Sci. Technol. Arts Res. J., April-June 2018, 7(2), 26-37
DOI: https://.doi.org/10.20372/star.v7i2.04
ISSN: 2226-7522 (Print) and 2305-3372 (Online)
Science, Technology and Arts Research Journal
Sci. Technol. Arts Res. J., April -June 2018, 7(2), 26-37
Journal Homepage: https://journals.wgu.edu.et

Original Research

Carbon Stock Estimation of Selected Tree Species of Gambo Plantation Forest, the Case of Arsi Negelle, Ethiopia

Hanbesa Hashim[1] Tena Regasa[1,2*] & Yirdaw Meride[3]

[1]Department of Environmental Resource Management, Wollega University, Nekemte, 395, Ethiopia
[2]Department of Biology, Wollega University, Nekemte, P.O. Box, 395, Ethiopia
[3]Department for Environmental Science, Hawassa University, P.O. Box, 05, Hawassa, Ethiopia

Abstract

Carbon stock assessment is important to estimate carbon stock potential of forest. In Ethiopia, assessment of carbon stock potential of forest begun in recent years. Though, different studies have been made in Ethiopian forests, Gambo Plantation Forest has not yet been studied. So, the aim of this study was to analyze the carbon stock potential of selected tree plant species in Gambo plantation forest. A systematic random sampling method was used to take samples. Sampling plot of (20m x 20 m) was established for each species. The diameter was measured at breast height to estimate biomass of trees in sampling plots. Tree height was recorded by using a measuring hypsometer. Soil and litter samples were collected from the field with five sub-plots within each major plot. Results revealed that the total mean carbon stock of the Gambo plantation forest was 795.51t/ha of which above ground carbon share 407.07, below ground carbon 80.37, litter fall carbon share 1.43 and soil organic carbon was 306.64 (up to 30cm depth). The ultimate result implies that Gambo Plantation forest is a reservoir of high carbon stock. The presence of high range value of carbon stock in the sites indicates its potential to mitigate climate change by absorbing greenhouse gases from the atmosphere. Effective forest revenue system should be in place, and revenues generated from all marketed forest goods and services should be reinvested in the sector for the sustainable production and forest management.

Article Information

Article History:
Received : 21-04-2018
Revised : 15-05-2018
Accepted : 20-06-2018

Keywords:
Above ground biomass, Carbon sequestration, Litter fall, Plantation forest, Soil organic carbon

*Corresponding Author:
Tena Regasa

E-mail:
tenaregasa@gmail.com

INTRODUCTION

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It is an alarming issue in the world that needs higher priority and immediate concern of every individual stakeholder of the Earth (Anup *et al*., 2013). Increment in Carbon dioxide (CO2) concentration, along with other greenhouse gases (GHG), are the causes for global climate change. Carbon dioxide is by far the most contributors, accounting 72% of the total anthropogenic greenhouse gases, causing between 9-26% of the greenhouse effect (Kiehland & Trenberth, 1997). Increasing of CO2 concentration in the atmosphere linked to an increase in the atmospheric temperature (Correia *et al*., 2010).

Carbon emission is resulted from various anthropogenic activities mainly, from deforestations and forest degradation. Deforestation and forest degradations in the tropic regions, have contributed to 90% of the greenhouse gas emissions from Land Use, Land Use Change, and Forestry (LULUCF) (Correia *et al*., 2010).

Globally, forests cover about 4 billion hectares (ha) of land, or 30% of the Earth's land surface (FAO, 2009). Tackling climate change is one of the most important roles of forest by storing and sequestering carbon (IPCC, 2007). FAO (2010) estimated that the world's forests store 289 Giga tone (Gt) of carbon in their biomass alone. Furthermore, the report highlighted that 5.2 million hectares of tropical forest land were lost per year between 2000 and 2010, with the highest deforestation rates reported in Africa and South America. It is projected that if the forest loss continues at this rate, there will be nearly no tropical rainforest remaining by 2035 (Anup *et al*., 2013).

Ethiopia is one of the countries that have significant amount of forest resources. The recent data on forest resources of Ethiopia reported in FAO (2010) puts Ethiopia among countries with forest cover of 10-30%. According to this report Ethiopia's forest cover (FAO definition) is 12.2 million ha (11%). The trees and forests of Ethiopia are under tremendous pressure because of the radical decline in mature forest cover and the continual pressures of population increase, inappropriate farming techniques, land use competition, land tenure, and forest modification or change and conversion (Yitebtu Moges *et al*., 2010).

Gambo Plantation Forest is a state-owned forest managed by Oromia forest and wildlife enterprise (OFWE). It is degraded due to illegal cutting and extraction of fuel wood (Mulugeta Lemenih *et al*., 2008). The rate at which Carbon dioxide is being sequestered from the atmosphere has increased as a result afforestation, reforestation and reducing deforestation (IPCC, 2001). Therefore, this study was intended to show the carbon stock storage potential of selected tree species and their role in climate change mitigation.

MATERIALS AND METHODS

Description of Study Area

Gambo Plantation Forest is situated in Arsi Negelle district, Oromia National Regional state of Ethiopia. The forest is located at the latitude 6° 50'-7°38' N and longitude 38°40'-39° 06' E and at an elevation ranges from 2100-2450m.a.s.l (Figure 1). The Gambo Plantation Forest is situated on the eastern escarpment of the Rift Valley with the total area of 622.1 ha. The forest is located 240 km south of Addis Ababa and 14 km east of Arsi Negelle town (Mulugeta Lemenih *et al*., 2004).

.

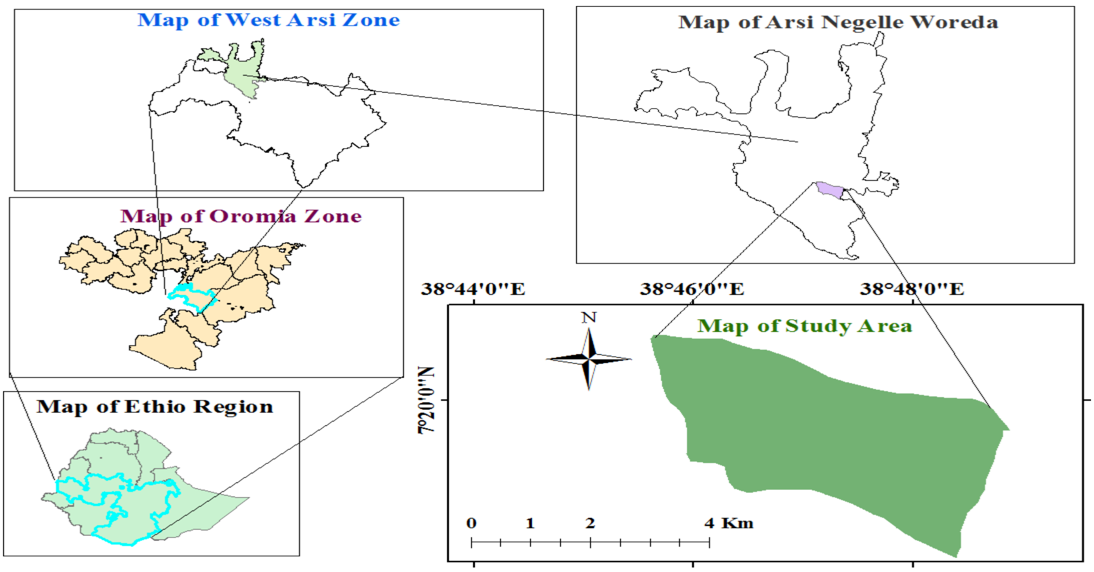

Figure 1: Map showing Ethiopia, Oromia and the study area

The soils are classified as Mollic Andosols (FAO, 2000) with their parent material originating from volcanic lavas, ashes and pumices. The forest is a tropical dry Afromontane forest (Mulugeta *et al*., 2008). Since the forest is situated within the Ethiopian Great Rift Valley, it is plantation forest is characterized by hard wood and coniferous species such as *Gravillea robusta, Eucalyptus* species, *Podocarpus falcatus, Pinus patula, Cupressus lusitanica, Junipers procera* and others (Motuma Tolera *et al*., 2008).

Sampling Methodology

Sampling size and techniques

A Systematic random sampling method was used to take samples. Forty plots were laid to sample the selected plant species of study area. According to Condit (2008) the consistent plot size of 20x20 m is required to sample plantations forest. Accordingly, the sampling plot of (20m x 20 m) was established for each species (Condet, 2008). The square plots were chosen as they tend to include more plant species within-plot, and thus be more representative than circular plots of the same area (Kurniatun *et al*., 2001). All trees with a diameter ≥ 5 cm was recorded as indicated by (Pearson *et al*., 2005). In order to eliminate any influence of the edge effects on the forest biomass, all plots were laid 50 m away from nearest roads.

Method of Data Collection

Tree data measurement

The diameter was measured at breast height (DBH, 1.3 m height from the ground) to estimate biomass of trees in a sampling plot. DBH was measured by using tree Caliper and measuring tape. Tree with multiple stems connected near the ground was counted as single individuals and bole circumference was measured separately. Tree height was recorded by using a measuring hypsometer.

The methodology and procedures used to estimate carbon stocks was step by step procedures using standard carbon inventory principles and techniques (Pearson *et al*., 2005). Procedures was based on data collection and analysis of carbon accumulating in the above ground biomass, below-ground biomass, leaf litter, and soil carbon of forests using verifiable modern methods.

Litter sampling

Quadrate with a size of 1 m × 1 m was established to sample litters. In each sample plot a total of five small quadrates were laid, four at the corner and one in the center to make more representative. The litter samples were taken in sub quadrate of (1 m × 1 m) along diagonal from one corner to the other and then the leaf litters within the 1m^2 sub plots was collected.

Laboratory analysis: The 100 gram sub sample fresh weights were sampled from the five sub-samples collected from each quadrant. Litter sample was mixed homogenously and then taken to Wondo Genet College of Forestry and Natural Resource (WGCFNR) for laboratory and oven dried at 105^{0}C.

Soil sampling

Soil samples were collected from the field with five sub-plots within each major plot. The Samples were dug using core sampler with a diameter of 5 cm and the soil was taken at 30 cm depth. Soil sample was mixed homogenously and 100 gm sample was taken from each sample quadrant.

After organizing the samples in such a way, the samples were taken to Wondo Genet College of forestry and Natural resources for laboratory analysis. In the laboratory, soil was prepared and oven dried at 105^{0}C for 24 hours to remove the soil moisture so as to determine the percentage of organic carbon. Finally, soil organic carbon was determined after getting percentage of organic carbon.

Source of Data Collection

The primary and secondary data were used in order to collect the important data to meet the objectives of this study. Primary data was obtained through field measurement in the study area and the secondary data were collected from different resources like published and unpublished materials, books, journals, articles, and reports.

Methods of Data Analysis

The major activities of carbon measurement during the field data collection was measuring DBH, height and taking litter fall and soil sample.

Estimation of above ground biomass and carbon stock

Total aboveground biomasses of four trees were estimated using a regression equation developed by (Henry *et al*., 2011) for Sub-Saharan African forests and for Juniperus procera the regression equation developed (Eyosias & Teshome, 2015) was used. These regression equations were selected for the study site since the general criteria described by the authors are similar to the study area. These equations are as follows:

Cupressus lusitanica **in Tanzania**

$$AGB = 0.0355 + 0.00003*\hat{}^{2} \times W \quad \text{.......................................} \quad (1)$$

Pinus patula in Kenya

AGB= -0.00041-0.00005711 x *+0.0001352x (* x W) +0.00003313 x (*×W)......................(2)

Eucalyptus globulus in Munessa shashamenne, Ethiopia

AGB= ((0.08283 x (*^1.873)) x (w^0.8242) + 10^(-3) ....(3)

Eucalyptus saligna in Kenya

log10AGB= 2.18435xlog10*+ (0.25088xlog10*)-1.13558 ....(4)

Juniperus procera in Wof-washa forest in Ethiopia

ln(AGB)=ln(2.48)+2.321ln(*)........................ ....(5)

Where AGB, represents the aboveground biomass of a tree in kg, and * represents diameter of the tree in cm whereas W is for height of tree in m. The corresponding carbon content in biomass was estimated assuming 50% of carbon in the biomass (IPCC, 2003).

Estimation of below ground biomass and carbon stock

Below ground biomass estimation is much more difficult and time consuming than estimating aboveground biomass (Geider *et al*., 2001).As indicated by MacDicken (1997), standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root to shoot ratio value of 1:5 is used. The equation is given below:

BGB = AGB × 20% ……………………………. (6)

Where, BGB is below ground biomass, AGB is above ground biomass, 0.2 is conversion factor (or 20% of AGB)

Estimation of Litter Biomass and Carbon content

According to Pearson *et al*. (2005), estimation of the amount of biomass in the leaf litter can be calculated by: LB = Wfield/A*Wsub sample dry/Wsub sample fresh∗1/10,000........................ (7)

Where: LB = Litter biomass (t ha^{-1}) ,W field = Weight of wet field sample of litter sampled within an area of size 1 m^2 (g); A = Size of the area in which litter was collected; W sub-sample dry = Weight of the average air dry sub-sample of litter (g), and W sub-sample, fresh = Weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).Therefore, total carbon content of litter (ton/ha) =Total dry litter biomass* carbon fraction.

CL = LBM × % C ....(8)

Where, CL is total carbon stocks in the litter in ton/ha, %C is carbon fraction determined in the laboratory (Pearson *et al*., 2005).

Estimation of Soil Organic Carbon

The carbon stock of soil was done by using the following formula which is recommended by (Pearson *et al*., 2005) from the volume and bulk density of the soil.

V = h × ∏ r^2.. (9)

Where, V is volume of the soil in the core sampler in cm3, h is the height of core sampler in cm, and r is the radius of core sampler in cm (Pearson *et al*; 2005). More over the bulk density of a soil sample was calculated as follows:

BD = Wav*dry/V …………………………. ……… (10)

Where, BD is bulk density of the soil sample per quadrant, Wav, dry is average oven dry weight of soil sample per the quadrant, V is volume of the soil sample in the core sampler auger in cm^3 (Pearson *et al*., 2005).

SOC =BD*D*% C.. (11)

Where, SOC= soil organic carbon stock per unit area (t ha^{-1}) BD = soil bulk density (g cm-3), D = the total depth at which the sample was taken (30 cm), and %C = Carbon concentration (%)

Estimation of total carbon stock density

The total carbon stock was calculated by summing the carbon stock densities of the individual carbon pools of the stratum using the (Pearson *et al*., 2005) formula. Carbon stock density of a study area:

CT = AGC + BGC + LC +SOC... .... (12)

Where, CT = Total Carbon stock for all pools (ton/ha), AGC=above ground carbon stock (ton/ha), BGC= below ground carbon stock (ton/ha), LC=litter carbon stock (ton/ha) and SOC= soil organic carbon (ton/ha). The total carbon stock was, then converted to tons of CO2 equivalent by multiplying it by 44/12, or 3.67 as indicated by (Pearson *et al*., 2005).

Data Analysis

The data analysis for estimation of above ground carbon, below ground carbon, litter fall carbon and soil organic carbon stock for each tree species were done by using Microsoft excel 2010. The difference in mean carbon stock of selected tree species was evaluated using a one-way analysis of variance (ANOVA) at α= 0.05 (95% degree of freedom) by using SPSS software version 20.

RESULTS AND DISCUSSION

Existing Forest Condition

Gambo plantation Forest is characterized by dry afromontane forest type vegetation. The height class, DBH class and also the species configuration of the study site is varied one another. The altitude of the Gambo plantation forest ranges about 2100-2450m and due to the variability of these conditions, it undergoes to dry afromontane forest (1500-3400m). *Juniperus procera, Cupressus lusitanica, Pinus patula, Eucalyptus saligna, and Eucalyptus globulus*, were the tree species observed in the plots (Figure 2). *Cupressus lusitanica* was the most dominant species in plantation forests. The enterprise has focused mostly on this species due to its high timber production. It covers 47.5 % of the tree in the study plot sites. *Pinus patula, Eucalyptus saligna, Juniperus procera, and Eucalyptus globulus* were the 2nd, 3rd, 4thand 5th most abundant tree species in the sample plots, and their relative coverage was 19.5%, 14.7%, 12% and 6.3% respectively

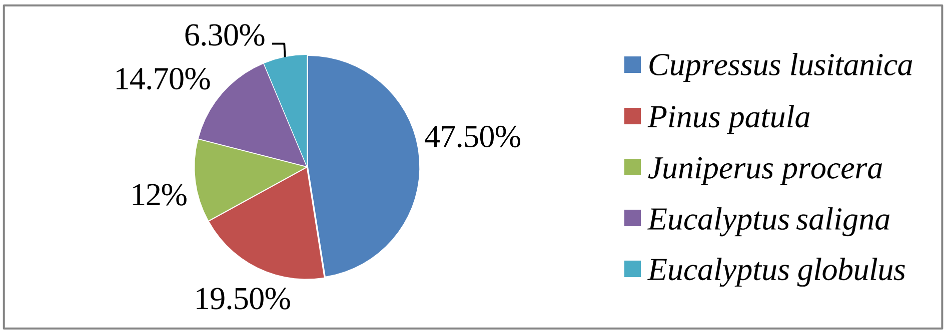

Figure 2: Relative abundance of tree species of the study area

The DBH value was largest for *Eucalyptus globulus* with the average value of 31cm. The 2nd and 3rd largest DBH average values were *Eucalyptus saligna* and *Juniperus procera* with average DBH of 20.5 cm and 20 cm, respectively (Figure 3). Smallest DBH of 10 cm was observed from *Pinus patula.* The DBH for other species ranged between 10 cm and 41 cm.

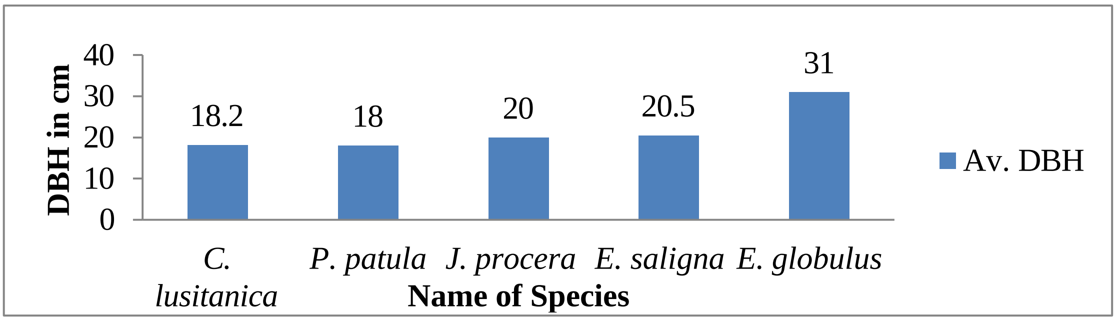

Figure 3: Average DBH for each species

The Average height value was largest for *Eucalyptus globulus* with 28.5cm (Figure 4). Smallest DBH of 18.53 cm was observed from *Pinus patula.* The DBH for other species ranged between 10 cm and 41 cm.

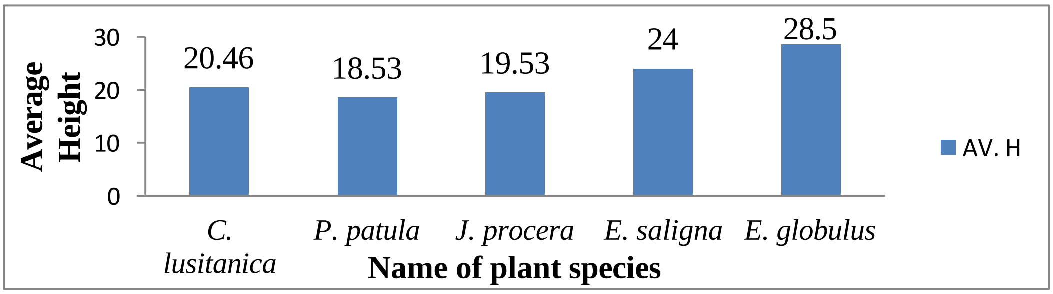

Figure 4 Average Height for each species

Biomass and Carbon Stock Estimation

Above ground biomass and carbon stock

Above ground biomass

According to Tobin (2007), the forest has a large potential for temporary and long-term carbon storage in their biomass. The biomass estimation method was used to determine the biomass and the carbon stock of the tree in the study site. A greater amount of carbon stock has been observed in a species which has counted long lived in the study site and also species which are densely populated in the pool. As a result, the current study of the site indicates unbalanced tendency of carbon stock input in the above ground. High biomass rate has been caught by species such as *Juniperus procera* and *Cupressus lusitanica*; on the other hand, species such as *Eucalyptus globulus* and *Pinus patula* had relatively less contribution. The result of this study shows that, the maximum above ground biomass (AGB) and minimum above ground biomass was 2119.18 and 113.04 ton/ha respectively. The average above ground biomass was 871.32 t/ha.

The present study result was higher than the study conducted on Ades forest (Kidanemariam, 2014). The maximum above ground biomass (ABG) and minimum above ground biomass of Ades forest was 9269.13 and 22.36 ton/ha respectively. The average biomass stock of the study site was recorded as 521.7475 ton/ha. However, the present study result was almost similar to the study conducted Woody Plants of Arba Minch Ground forest which is the average above ground biomass of 829.12ton/ ha (Belay Melese *et al.,* 2014). The result of the study site had almost a positive carbon stock potential and this indicates the forest status was well managed and protected even if some human interference could be there.

Above ground carbon stock

The maximum and minimum above ground carbon stock of Gambo plantation forest was ranges between 1059.59 and 56.52 ton/ha respectively. The average above ground carbon stock of the study area was 407.07 ton/ha. This is graphically represented as follows Figure 5.

.

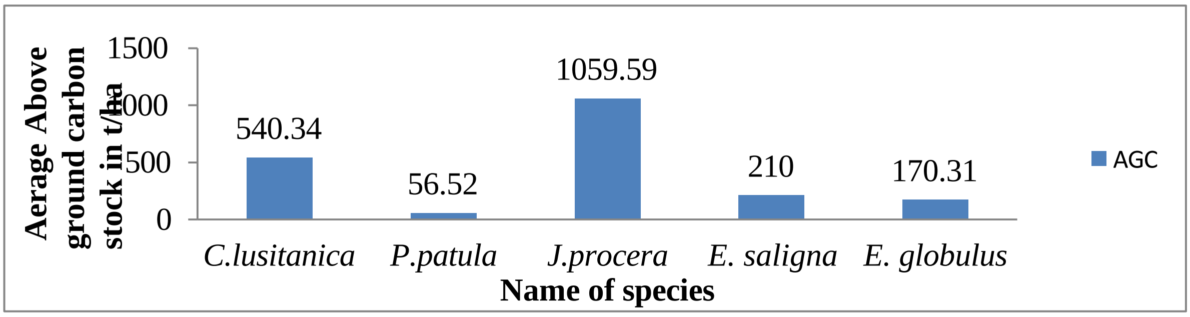

Figure 5: Above ground carbon for each species

According to different literature, global above ground carbon stock in tropical dry and wet forests ranged between 13.50-122.85 t ha^{-1} and 95- 527.85 t ha^{-1}, respectively (Murphy & Lugo, 1986). Above ground carbon in Amazonian Brazil forests ranged between 130- 223 t ha^{-1} (Alves *et al.,* 1997). The average above ground carbon in the Menagesha Suba State Forest and Ades forest was 133 t ha^{-1} and 259.165 ton/ha (Mesfin, 2011; kidanemariam, 2014).

The average above ground carbon in the Gambo Plantation Forest was seven times higher than the previous estimates (about 45.45 t ha^{-1}) of plant carbon stock for forests of Ethiopia (Brown *et al.,* 1986). On the other hand, Above ground carbon stock estimated in this study was almost similar with the study conducted in Woody Plants of Arba Minch Ground which is the average above ground carbon is 414.7 tons ha^{-1} (Belay Melese *et al.,* 2014). Tree species in the forest area were evergreen year-round and protection due to its reserved status. The higher carbon stock in aboveground carbon stock in this study site could be related to age of forest and the presence of protection from human interference by the enterprise.

Below ground biomass and carbon stock

Below ground biomass

As indicated in the methodology part estimation of below ground biomass can be obtained as 20% of above ground tree biomass *i.e.,* root-to-shoot ratio value of 1:5 was used by MacDicken (1997). The maximum and minimum below ground biomass value was 423.8 and 22.6 ton/ha respectively. The average below ground biomass of present study was 172.03t/ha.

Below ground carbon stock

Below ground Carbon stock in selected plant species was calculated by summing up the below ground carbon stock in each plot. The minimum and maximum carbon stock of this study was 11.3 and 211.9 t/ha for *Pinus patula* and *Juniperus procera* respectively. The average of below ground carbon was 80.37 t/ha.(Figure 6)

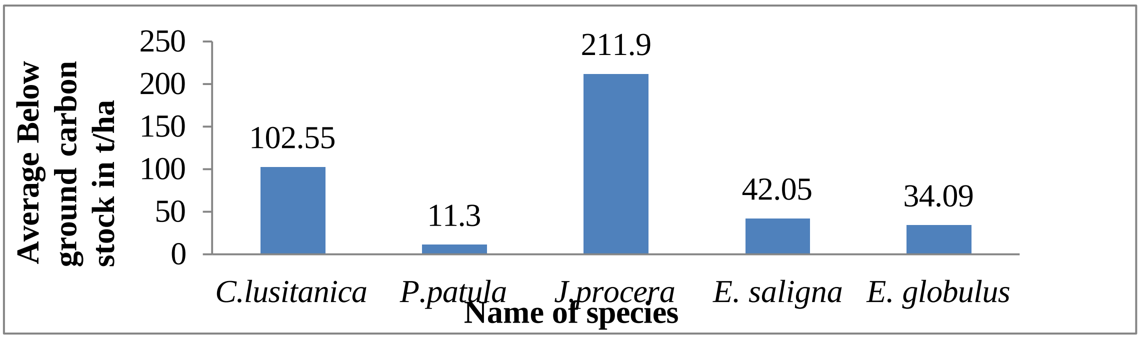

Figure 6: Below ground carbon stock for selected tree species

The mean value of below ground carbon stock of the present study had a greater value when compared with of the selected plants of Ades forest, Addis Ababa church forest and Menagesha Suba state forest with below ground carbon value of 25.97, 52.69, and 26.99 respectively (Tullu, 2011, Mesfin, 2011; kidanemariam, 2014).

On the other hand, average below ground carbon stock estimated in this study was almost similar with the study in woody Plants of Arba Minch ground which is the average below ground carbon stock is 83.48 tons ha^{-1} (Belay Melese *et al.,* 2014). This is due to the fact that it was derived from above ground carbon.

The maximum and minimum below ground carbon stock per hectare was 208.29 tons in plot 28 and9.12 tons in plot 12 respectively. The below ground carbon stock for other plots was between these ranges.

Litter biomass and carbon stock

Litter Biomass

The maximum and minimum value of litter biomass was resulted in 0.058 and 0.004 ton/ha respectively. The average biomass stock of the study site was 0.027.

Litter Carbon stock

The maximum litter carbon was observed in *Pinus patula* with a carbon stock content of 3.14ton ha^{-1}

(Figure 7). This species had the largest because of its age and amount of litter under it as compared to the others. The minimum litter carbon was observed in *Juniperus procera* with a carbon stock of 0.23 tons ha^{-1} this is due to its age. The average litter carbon stock was 1.43t/ha.

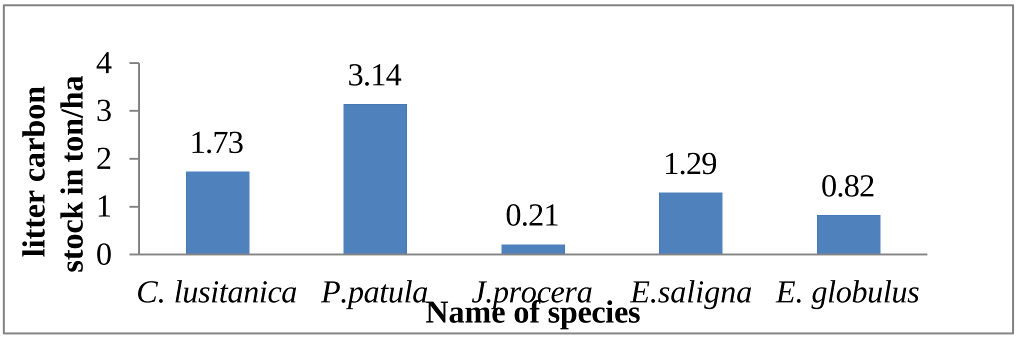

Figure 7: Litter carbon stock for each species per hectare

The litter carbon stock estimated in Addis Ababa church forest was 4.95 t/ ha (Tulu, 2011). Average Litter carbon stock estimated in this study was less than the study in Menagesha Suba State Forest which is the average Litter fall carbon stock is 5.25 ton ha^{-1} (Mesfin, 2011).

The mean carbon stock in litter pool of the present study was less as compared to values recorded from other forests. The value reported for tropical dry forest is 2.1t ha-1 which was greater than the present study value (IPCC, 2006). The amount of litter fall and its carbon stock of the forest can be influenced by the forest vegetation (species, age and density) and climate. Similarly, since the study area is located in tropical areas, the rate of decomposition is relatively fast (Fisher & Binkly, 2000) as cited by Belay Melese *et al.,* (2014). Thus, the lowest carbon stock in litter pool could probably be due to the high decomposition rate and less amount of litter falls due to the ever greenness of the forest year-round.

Soil organic carbon stock

The average bulk density of soil investigated in Gambo plantation forest was 0.96gm/cm^3, suggesting high soil organic matter in the mineral soils. The highest and the lowest bulk density were 1.57 gm/cm^3 and 0.43 gm/cm^3 in plot 40 and 29 respectively.

The mean bulk density of the woody Plants of Arba Minch ground forest was (0.85 g cm^{-3}, ranging between 0.72 to 0.98 g cm-3) (Belay Melese *et al.,* 2014). The average bulky density of present study almost similar to the study conducted in woody Plants of Arba Minch ground forest (Belay Melese *et al.,* 2014). This indicates that the study site has high organic matter content in the soil (Lal, 2005).

The organic carbon percentage of the soil in Gambo plantation forest was ranges from 3.13% to 26.88 %. The lowest organic carbon percentage in plot 40 was affected by deforestation due to misunderstanding between society and enterprise. The average organic carbon in soil investigated in the study area was 12.6 % by oven-dry weight (Appendix 4).

The minimum and maximum soil organic carbon stock in selected tree plants of Gambo plantation Forest was varied from 132.68 t/ha to 551.69 t /ha with the average soil organic carbon stock of 306.45t ha^{-1}

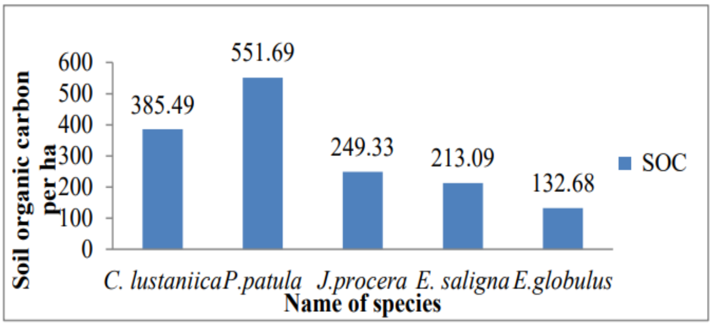

Figure 8 Soil organic carbon stock in selected plants of study area

The average value of SOC of this study has greater value than the study conducted at Egdu Forest, Selected Church Forest and Menagesha Suba State Forest (Adugna Feyissa *et al.,* 2013; Tulu, 2011; Mesfin Sahile, 2011) which had 135.94t ha^{-1}, 121.28t ha^{-1}277.56tha^{-1}. The carbon stock and organic matter of the soil have direct relationship, as the laboratory result indicates the carbon pools of the study site which had large amount of organic matter had recorded high carbon stock value, and thus, the higher mean value of soil organic carbon of this study is probably owing to the existing of high soil organic matter. Soil organic carbon of the forest again highly depends on the moisture, decomposition of litter carbon, climatic zone, temperature, rainfall and the nature of soil as well (Jabbagy & Jacksen, 2000) as cited by Belay Melese *et al.,* (2014) . Carbon enters the soil as roots, litter, harvest residues, and animal manure. It is stored primarily as soil organic matter (SOM) (Beedlow *et al.,* 2004). The density of carbon is highest near the surface. Thus, the higher mean of SOC stock is may be also due to the presence of high SOM and fast decomposition of litter which results in maximum storage of carbon stock (Sheikh *et al.,* 2009). As the study shows that Gambo plantation forest plays a great role for the mitigation of climate change phenomena by its solid potential of carbon dioxide sequestration(Figure 8).

Total Carbon Stock Density

The total carbon stock of this study was obtained by adding all carbon value of each pool which revealed (above ground carbon, below ground carbon, litter carbon and soil organic carbon) for the selected tree species of the study area. As a result, the total carbon stock of Gambo plantation forest was ranged from maximum 1521.03 ton /ha for *Juniperus procera* and to minimum value of 337.9 ton/ha for *Eucalyptus globulus*. The average total carbon stock for this study was 795.62t/ha with the carbon dioxide sequestration potential of 2919.92t/ha.

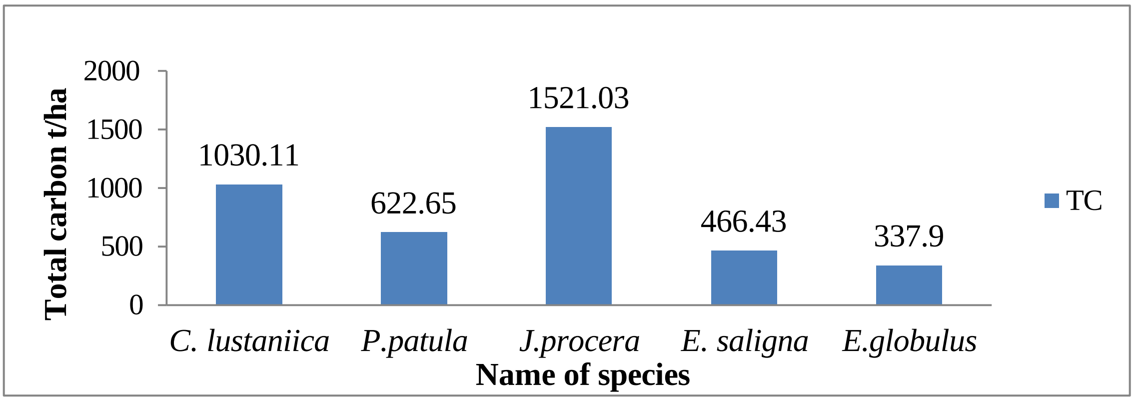

Figure 9: Total carbon stock density for selected tree species

Forests play an important role in the global carbon cycle because they store large amount of carbon in their biomass and soil (Brown *et al.,* 1996), and they serve as long term sink if forest fire and forest degradation is strictly precluded. Therefore, plantation, afforestation and preservation as happened in Gambo plantation forest could serve as a potential sink for carbon emission. This suggests that the forests of Ethiopia could play significant role in the carbon cycle of east African region because it could lead to decrease atmospheric CO_2 via increasing in CO_2 uptake by plants. The present result also revealed that the Gambo plantation forest had large carbon stock and thus sequestered large amount of CO_2 contributing to the mitigation of global climate change (Figure 9).

Comparison of Different Carbon Stock Pools

In the present study, the largest carbon stock covered by above ground carbon and which accounts averagely 51.2% of the four carbon pools and sufficient amount of carbon was observed below ground with coverage of 10.1% (Figure 10). This carbon stock was mainly derived from the forest biomass. 38.52% of the carbon storage was in soil organic carbon pool. Carbon pools in litter cover a small part of the total coverage and they accounts only for 0.18%.

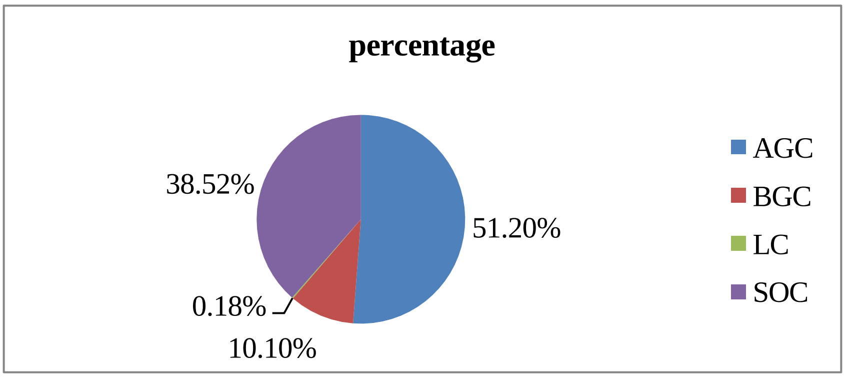

Figure 10: Comparison of different carbon pools of this study

As shown in the above (Figure 10) the highest carbon stock has been scored in the *Juniperus procera,* followed by *Cupressus lusitanica* and the lowest was scored by *Eucalyptus globulus.* The condition is also significant at 95% confidence interval for the case of the mean carbon stock among the selected species (F=1.789) and (P=0.045).

Table 1: *Comparison of average carbon stock of the present study with other studies*

Study place	AGC	BGC	LC	SOC
Gambo plantation forest	407.35	80.37	1.43	306.64
Edgu forest	279.08	55.62	3.47	277.56
Menagesha Suba state forest	133	26.99	5.26	21.28
Selected Church forest	122.85	25.97	4.95	135.94
Danaba community forest	278.03	41.76	1.06	186.4
Tara Gedam Forest	306.37	61.52	0.90	274.32

The variation might come from variation of age of trees, existing species, and management of forests. The use of an allometric equation model for biomass estimation might also help in explaining the difference in estimated values as explained the reliance on allometric equations could be one of the limitations resulting in large variations in such estimates. The use of specific equation versus general equation has also greater effects which result in variation of values(Table 1).

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The study shows that Gambo plantation forest makes a significant contribution to carbon stock storage. It is expected that much income can be earned by selling carbon credits in the carbon market through CDM projects. The study plots contain plant species like *Cupressus lusitanica, Pinus patula, Juniperus procera, Eucalyptus saligna and Eucalyptus globulus. Cupressus lusitanica* were the most dominant in density and *Eucalyptus globulus* has relatively lower density than the other species.

The amount of carbon stocks in selected species was varied and the average total carbon stock was large. The Average carbon stock of the Gambo plantation forest was 795.51t/ha of which above ground carbon (AGC) share 407.07, below ground carbon (BGC) 80.37, litter fall (LC) carbon share 1.43, and soil organic carbon (SOC) was 306.64 (up to 30cm depth). *Juniperus procera* and *Eucalyptus globulus* had highest carbon stock and lowest carbon stock from the selected plant species. Juniperus procera had AGC, BGC, LC, and SOC of 1059.59, 211.9, 0.21 respectively and Eucalyptus globulus had AGC, BGC, LC, and SOC of 249.93 for and 170.31, 34.09, 0.82, and 132.68 respectively.

The carbon stocks of the study site were varying among the plots due to the presence of higher biomass in some plots and small biomass in other plots. The mean carbon stocks of the different carbon pools of the study sites were higher than most research done in the country related to carbon sequestration potential of forests, even if the results were within the range of considerable proportion.

The presence of high range value of carbon stock in the sites indicates its potentials to the mitigation of climate change by absorbing greenhouse gases from the atmosphere. The carbon sequestration in this forest is comparable with the forest in the country indicating that the contribution of the forest for carbon sequestration and climate regulation is significant. The Average carbon dioxide sequestration potential of Gambo plantation forest was 2919.92 t/ha, thus the forest has great contribution in climate change mitigation and attracting climate change mitigation finances to the country.

Recommendations

Based on the findings of this study the following recommendations have been made.

- The carbon stock potential of Juniperus procera was statistical higher than the other species which is exotic species in the study area so, it's very important to plant this species to sequester large amount of carbon from the atmosphere.
- It is better to provide an alternative source of energy for the local people in order to protect the Gambo plantation forest from deforestation for the purpose of satisfying their fuel demand.
- Even though inventory data has a capacity for estimation, future research will be needed to integrate inventory data and remote sensing data, to produce different years carbon stock estimation and mapping the carbon density for the study area.
- Finally, integration of indigenous knowledge with modern conservation approach in the planning and implementation process must be encouraged.

REFERENCES

Adugna Feyissa, Teshome Soromessa & Mekuria Argaw (2013). Forest carbon stocks and variations along altitudinal gradients in Egdu Forest: implications of managing forests for climate change mitigation. *Star Journal, 2*(4), 40-46.

Alves, D.S., Soares, J.V.S., Amaral, E.M.K., Mello, S.A.S., Almeida, O., Fernandes, S. & Silveira, A.M. (1997). Biomass of primary and secondary vegetation in Rondonia, western Brazilian Amazon. *Global change Biology, 3*(5), 451-462.

Anup, K.C., Bhandari, G., Joshi, G.R. & Aryal, S. (2013). Climate change mitigation potential from carbon sequestration of community forest in mid hill region of Nepal. *International Journal of Environmental Protection*, *3*(7), 33-40. 79

Beedlow, P. A., Tingey, D. T., Phillips, D. L., Hogsett, W. E., & Olszyk, D. M. (2004). Rising Atmospheric CO_2 and Carbon Sequestration in Forests. *US Environmental Protection authority, 2*(6), 315-322.

Belay Melese, Ensermu Kelbessa & Teshome Soromessa (2014). Forest carbon stocks in woody plants of Arba Minch ground water forest and its variations along environmental gradients. *Science Technology and Arts Research Journal*, *3*(2), 141-147.

Brown, S., Lugo, A.E. & Chapmen, J. (1986). Biomass of tropical tree plantations and its implications for the global carbon budget. *Canadian Journal of Forest Research, 16,* 390-394

Brown, S., Sathaye, J., Cannell, M. & Kauppi, P.E. (1996). Mitigation of carbon emissions to the atmosphere by forest management. *US Environmental Protection authority*, *75*(4), 80-91.

Condit, R. (2008). Methods for estimating above-ground biomass of forest and replacement vegetation in the tropics. *Center for Tropical Forest Science Research,* 73 pages.

Correia, A. C., Tome, M., Pacheco, C.A., & Pereira, J. S. (2010). Biomass allometry and carbon factors for a Mediterranean pin (*Pinus pinea*) in Portugal. *Forest Systems, 19*, (3), 418-433.

Eyosias Worku & Teshome Soromessa (2015). Allometric equation for biomass determination in *Juniperus procera* and *Podocarpus falcatus* of Wof-Washa Forest: implication for climate change mitigation. *American Journal of Life Sciences, 3* (3) 190-202.

FAO. (2007). *Global forest resource assessment*, Rome, Italy.

FAO. (2009). *Climate change adaptation and mitigation in the food and agriculture sector. technical background document from the expert consultation,* Rome, Italy

FAO. (2010). *Global forest resources assessment main report 163, FAO forestry paper*. Main report. Rome. Italy.

Fisher, R. F. & Binkley, D. (2000). *Ecology and management of forest soils*. (4th ed.). New York, USA.

Geider, J. R., Delucia, H. E., Falkowsk, G. P., Finzi, C. A., Grime, P. J., Grace, J., Kana, M.T., & Roche, J. (2001). Primary productivity of planet earth: biological determinants and physical constraints in terrestrial and aquatic habitats. *Global Change Biology*, *7*, 849-882.

Henry, P. N., Trotta, C., Manlay, R. J., Valentini, R., Bernoux, M., & Saint-André, L. (2011). Estimating tree biomass of sub-Saharan African forests: A review of available allometric equations. *Silva Fennica 45*(3B), 477-569.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Climate Change: Working Group I: The Scientific Basis.* Cambridge University Press, New York.

IPCC. (2006). IPCC guidelines for national greenhouse gas Inventories 4. Prepared by national greenhouse gas inventories program. *Institute for Global Environmental Strategies (IGES)*, Hayama, Japan.

Kidanemariam Kassahun (2014). Forest Carbon Stock in Woody Plants of Ades Forest and its Variation along Environmental Factors: Implication for Climate Change Mitigation, at Western Hararghe. (MSc. thesis). Addis Ababa University, Addis Ababa. Ethiopia.

Kurniatun H. SM., Sitompul, M. V. N., & Cheryl P. (2001). *Methods for sampling carbon stocks above and below ground,* Bogor, Indonesia

Kiehland, J. T. & Trenberth, K. E. (1997). Earth's annual global mean energy budget. *Bulletin of the American Meteorological Society, 78*(2), 197-208.

Lal, R. (2005). Forest soils and carbon sequestration*. Journal of Forest Ecology and Management, 220*(4), 242-258

MacDicken, K. G. (1997). A guide to monitoring carbon storage in forestry and Agro-forestry Projects. In *Forest Carbon Monitoring Program, Win rock International Institute for Agricultural Development,* Arlington, Virginia

Mesfin Sahile (2011). *Estimating and mapping of carbon stocks based on Remote sensing, GIS and ground survey in the Menagesha Suba state forest*. (MSc. thesis). Addis Ababa University, Addis Ababa, Ethiopia.

Mohammed Gudeta, Teshome Soromessa & Satishkumar., B. (2015). Estimation of above and below ground carbon stocks of forests: Implications for sustainable forest management and climate change mitigation: A case study of Tara Gedam forest, Ethiopia. *Science, Technology and Arts Research Journal, 3*(1), 101-107

Motuma Tolera & Karltun, E. (2008). Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. *Agriculture Ecosystems and Environment, 128*(1-2), 52-58.

Mulugeta Lemenih, Motuma Tolera, & Karltun, E. (2008). Deforestation: Impact on Soil Quality, Biodiversity and Livelihoods in the Highlands of Ethiopia, *Nova Science Publishers,* 21-39

Muluken Nega (2014). Carbon stock in Adaba-Dodola community forest of Danaba district, West-Arsi zone of Oromia region, Ethiopia: An implication for climate change mitigation, (M.Sc. thesis). Addis Ababa, Ethiopia.

Murphy, P. G. & Lugo, A. E. (1986). Structure and biomass production of a dry tropical forest *18*, 89-96

Pearson, T. R., Walker, S., & Brown, S. (2005). *Source book for land-use, land-use change and forestry projects.* Arlington, USA, Pp. 1935.

Sheikh, M. A., Kumar, M., Rainer, W., & Bussmann, R. W. (2009). *Altitudinal variation in soil organic carbon stock in coniferous sub-tropical and broad leaf temperate forests in Garhwal Himalaya*, India.

Tulu Tolla (2011). *Estimation of carbon stock in church forests: Implications for managing church forest for carbon emission reduction.* (Msc. thesis). Addis Ababa University, Addis Ababa, Ethiopia.

Yitebitu Moges, Zewdu Eshetu & Sisay Nune (2010). *Manual for assessment and monitoring of carbon in forest and other land uses in Ethiopia*. Addis Ababa, Ethiopia.