectives of this study. Primary data were obtained through field measurements in the study areas and the secondary data were collected from different resources like published and unpublished materials, books, journals, articles, reports from enterprise itself at different time, and electronic web sites. Data were collected from enterprise's plantation forest area by using complete listing method of individual woody plant species which have DBH ≥ 5 cm from field. Unfortunately, due to the management by the enterprise there is no sample having with less than 5 cm diameter. The complete listing method is preferred because it was easy to enumerate all the woody plants with in the study area. The area covered by woody plant species was calculated from the coordinate points recorded by GPS. The location of each quadrat was recorded using GPS.

Data collection (Vegetation data collection and identification)

The field work for data collection was made in March-April, 2015 for the first round and this has been repeated in September-November, 2016. Above ground biomass carbon stocks of trees were estimated using allometric equations from Chave et al. [20] and Chave et al. [21]. Measuring the height of trees can be a lengthy operation and increase the cost of any monitoring program. In the first round we have collected the data after the tree fall because the time is overlapped with the enterprise harvesting time. We made first marks for DBH at standing point then we took the height after fall. This will help us to get exact height of sampled tree but in the second round we have used instrument to estimate the height of the tree which is very accurate and close to the first round results which is ± 1 M differences. The quadrat size of 10 m \times 10 m was used to collect data for tree biomass following the guidelines given by Savilaakso et al. [22]. Similarly, others used [23-28], trees on the border were only included if more than 50% of their basal area falls within the plot. Trees overhanging in to the plot were excluded, but trees with their trunk inside the sampling plot and branches outside were included. Trees with DBH \leq 5 cm were measured in each plot using diameter tape but unfortunately we did not get tree with diameter of \leq 5 cm. Each tree (plants species) was recorded individually, together with its species name and vernacular name using published volumes of Flora of Ethiopia and Eritrea. To be included in the compilation, the following measurements had to be available for each tree species; diameter at breast height, (cm), total tree height, (m) and wood density, (g cm⁻³). Trees with DBH \leq 5 cm were excluded because such trees hold a small fraction of AGB in forests and woodlands [29]. The common practice for measuring DBH is to measure trunk diameter at 1.3 m aboveground. Wood density of tree species was taken from Global Wood Density Data Base [20,30]. In our actual field work we have used circumference of the tree to reduce the impact of irregular shape of tree because in most case they are not quit round shaped then the circumference was converted to diameter in which where C is circumference and r is radius of the tree. Trees with multiple stems at 1.3 m height are treated as a single individual and DBH of the largest stem were taken. Trees with multiple stems or fork below 1.3 m height were also treated as a single individual [31]. The DBH of irregular trees was measured by the help of methods developed by Smith et al. [32], Teixeira et al. [33] and Pearson et al. [34]. Trees on a slope area were measured on the uphill side. The heights of each tree were measured both at ground level and at the top tip of the tree to include the effects of slope using hypsometer in the position where possible to observe the tip of the trees.

Data analysis

Estimation of carbon in the above ground biomass: The tree biomass carbon stocks were estimated using appropriate equations applied to the tree measurements. Furthermore, databases of trees from around the world show that highly significant biomass regression equations can be developed with very high accuracy using just DBH and height. There are different allometric equations that have been developed by many scholars to estimate the above and below ground biomass. These equations differ depending on type of species, geographical locations, forest types, climate and others [35-36]. Therefore, the application of these equations to the study area was advantageous in a view of cost, accuracy and time. The equation used for the present study were two models which fit almost the condition of the study area in relation to different factors like rain fall, forest types (tropical) and so on. These two models were Chave et al. [20,21]. The general equation that was used to calculate the aboveground biomass is given as follows:

$$AGB=0.012 (\rho * DBH^2 * H)^{0.916} \quad (1) [20]$$

Alternatively, and/or

$$AGB=0.0673 (\rho * DBH^2 * H)^{0.976} \quad (2) [21]$$

Where; AGB: is aboveground biomass, DBH: is diameter at breast height, cm, H: is total tree height, m; and ρ : is wood density and species specific density that was taken from global wood density data base, g cm⁻³ [20].

Based on the relation of the biomass of the plant with carbon stock of the plant the tree biomass was converted to carbon stock in which it will found by multiplied by 50% (0.5) to get the aboveground biomass carbon content.

$$AGCs = AGB * 0.5 \quad (3) [37,38]$$

Where, AGCS is above ground carbon stock, 0.5: is conversion factor (or 50% of AGB while AGB is Above Ground Biomass).

Estimation of carbon in below ground biomass: According to Cairns et al. [39], standard method for estimation of belowground biomass can be obtained as 18%-30% of aboveground tree biomass, i.e., root-to-shoot ratio. The below ground (root) biomass to above ground (shoot) biomass ratio developed by taking the range between 0.18-0.3. So according to Cairns et al. [39], the ratio did not vary significantly with latitude (tropical, temperate or boreal), soil type (fine, medium or coarse) or tree type (angiosperm or gymnosperms). Thus, the equation developed by Cairns et al. [39], to estimate belowground biomass is depicted as follows:

$$BGB = AGB * 0.26 \quad (4) [39]$$

Where: - BGB: is belowground biomass, AGB: is aboveground biomass and 0.26: is conversion factor (or 26% of AGB).

The estimation for the below ground biomass carbon stock (BGBCS) or content of CO₂ will be derived easily from above ground biomass of the tree. Therefore, carbon stock of below ground biomass is 50% its weigh in which the same procedure was applied like that of AGB.

$$BGBCs = BGB * 0.5 \quad (5)$$

Similarly, yearly carbon sequestration amount of each species will be calculated by dividing the total sequestered carbon (C) for the total age of the tree sampled. However, this result will show that the averagely yearly sequestered C amount but not exact result as a result of the yearly sequestration performance properties of the tree will be varied with many natural and man induced factors. Therefore, the yearly sequestered Carbon (YCs) of selected tree is as follow.

$$YCs = TCs / (Tree\ age * Ni) \quad (6)$$

Where: - YCs is yearly sequestered C by individually selected tree of the species, TCs is total sequestered C in the quadrat plot while Ni is number of tree in the plot area of sampling. But TCs is the total carbon which is the summation of AGBCs and BGBCs.

Results

Assessment on Arsi forest and wildlife enterprise

The Existing Situation at Arsi Nagelle forest and wildlife Enterprise's 97% of the area is covered by forest which is composed of plantation forest, natural forest and wildlife protection areas while the rest 3% are

other land types which is occupied by building, river, road and grasses. The enterprise is one of the largest ecosystem in which it is covering the total land area of 586,195 hectares from which 407,165.24 hectares is covered with the protected natural forest, 11,562 is plantation forest mainly serving as economic appraisal sources and environmental values, 152,209.6 hectare is wildlife protected area and 15,259 hectare is other land types (enterprises office data, 2016). Total forest coverage is shown in Figure 1. This total forest in the enterprise is not in a single or continues area/ecosystem rather they are existing in different enterprises' district. In all district the concern given to the natural in other word indigenous is considerably high and appreciable. In general on aggregate 69% of the enterprise's forest is protected natural forest. In the Table 1 there is the detailed highlighted one which is Gambo district is specific selected study area which is 4th largest district in the enterprises. The distribution in entire enterprise is detailed in Table 1.

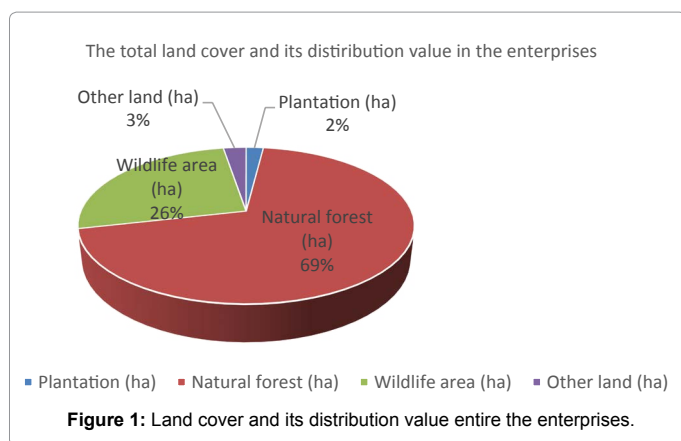
Forest composition of the entire enterprise

Natural forest: According to the field study during specified period and as of the sample taken from the field for the confirmation of secondary data collected from the main office documents, natural forest areas are not only the major and large enough in term of coverage but also in terms of plant species it also will take the majorities and many in numbers. Some of the identified and having significant and considerable coverage area are the following *Podocarpus falcatus* (podo), *Yushinia alpine* (highland bamboo), *Oleo Africana* (weira), *Cordia Africana* (wanza), *Hygenia abyssinica* (koso), *Croton macrostachyus* (Bisana), *Ficus vasta* (warka), *Syzygium guineese* (Dokma), *Milletia ferruginea* (Birbira) and some lower plant species like ferns and mosses, *Celtis africana*, *Olea hochstetteri*, and *Prunus africana*. In areas where formerly clearing has been carried out and the canopy is low *Croton macrostachyus* is a frequent species. Less common species are *Aningeria adolfi-friedrici*, *Apodytes dimidiata*, *Ficus sur*, *Schefflera abyssinica*, and *Syzygium guineense*, *Euphorbia species*, probably *E.candelabrum* occur occasionally. Frequent smaller trees are *Allophilus abyssinicus*

and *Bersama abyssinica*. *Dombia* spp., *Ekebergia capensis*, *Nuxia congesta*, *Fagaropsis angolensis*, *Linocier gordani*, *Milletia ferruginea*, *Olinia rochetiana* and *Ochna holstii* are occasional or rare. Understory species which form small trees shrubs include *Brucea antidysenterica*, *Canthium* spp., *Cassinpourea malosena*, *Caliniera coffeoides*, *Lipidotrichilia volkensi*, *Mytenus* spp., *Tecla nobilis* and *Vepris dianelli*. Smaller woody species are *Dovalis abyssinica*, *Erythrococoa*, *Rytigynia neglecta*, and *Trichocladus ellipticus*. In the herb layer *Hypoestes trifolora*, *H. vertillilaris* and *Isoglossa* spp., are frequent. Among the many other herbs which occurs on the forest floor area *Acenthopale pubescens*, *Achyrosperrum schimperi*, *Achyraanta aspera*, *Coleus garkeanus*, *Cyathula uncinulata*, *Impatiens holshetteri*, *I. rothii*, *Pavonia urens*, *Plectranthus assurgens* and other *Plectranthus* spp. Climbers include *Ipomea cairia*, *Stephania abyssinica*, *Lndolphia buchanani* and *Urera hypselodendron*. The frequently found species at or near the forest edge are *Albizia schimperana*, *Calpurnea aurea*, *Cordia abyssinica*, *Maytenus* spp. and *Olea africana*. *Vernonia stipulacea* or *Vernonia amygdalina* and the smaller *V. ampla*, are common at forest edge. Also common on these sites are *Acanthus* spp. and *Solanum* spp., climbers and other shrubs at the forest edge and include *Jasminum abyssinicum*, *Oncoba routledgii*, *Pterulobium stellatum*, *Rubus steduneri* and *Toddalia asiatica*. The bamboo occupies the more moderate slopes along the middle and upper elevation of the escarpment. It may be virtually pure *Arundinaria alpina* or may contain other woody species such as *Podocarpus gracilior*, *Hagenia abyssinica*, *Rapanea melanopholeos*, *Schefflera abyssinica* and *S. Volkensii*, *Juniperus procera*. Occurs at higher elevation but it is mostly of poor form. A small strip of forest near the south east corner of Lake Langano occupies the gently rising ground at an altitude of about 1600 m. The land lies between seasonal swamps near the lake shore and the drier woodland and cultivated land farm lots. The forest is considerably disturbed by the grazing of cattle. Principal tree species at this area are *Celtis africana*, *Croton machrostchyus*, *Ficus* spp, *Mimusops kumel*, *Podocarpus gracilior*, *Cordia abyssinica* and *Maytenus* spp.

Plantation forest species and area coverage of Arsi branch plantations.

Plantation forest is playing great role not only as a major sources of income for the entire management and running of the enterprises but it also play an important role in environmental protection activities. This category also covers considerable amount and composed of more than 20 identified and planted species. In the following table some of plantation species and their coverage area are listed in Table 2. In this plantation forest there is periodically planed yearly reforestation or plantation program is going on constantly. The average plantation rate is balanced with cutting rate and sawmills processing capacity. On average yearly 450 to 500 hectares will be planted each year of which 90% plantation is in terms of *Cupresses lustanica* species. However, equivalent amount of tree will be harvested yearly mainly for the production of lumber of different graded in volume 50000-55000 m³ is an average yearly loaded log to the sawmill. According to the data from the enterprise all the selected species



District	Plantation (ha)	Natural Forest (ha)	Wildlife Area (ha)	Other Land (ha)	Total (ha)
Adaba dodola	1,233.4	289,834	51,350	14,518	356,935.4
Arba gugu	1,364.55	62,871.78	7,886	740.7	72,989.04
Chilalo Galema	2,720.39	18147.37	87,861.31	0	90,581.7
Munessa	2,603.2	30,365.49	4,911.93	0	56,027.99
Gambo	1,341.11	5,811.38	200.31	0	7,352.8
Shashemene	2,299.37	135.22	0	0	2,434.59
Sum	11,562	407,165.24	152,209.6	15,259	586,195

Table 1: The total land cover and its distribution value in the enterprise's district.

No.	Species	Area (ha)	Percentage %
1	<i>C. lusitanica</i>	5563.19	47.38
2	<i>E. species</i>	4736	40.34
3	<i>P. patula</i>	685.88	5.84
4	<i>J. procera</i>	498.71	4.25
5	<i>P. radiata</i>	7.93	0.07
6	<i>G. robusta</i>	89.65	0.76
7	<i>H. abyssinica</i>	8.44	0.07
8	<i>O. africana</i>	0.58	0.00
9	<i>P. falcatus</i>	7.45	0.06
10	<i>E. abyssinica</i>	0.19	0.00
11	<i>C. equistifolia</i>	6.03	0.05
12	<i>A. saligna</i>	1.9	0.02
13	Coffee plantation	3.17	0.03
14	Open area	131.56	1.12
Total		11740.68	100.00

Table 2: Main plantation species composition and proportion.

S.N	Species	Coverage	Min Cutting age	Max Age	Specific Purpose of the Product	Remarks
1	<i>C. lusitanica</i>	5563.19	12	25	Lumber production	
2	<i>E. species</i>	4736	7	20	Construction, Transmission pole	
3	<i>P. patula</i>	685.88	12	25	Lumber production	
4	<i>G. robusta</i>	89.65	12	25	lumber production	
5	<i>Pinus radiata</i>	7.93	12	25	lumber production	

Table 3: Selected plantation composition cutting age and distribution.

is fast growing plant species in which the minimum maturity age is 7 for E species while 12 for other species and also the maximum saturation or maximum productivity age is 25 years for other species while in case of E species is 20 years. The main planned product of the enterprise is to produce products for last long uses which is environmentally important products. Those are for lumber, construction material like pole for transmission and the like. The following table will illustrate the selected species coverage minimum and maximum cutting/productivity age of the species (Table 3).

Trend of the sawmill industries for end product impact assessment

Lumber and other low graded material production: The enterprise has its own sawmill in each district. Those sawmills will produce all most all types of products with relatively close production efficiencies. They are basically six types of products produced in the industry. Those product types are lumber with maximum quality which covers nearly around 16% of the products, first graded slab products which is 16% of the total production, 2nd graded slab which is about 13% of the products, fuel wood is about 4%, the largest amount of the product is locally called “kurtame” which is accounted about 48% and sawdust is 4% of the products. Kurtame is not the major product in the industries it is accounted as byproduct of sawmill and can be used for diversified uses such as fuel wood, furniture, fences, construction and the like. It is byproduct types with irregular shape and sizes. The types and distribution of the product is exactly the same entire the enterprise’s different district. The distribution patterns of the product type are as follow in Figure 2. The duration of carbon storage will be affected by the types of the product for what purpose it has been designed. If the produced product is used for the purpose like construction, sequestered

carbon amount will be good and environmental advantages’ of the sawmill will be high but if the product is for immediate use such as fuel purposes, it has high negative impact on the environment. Among those product of sawmill lumber, 1st and 2nd graded slab is used for last long purposes which is environmentally important. However this is only accounts 45% of the products while sawdust which is 4% and fuel wood of 4% totally 8% of the product is used for the immediate carbon releasing purposes. This means that from this enterprise alone 7374.266 m³ of wood is produced for fuel wood. Its equivalent carbon release is huge enough to worry but it is difficult to measure because there are many species being mixed. Even though the 48% of the product is unknown for what purpose the user is using and needs other investigation, the amount of fuel wood and sawdust is high enough for environmental impacts of current status of the industries. Generally kurtame (cut-off) is accounted for 48% of the product which irregular shape and sizes mostly used by the local people for fuel wood. Therefore, in this regard enterprise has to be upgraded to utilize those byproducts for last longer products rather than providing them for fuel wood. The product composition and amount for the last three years are as follow in Tables 4-7. On average the sawmill have been processed 188445.4 m³ log for the past 6 year on average yearly 31407.57M³ with average conversion of lumber is that of 49% in which yearly 15389.71 m³ of lumber is produced on yearly basis. The following table is showing the yearly production of the enterprise’s in different districts.

Byproduct and fuel wood products: It is clear and so natural that in any sawmill industrial activities there are left over/byproduct will rise up. Surely all industries are unwilling to have such high byproducts and all kinds of industries are so interested to reduce or to reuse this byproduct. In case of sawmill in the Enterprise’s averagely 49% is planned or main product while the other 51% is byproducts. Among

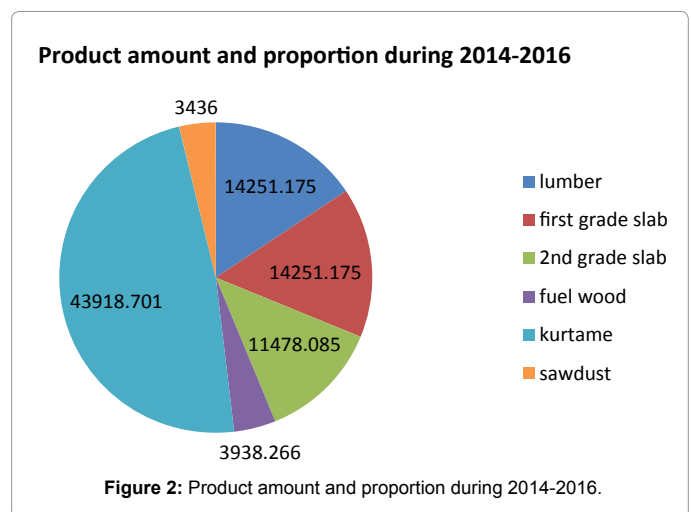


Figure 2: Product amount and proportion during 2014-2016.

Product Proportion of the Enterprise’s During 2014-2016		
Product type	Amount	Percentage
Lumber	14251.175	16%
First grade slab	14251.175	16%
2nd grade slab	11478.085	13%
Fuel wood	3938.266	4%
Kurtame (cut-off)	43918.701	48%
Sawdust	3436	4%
Total	91273.402	100%

Table 4: Product of the enterprise during 2014-2016.

S. No.	District	General Proportion of Product Type and their Percentage of Recovery with Total Input 2014/15 g.c or 2007-08 e.c.									
		Lumber		First grade slab		2nd grade slab		Fuel wood		Kurtame	
		Amount in m ³	Percentage of recovery	Amount in m ³	Percentage of recovery	Amount in m ³	Percentage of recovery	Amount in m ³	Percentage of recovery	Amount in m ³	Percentage of recovery
1	Munessa	3700.72	49.7	156.633	2	2725.165	37	688.488	9	80.8	1
2	Gambo	1360.63	48	114.182	4	1398.116	50	222.789	8	18.9	1
3	Shamanne	2949.45	47.5	223.689	4	2262.911	36	1010.9	16	115.7	2
4	A/Nagelle	5456.14	48.7	559.038	5	4429.489	40	1664	15	276	2
5	A/Gugu	784.24	42.5	77.901	4	662.404	36	352.129	19	121.5	7
6	Total	14251.175	48.3	1131.443	4	11478.085	39	3938.266	13	612.9	2

Table 5: Proportion of product type and their percentage of recovery.

Yearly Lumber Production rom 2003-2008 E.C in Cubic Meter								
S. No.	District	2003-05	2006	2007	2008	Total Lumber	Log Input	% of Conversion
1	Munessa	14642.64	4181.475	3517.21	3700.717	26042.04	53147.03	49.0%
2	Gambo	7112.515	1889.791	1780.843	1360.634	12143.783	24783.23061	49.0%
3	Shamanne	8961.58	2442.499	2379.496	2949.447	16733.022	34149.02449	49.0%
4	A/Nagelle	17834.132	5119.84	4668.573	5453.14	33075.69	67501.4	49.0%
5	A/Gugu	2722.849	187.966	648.664	784.237	4343.716	8864.727	49.0%
	total	51273.716	13821.571	12994.786	14248.175	92338.251	188445.4121	49.0%

Table 6: Average yearly lumber production for the past 6 years.

S. No.	District	July–September, 2015, m ³	October–December, 2015, m ³	January–March, 2016, m ³	April–June, 2016, m ³	Planned for 2015-2016, m ³	Total	Remark
1	Munessa	90	296	294	258	938	938	
2	Gambo	46	152	150	132	480	480	
3	Shamanne	69	226	229	196	720	720	
4	A/Nagelle	114	378	378	330	1200	1200	
5	A/Gugu	9	31	31	27	98	98	
	Total	328	1083	1082	943	3436	3436	

Table 7: Saw dust produced proportion in 2015/16 G.C or 2008-09 E.C.

S/No.	District	2015/16 G.C or 2008-09 E.C.					2014/15 G.C		Remark
		July-September, 2015, m ³	October-December, 2015, m ³	January-March, 2016, m ³	April-June, 2016, m ³	Planned for 2015-2016, m ³	Total	total	
1	Munessa	8	28	26	24	86	86	80.8	1
2	Gambo	4	13	13	11	41	41	18.9	1
3	Shamanne	12	36	40	36	124	124	115.7	2
4	A/Nagelle	32	106	108	83	329	329	276	2
5	A/Gugu	6	20	21	18	65	65	121.5	2
6	Total	62	203	208	172	645	645	612.9	

Table 8: Kurtame produced in 2014-16 G.C or 2007-09 E.C. in m³.

the byproduct which is common in anywhere sawmill established there is saw dust. In Arsi branch alone yearly on average 3,436 m³ of saw dust will be produced which is mainly used for fuel wood.

Kurtame (cut-off): This is a kind of byproducts of the enterprises which is irregular in shape and sizes. Mostly kurtame has 5-10 cm long and irregular width and thickness. This cut of product is basically come from the allowance added from harvesting sizes in order to produce marketable lumber sizes. Till now there is no any attempt to either to reduce the amount or to convert to other valuable product especially products which is significant to the environmental problem. So therefore, called kurtame and sawdust is one of the major problem in all visited sawmill and that is used by local community for fuel wood. The following table shows one year kurtame produced in the enterprises (Table 8).

Selected species carbon sequestration performances

Cupressus lusitanica: *Cupressus lusitanica* is one of the largest

compositions/compartments in the area. Currently 47% of the existing plantation and 90% yearly plantation as per the data from the enterprise have averaged 29.28 tons of carbon by a single plant. This will make the species 3rd ranked among selected plants for this study. This plant shows us highly deviated from average value due to some of either of natural and anthropogenic activities or both factors. In this plant there is less possibility for other plants to grow under the canopy in the area as compared with *Pinus radiata* and *Pinus patulla* species. Both species are affected by other invasive and natural forest. Because, other species can easily grow under the canopy of *P. radiata* and *P. patulla* and reduces the growth rate of them (Table 9).

Grevillea robusta: *Grevillea robusta* is one of the largest compositions/compartments in the area. Currently 0.79% of the existing plantation and one of highly planned plant species future onwards as per the data from the enterprise. This plant is also accounted highest plantation species in Adama city for urban

greenery and holding 60% tree plantation in the city. It has averagely 44.61 tons of carbon by a single plant on yearly basis. This will make the species first ranked among selected plant for this study. This plants shows us highly deviated from average value due to some of either of natural and anthropogenic activities or both factors. The maximum sequestration is 140.18 while the minimum is 9.47 tons. In this plant there is less possibility for other plants to grow under the canopy in the area as compared with *Pinus radiata* and *Pinus patulla* species. Both species are affected by other invasive and natural forest. Because, other species can easily grow under the canopy of *Pradiata* and *P.patulla* and reduces the growth rate of them. *G. robusta* is highly dominant species and it is easier to increase sequestration performance with silvicultural treatment and favorable natural environments (Table 10).

***Pinus radiate*:** *Pinus radiata* will cover 7.93 hectares in the enterprises which is 0.7% of the total plantation and 2nd major plant species in Adama city for urban greenery. It is one of the largest compositions/compartment in the area. This plant is also accounted earlier it was highest plantation species in Adama city for urban greenery and but now rarely planted in the city. In the observation we have seen that this plant shoot and rood will be affected easily as compared to other and also serving/hosting plant for wildlife. It has averagely 37.75 tons of carbon by a single plant on yearly basis with other plant competition while individually 39.99 tons of carbon will be sequestered. This will make the species 2nd ranked among selected plant for this study. This plant shows us low deviation from average value due to some of either of natural and anthropogenic activities or both factors. Good resistance of those factors. The maximum sequestration is 77.23 while the minimum is 2.7 tons. In this plant there is high possibility for other plants to grow under the canopy in the area as compared with other species. This species is affected by other invasive and natural forest. Because, other species can easily grow under the canopy of *P. radiata* and *P. patulla* and

reduces the growth rate of them. *P. radiata* is highly dominated by other species however the performance is constant relatively so not easier to increase sequestration performance with silvicultural treatment and favorable natural environments (Table 11).

***Eucalyptus grandis*:** *Eucalyptus grandis* is one of the largest compositions/compartment in the area. Currently 40.34% of the existing plantation and one of highly planned plant species future onwards as per the data from the enterprise. However this plantation species does not exist in Adama city for urban greenery. It has averagely 11.19 tons of carbon by a single plant on yearly basis. This will make the species least ranked among selected plant for this study. This plant also shows us least deviation from average value due to some of either of natural and anthropogenic activities or both factors. Good in survival capacity than others. The maximum sequestration is 89.74 while the minimum is 1.58 tons. In this plant there is less possibility for other plants to grow under the canopy in the area as compared with *Pinus radiata* and *Pinus patulla* species (Table 12).

***Pinus patella*:** *Pinus patulla* is one of the 3rd largest compositions/compartment in the area. Currently 5.84% of the existing plantation which is 685.88 hectare. However this plantation species exist very rarely in Adama city for urban greenery. It has averagely 28.68 tons of carbon by a single plant on yearly basis. This will make the species 4th ranked among selected plant for this study. This plant also shows us moderate deviation from average value due to some of either of natural and anthropogenic activities or both factors. Relatively moderate in survival capacity. The maximum sequestration is 105.23 while the minimum is 1.88 tons. In this plant there is less possibility for other plants to grow under the canopy in the area as compared with *Pinus radiata* species. The main unique property of this species is highly eaten by wildlife so the growth is retarded & affected by microorganism (Table 13).

	DBH cm	Height m	Density g/cm ³	AGB kg	BGB kg	AGCs t/sps	BGCs t/sps	TCs t/sps	Ycs t/sps
Count No	126.0	126.0	126.0	126.0	126.0	126.0	126.0	126.0	126.0
Mean	27.08	21.08	0.43	418.28	108.75	209.14	54.38	263.52	29.28
Minimum	11.78	7.60	0.43	40.15	10.44	20.08	5.22	25.30	2.81
Maximum	47.74	34.00	0.43	1334.15	346.88	667.08	173.44	840.51	93.93
Standard	7.29	5.83	0.00	269.30	70.02	134.65	35.01	169.66	18.85

Table 9: *Cupressus lusitanica* carbon sequestration performances.

	DBH cm	Height m	Density g/cm ³	AGB kg	BGB kg	AGCs t/sps	BGCs t/sps	TCs t/sps	Ycs t/sps
Count No.	126.0	126.0	126.0	126.0	126.0	126.0	126.0	126.0	126.0
Mean	23.18	28.51	0.63	566.44	147.28	283.22	73.64	356.86	44.61
Minimum	14.96	10.00	0.63	120.21	31.26	60.11	15.63	75.73	9.47
Maximum	40.43	39.00	0.63	1780.04	462.81	890.02	231.41	1121.43	140.18
Standard	4.69	5.93	0.00	316.84	82.38	158.42	41.19	199.61	24.95

Table 10: *Grevillea robusta* carbon sequestration performances.

	DBH cm	Height m	Density g/cm ³	AGB kg	BGB kg	AGCs t/sps	BGCs t/sps	TCs t/sps	Ycs t/sps
Count NO.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean	31.18	25.69	0.48	719.09	186.96	359.55	93.48	453.03	37.75
Minimum	13.69	10.00	0.43	51.40	13.37	25.70	6.68	32.38	2.70
Maximum	42.34	34.00	0.50	1471.00	382.46	735.50	191.23	926.73	77.23
Standard	6.96	6.50	0.02	377.01	98.02	188.50	49.01	237.51	19.79

Table 11: *Pinus radiata* carbon sequestration performances.

	DBH cm	Height m	Density g/cm ³	AGB kg	BGB kg	AGCs t/sps	BGCs t/sps	TCs t/sps	Ycs t/sps
Count NO.	113.0	113.0	113.0	113.0	113.0	113.0	113.0	113.0	113.0
Mean	12.91	12.15	0.69	88.79	23.08	44.39	11.54	55.94	11.19
Minimum	6.68	6.90	0.69	12.57	3.27	6.28	1.63	7.92	1.58
Maximum	21.96	68.00	0.69	712.22	185.18	356.11	92.59	448.70	89.74
Standard	3.88	6.19	0.00	79.86	20.76	39.93	10.38	50.31	10.06

Table 12: *Eucalyptus grandis* carbon sequestration performances.

	DBH cm	Height m	Density g/cm ³	AGB kg	BGB kg	AGCs t/sps	BGCs t/sps	TCs t/sps	Ycs t/sps
Count No.	113.0	113.0	113.0	113.0	113.0	113.0	113.0	113.0	113.0
Mean	23.03	22.57	0.48	364.19	94.69	182.09	47.34	229.44	28.68
Minimum	7.64	8.00	0.45	23.89	6.21	11.94	3.11	15.05	1.88
Maximum	39.00	37.00	0.69	1336.21	347.41	668.10	173.71	841.81	105.23
Standard	6.61	7.79	0.07	272.99	70.98	136.50	35.49	171.98	21.50

Table 13: *Pinus patulla* carbon sequestration performances.

Conclusion and Recommendation

Conclusion

This study was conducted at Arsi Nagelle Forest and wildlife enterprises of Gambo district for the field works, secondary data is taken from each sawmill of the enterprises and assessment of urban greenery have been made at Adama. The sites contain only plantation of the selected species in a very rare case 5 species have found in the area of plot for the study. In the site *Grevillea robusta* is less support of other species and having highest survival capacity as compared to other selected species. This species have maximum potentials to sequester carbon this potential will reach up to 140.18 ton/tree in a favorable condition to grow. This plant species is recommendable for urban greenery but less tolerable with other species and will get dominance over the other and will destroy other. *Pinus radiata* and *Pinus patulla* is showing good characteristics in supporting other species both animal and plant species but less carbon sequestration performance when it is compared with *Grevillea robusta* in the area. In other case except *Grevillea robusta* and *Eucalyptus grandis* all are susceptible for root and shoot damage in case of urban greenery. In selected study site with concerned plant species, the study finding shows that *Grevillea robusta* is the 1st ranked best plant species among five selected species having minimum 9.47 tons/tree carbon sequestration performance for a single tree, mean 44.61 tons/tree and maximum of 140.18 tons/tree in some exceptional and favorable condition with good control of invasive plant species and healthy stand in all 5 plots. Similarly, *Pinus radiata* is the 2nd ranked best plant species among five selected species having minimum 2.70 tons/tree carbon sequestration performance for a single tree, mean 37.75 tons/tree and maximum of 77.23 tons/tree in some exceptional and favorable condition with good support of invasive plant species and wildlife with relatively affected root and shoot in all 5 plots. *Cupressus lusitanica* is the 3rd ranked best plant species among five selected species having minimum 2.81tons/tree carbon sequestration performance for a single tree, mean 29.28 tons/tree and maximum of 93.39tons/tree in some exceptional and favorable condition with fair control of invasive plant species and healthy stand in all 5 plots.

Pinus patulla is the 4th ranked best plant species among five selected species having minimum 1.88 tons/tree carbon sequestration performance for a single tree, mean 28.68 tons/tree and maximum of 105.23 tons/tree in some exceptional and favorable condition with good support of invasive plant species and wildlife with relatively affected root and shoot in all 5 plots while *Eucalyptus grandis* is the

least plant species among five selected species having minimum 1.58 tons/tree carbon sequestration performance for a single tree, mean 11.19 tons/tree and maximum of 89.74 tons/tree in some exceptional and favorable condition with good control of invasive plant species and healthy stand in all 5 plots. The tree plantation and harvesting it and then reforesting that same land has importance in socioeconomic appraisal and environmental values if and only if the forest product is used for last long products such as furniture, construction materials and others such like but more than 50% of forest enterprise product after sawmill process is used for fuel wood or left as solid waste in and around the sawmill industries. This is more and more problem as far as environments concern. Therefore, sawmill has to be upgraded and try to reduce the by-products used for fuel rather for product like chip wood and others. In Adama city the concern given to tree species with longer height is less than 45% as per the assessment made during this study. With high attention for aesthetics values and due to local practices more attention is given for shrubs and grass. The basic foundation for the selection of the species are local practices, survivals capacity of the species and easily availability in the area but no selection of species specially its environmental significance. So this study highlights, the role of each tree species covers in carbon sequestration.

Recommendations

The study will contribute as a baseline research for the contribution of urban greenery, the planner of Public Park in the emerging city and wood base industries to climate change mitigation and get advantage over carbon offset projects in addition to its recreation and aesthetic value. There are a number of parks visited throughout the Adama town and Addis Ababa which are designed for the purpose of recreation and some of them just have the name but there is no more number of trees due to poor management which converted it in to mostly grass. Therefore, action has to be taken in including important tree species plantation same as grass. This study highlight the role of each tree species cover in carbon sequestration and emphasize the need for greater attention to be paid to the selection of trees species in cities, not just with a view to easy maintenance as is currently the case in most of Ethiopian city beautification in general and specifically Adama the most fastest growing city and becoming center of trade and surrounded by industrial expansion. The Adama city urban greenery and any other concerned for urban greenery and carbon offset project in the country has to select an appropriate mix of trees species that supports biodiversity and maximizes environmental services. In most of wood based industrial process especially sawmill industries are mainly concerned

with the proportion of the amount of harvesting and re-plantation of harvested land. But the types of end product uses of sawmill has to be the major concern as far as environmental problem is concerned. Those industries with high proportion of last longing product such as construction material and the like, has to get more the advantage of carbon financing. In Oromia forest and wildlife enterprises, sawmill industrial processed product/by-product such as fuel wood, kurtame (cut-off) and sawdust is the major environmental problem need to be addressed. The end uses of product of forest based industries, has to get the same value of concern as of forestation and reforestation from carbon financing. In this study the potential difference of selected tree species are identified. Accordingly, *Grevillea robusta*, *Pinus radiata*, *Cupressus lusitanica*, *Pinus patulla* and *Eucalyptus grandis* is ranked 1st, 2nd, 3rd, 4th and 5th in carbon sequestration performance in the same condition respectively based on mean value of yearly sequestered value of carbon per a tree. Therefore, by considering the potential of the species in carbon sequestration performance in addition to sanctification, survivals capacities of the species in the proposed area and resistance to anthropogenic activities *Grevillea robusta* is best recommended both for Public Park and urban greenery. Generally the study shows that in the future it should be known that the role of tree and selection of tree species in climate change mitigation and organizing the urban area park for carbon finance behind beautification of the cities can help for the entry point of climate finance. Doing carbon sequestration research and organizing the data for the country is mandatory to know the amount of country emission and offset of CO₂ in city. This helps the country to plant more trees to compensate it. To withstand forest/tree in the urban area, public awareness needs appraisal, anybody including government and non-governmental organization one who is taking the responsibilities of urban area beautification supposed to integrate the idea of carbon finance, urban beautification and providing good air filter for the community has to be mandatory.

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