International Journal of Scientific Research in Multidisciplinary Studies
Vol.6, Issue.2, pp.88-96, February (2020)

Research Paper
E-ISSN: 2454-9312
P-ISSN: 2454-6143

Determining Tree Biomass and Soil Carbon Stock Potential of Selected Sites of Munesa Forest, Western Arsi Zone, Oromia Region, South-Eastern Ethiopia

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Available online at: www.isroset.org

Received: 02/Feb/2020, Accepted: 14/Feb/2020, Online: 28/Feb/2020

Abstract-The study was undertaken to estimate carbon stocks in Munesa forest. The aim of the study was to estimate the carbon stock potential of Munesa forest for selected sites and indicating its contribution to climate change mitigation. A total of 63 nested sample plots of 20m x 20m were laid systematically representing 35 plots for natural and 28 plots for plantation forests respectively. Within larger square plots, five (1m x 1m each) sub-plots in the four corners and one at the center were established for Litter, Herbs and Grasses and soil collection. Soils samples were collected from 0-10, 10-20 and 20-30 cm depths. Above ground biomass was estimated by using allometric model equation using non-destructive method. But, belowground biomass was determined based on the ratio of below ground biomass to above ground biomass factors. The results of this study showed that the average carbon stock of the natural forest was 195.34, 50.79, 1.56 and 325.97 t.ha-1 for above ground biomass, below ground biomass, litter, herbs and grasses and soil organic carbon respectively. Similarly, the mean carbon stock recorded in aboveground biomass, belowground biomass, litter, herbs and grasses and soil organic carbon for plantation forest was 111.07, 28.88, 1.38 and 273.11 t.ha-1 respectively. The total carbon stock recorded was 573.66 and 414.44 t.ha-1 for natural and plantation forests respectively. Finally, this study has shown that Munesa forest ecosystem should be given conservation priority to benefit from carbon financing opportunities.

Keywords: Biomass, Carbon sequestration, Carbon storage, Climate change, Munesa Forest

I. INTRODUCTION

1.1 Background

Global climate change is a widespread and growing concern that has lead to extensive international discussions and negotiations. Responses to these concerns have focused on reducing emissions of GHGs, especially CO_2, and on measuring carbon absorbed by and stored in forests, soils, and oceans. One option for slowing the rise of GHG concentrations in the atmosphere, and thus possible climate change, is to increase the amount of carbon removed by and stored in forests (Broadmeadow and Robert, 2003; IPCC, 2000; IPCC, 2007).

Forest ecosystems can be sources and sinks of carbon (Watson *et al*., 2000). Deforestation and burning of forests releases CO_2 to the atmosphere. Indeed, land-use change and forestry is responsible for about 25% of all greenhouse emissions. However, forest ecosystems could also help to reduce greenhouse gas concentrations by absorbing carbon from the atmosphere through the process of photosynthesis. Globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above-ground, and 40% of terrestrial belowground biomass carbon storage (Kirschbaum, 1996). Thus, biomass is an important element in the carbon cycle, specifically carbon sequestration. It is used to help to quantify pools and fluxes of greenhouse gases (GHG) from the terrestrial biosphere to the atmosphere associated with land use land cover changes (Cairns *et al*., 2003).

In addition to being sequestered in vegetation, carbon is also sequestered in forest soils. Carbon is the organic content of the soil, generally in the partially decomposed vegetation (humus) on the surface and in the upper soil layers, in the organisms that decompose vegetation (decomposers), and in the fine roots (Gorte, 2009). The amount of carbon sequestered in forest soils varies widely, depending on the environment and the history of the site. However, Ethiopia lacks periodic inventory data of forests and carbon stocks and this makes the country fail to develop sustainable forest management planning that attracts climate finances.

According to World Bank, (2009) report, Ethiopia is facing rapid deforestation and degradation of forest resources and experiencing the effects of climate change such as an increase in average temperature, and rainfall pattern variability, and is one of most vulnerable countries to climate change. As Ethiopia is dependent on natural resources and agriculture, it is less able to cope with the shocks of climate change induced droughts, floods, soil erosion and other natural disasters. People will find it hard to escape poverty if vulnerability to climate change persists. In Ethiopia different factors like deforestation, overharvesting and permanent conversion to other forms of land use is leading to shrinkage of forest resources. As a result, forest cover has been declining rapidly and only remnant forests are confined to some areas specially in the south and south-western parts of the country, which are less populated (Tesfaye, 2002).

Munesa forest, containing both natural and plantation forests is one of the remaining forest reserves of the Ethiopia. The plantation forest comprised of mainly fast growing exotic species such as *Eucalyptus* spp., *Cupressus lusitanica*, *Pinus patula*, *Juniperus procera*, *Grevilea robusta,* and others that accounted for 3.4% of the total plantation in the country (EFAP, 1994). Tree plantations have a potential as a renewable source of bio-energy and could reduce the huge demands on fossil fuels, the main CO_2 source to the atmosphere. Besides these, tree plantations have many beneficial interactions with the surrounding environment such as watershed protection and improve the organic matter and nutrient status of the soil through the production of litter. Man made plantations can reach a natural equilibrium state in which decomposition and accumulation will balance.

The government of the Federal Democratic Republic of Ethiopia has therefore implemented National $REDD^+$ working document in 2008 and Climate Resilience Green Economy (CRGE) Framework in 2011 by means of protecting and re-establishing forests for their economic, ecosystem services and carbon storage. Even if the strategic frameworks focus on carbon emission management, Ethiopia does not have carbon accumulation records and data bank to monitor and enhance carbon sequestration potential of different forests.

Many researchers also agreed on significance of studying the forest resources of Ethiopia for the purpose of carbon storage. Because at current time the forest of Ethiopia become decline due to anthropogenic activities, (Teshome *et al.,* 2004, 2011 and 2013) However, no study has been conducted at Munesa forest that was intended to evaluate carbon stock potential. Therefore, this study was undertaken to estimate the carbon stock potential of Munesa forest for selected sites.

The Oromia Forest and Wildlife Enterprise (OFWE) is an autonomous fully government-owned organization established with regulation number 122/2009. It issued in July 2009 by the Oromia State Council under the Federal Democratic Republic of Ethiopia. OFWE works to ensure conservation, sustainable development and the use of forest and wildlife resources in its concessions through community participation. The Oromia Forest and Wildlife Enterprise is conducting business by opening nine branch offices at several locations in Oromia Region. Of these nine branch, Arsi branch, Munesa forest was one of them at which the study was undertaken. The Oromia forest and wildlife enterprise Arsi branch, Munesa forest would highly support the CRGE of Ethiopia by achieving carbon sequestration and conservation of biodiversity. On the one hand, empowering communities to take part and improve their living condition.

1.2 *Objective of the Study*

1.2.1 General Objective

The overall objective of the study was to estimate tree biomass and soil potential of selected sites of Munesa forest.

1.2.2 Specific Objectives

- Quantify the amount of carbon stock sequestered in the tree biomass (AGB and BGB), litter, herbs and grasses and soil;
- Estimate total carbon stock of natural and plantation forests;
- Estimate variation in carbon stocking potential of some woody species;
- Compare carbon stocking potential of study area with some other studies in the country.

The rest of the paper is organized as follows; Section 2 contains Related Works, Section 3 contains Materials & Methods, Section 4 contains Results and Discussion, and Section 5 contains Conclusion and Recommendations.

II. RELATED WORK

Related studies were conducted to know carbon sequestration potential of forests in Asia and Latin America. There are also some other studies done in Ethiopian country like that of Selected Church Forest (Tullu *et al*., 2013), Menagesha Suba State Forest (Mesfin, 2013), Chilimo Forest (Teshome and Ensermu, 2013b) and Humbo Forest (Chinasho *et al*., 2015), Egdu Forest (Adugna *et al*., 2013), Danaba Community Forest (Bazezew *et al*., 2014), Arba Minch Ground Water Forest (Belay *et al*., 2014), Tara Gedam Forest (Mohammed *et al*., 2014), Gedo Forest (Hamere *et al*., 2015), Ades Forest (Kidane *et al*., 2015) and Woody Plants of Mount Zequalla Monastery Church (Abel *et al*., 2104) and so on. But, none of these studies were specifically conducted at Munesa Forest. Therefore, this study shows how much carbon sequestered by Munesa forest so that concerned body will give conservation priority to get benefit from it.

III. MATERIALS AND METHODS

3.1 Description of study area

The study was conducted at Munesa forest which is administered under the Oromia Forest and Wildlife Enterprise (OFWE), Arsi branch in Oromia Regional State, Ethiopia. Munesa forest is located on the eastern escarpment of the Central Ethiopian Rift Valley. The study lies within latitudes of 7°12'N and 7°32'N, and longitudes of 38°45'E and 38°56'E at about 240 km south of Addis Ababa (Mulugeta, 2004). It is a dry afromontane forest and extends over an altitudinal range from 2100 to 2700 m asl.

Munesa forest has an estimated total coverage area of around 23,000 ha natural forest and 2578 ha plantation forest. The forest is divided in to different sites and compartments for the ease of management and controlling

3.2 Preliminary Field Observation
A short field observation was carried out during the month of September, 2015 to obtain basic information of the study area (forest). In order to obtain an impression in site conditions and vegetation composition, collection of information on accessibility and identifying sampling sites is important. Based on this, investigation was carried out from September 5-15, 2015.

3.3 Sampling Design and Measurements
To find out the amount of carbon stock of tree biomass, systematic transect sampling technique were used in this study. Using the GPS navigation system, sixty three plots were laid along line transects with 300 m interval between transect line and 200 m between each plots. Finally to lay the first sample plot in each forest type, the researcher randomly selected the starting location by intentionally 100 m away from border to avoid edge /or peripheral effects.

3.4 Data Collection
The field work for data collection was made in September, 20, 2015 to October 10, 2015.

3.4.1 Vegetation Data Collection and Identification
The quadrat size of 20m x 20m was used to collect data for tree biomass following the guidelines given by Subedi et al., (2010) and 1m x 1m for LHGs and soils collection. Following Bhishma et al. (2011) guideline, 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.

3.4.2 Vegetation Data Collection and Identification
The quadrat size of 20m x 20m was used to collect data for tree biomass following the guidelines given by Subedi et al., (2010) and 1m x 1m for LHGs and soils collection. Following Bhishma et al. (2011) guideline, 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 ≥ 5cm were measured in each plot using diameter tape (Figure 2). Each tree (plants species) was recorded individually, together with its species name and vernacular name using published volumes of Flora of Ethiopia and Eritrea. According to Chidumayo, (2002) trees with DBH < 5cm were excluded because such trees hold a small fraction of AGB in forests and woodlands. The common practice for measuring DBH is to measure trunk diameter at 1.3m aboveground (Cai *et al*., 2013). Wood specific gravity of tree species was taken from Global Wood Density Data Base (Chave *et al*., 2009).

Trees with multiple stems at 1.3m height treated as a single individual and DBH of the largest stem were taken. Trees with multiple stems or fork below 1.3m height also treated as a single individual (Kent and Coker, 1992). The DBH of irregular trees was measured by the help of methods developed by Pearson *et al*., (2005), (Figure 1). 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.

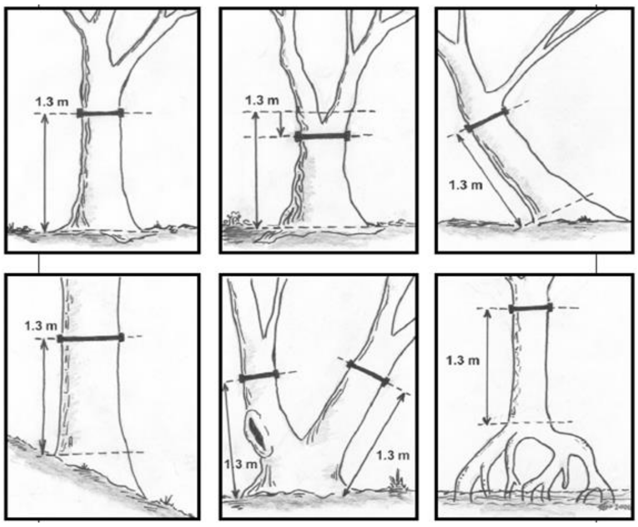

Figure 1: DBH measurement locations for irregular and normally shaped trees

Source: (Pearson *et al*., 2005)

Figure 2: Tree DBH measurement

3.4.2 Litter, Herbs and Grasses (LHGs)
Litter, herbs and grass samples were collected from 1m x 1m square sub-plot within 20m x 20m square of the larger plot. A total of five sub-plots within the larger plot (four at corners and one in the center) were used for LHGs collection (Figure 3). In each plot, five samples of litter, including leaves, twinges, fruits/flowers, and barks, herbs and grasses were collected and placed in a weighing bag. The total fresh weight of each LHGs sample was recorded on the site using a balance. A composite sample of 100 gm was taken to laboratory for further analysis.

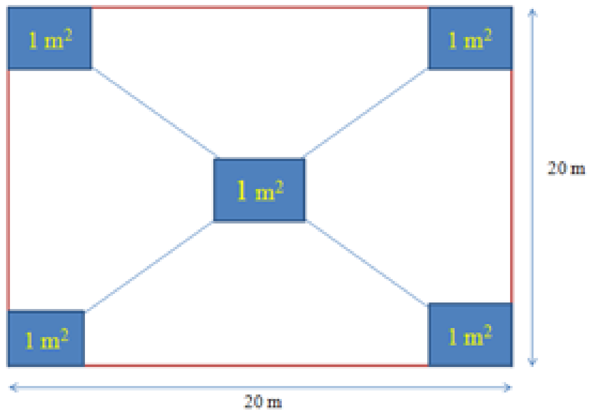

Figure 3: Nested plot laid out for Trees, LHGs and Soil Sample Collection

3.5 Estimation of Carbon Stock

2.5.1 Estimation of Carbon in the Above Ground Biomass

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*., (2005) and Chave *et al*., (2014). The general equation that was used to calculate the above ground biomass is given as follows:

$AGB=0.112*(\rho*DBH^2*H)^{0.916}$...................... (Equation-1) (Chave *et al*., 2005) and

$AGB = 0.0673*(\rho*DBH^2*H)^{0.976}$ …………... (Equation-2) (Chave *et al*., 2014)

Where,

AGB: is aboveground biomass;

DBH: is diameter at breast height, cm;

H: is total tree height, m;

ρ: is wood density and species specific density that was taken from global wood density data base, g cm^{-3} (Chave *et al*., 2009).

Then the tree biomass was converted to carbon stock multiplied by 50% (0.5) to get the aboveground biomass carbon content (IPCC, 2003; Sharma *et al*., 2013).

AGB Carbon Stock = AGB * 0.5..............................Equation (3)

Where,

AGB: Above Ground Biomass.

3.5.2 Estimation of Carbon in Below Ground Biomass

According to Cairns *et al*., (1997), standard method for estimation of belowground biomass can be obtained as 18%-30% of aboveground tree biomass i.e., root-to-shoot ratio. Thus, the equation developed by Cairns *et al*., (1997), to estimate belowground biomass is depicted as follows:

BGB = AGB * 0.26…………………… (Equation-4)

Where,

BGB: is belowground biomass;

AGB: is aboveground biomass;

0.26: is conversion factor (or 26% of AGB).

To estimate the carbon content and amount of CO_2 in BGB, the same procedure was applied like that of AGB.

BGBC = BGB x 0.5……………………..….. (Equation-5)

3.5.3 Estimation of the Biomass of leaf Litter, Herbs and Grasses

To estimate the biomass of leaf litter, herbs and grasses, the following formula described by Pearson *et al.,* (2005) is used:

$$LHGs = \frac{Wfield}{A} * \frac{W\ sub-sample\ dry}{W\ sub-sample\ wet} * \frac{1}{10,000}$$ .... (Equation-6)

Where:

LHGs: Biomass of leaf litter, herbs and grasses ($t.ha^{-1}$);

Wfield: Weight of the fresh field sample of leaf litter, herbs and grasses- destructively sampled within an area of size 1 m^2 (g);

A: Size of the area in which leaf litter, herbs and grasses were collected (ha);

Wsub-sample, dry: Weight of the oven-dry sub-sample (g);

Wsub-sample, wet: weight of the fresh sub-sample of leaf litter, herbs and grasses taken to the laboratory to determine moisture content (g).

The carbon content in LHGs were calculated by multiplying LHGs with the IPCC, (2006) default carbon fraction of 0.47, assuming there is no substantial decomposition of the litter layer to cause substantial losses of carbon.

CLHGs= 0.47*LHGs………………… (Equation-7)

Where CLHGs = is carbon content by mass in LHGs and LHGs = is oven-dry biomass of LHGs.

The litter carbon has to be multiplied by 3.67 to get the amount of CO_2 stocked in litter biomass.

3.5.4 Soil Sample Collection

Soil samples were collected from the five sub plots (1m x 1m each) in the four corners and one at the center of each plot after LHGs was collected. The soil samples for soil organic carbon determination was collected by inserting augur in to the soil in three depth categories at 0-10cm, 10cm-20cm and 20cm-30cm with five replications in the plot. Bulk density analysis was also sampled from the same points, using soil core sampler having 7.2 diameter and 10 cm length. Finally, soil samples were taken to the laboratory for further analysis.

3.5.4.1 Compositing Soil Samples

All soil samples that represent the same soil layer were composited respective to its plot to reduce the time and costs of laboratory analysis. Five equal weights of each sample from each sub-plot were taken and mixed homogenously. A composite sub-sample of each plot was taken for the laboratory analysis. These composite samples should always comprise the same number of sub-samples. Samples taken from different soil layers and plots were kept separately. A total of 63 soil samples (five replicates for each plot) were collected and analyzed.

IV. RESULTS AND DISCUSSION

4.1 Vegetation Characteristics

4.1.1 Natural Forest

The following tree species were recorded in the natural forest. These were *Celtis africana, Albizia gummifera,* *Cordia africana, Croton macrostachyus, Ficus vasta, Ficus sur, Grewia bicolour, Olea capensis subsp. macrocarpa, Podocarpus falcatus, Prunus africana,* and *Ziziphus mauritiana.* Under natural forest, the maximum DBH found was 210.1 cm and minimum DBH recorded was 6.4 cm. In general the mean DBH of the overall natural forest was 33.8 cm. Similarly, the maximum height recorded was 56 m whereas the minimum height was 5 m and mean H was 21.8 m.

4.1.2 Plantation Forest

Cupressus lusitanica, Eucalyptus grandis, Pinus patula and *Croton macrostachyus* were major tree species recorded in the plots. Like that of natural forest, maximum, minimum and mean DBH and H were also recorded. The maximum DBH found was 44.9 cm, 43.0 cm, 63.7 cm for Degaga, Petros and Kuke2 sites respectively. The minimum DBH recorded in the three sites was 6.7 cm (Degaga) and 8 cm for both Petros and Kuke2 sites. In general the mean DBH recorded was 17.3 cm, 21.7 cm and 25.8 cm for Degaga, Petros and Kuke2 sites respectively. Similarly the maximum height recorded was 34.5 m, 26 m and 26.9 m for Degaga, Petros and Kuke2 sites respectively. Minimum H recorded was 5.8 m, 10 m, and 7.6 m for Degaga, Petros and Kuke2 sites respectively. Also the mean H recorded was 13.7 m, 15.1 m, and 17.6 m for Degaga, Petros and Kuke2 sites respectively (Table 4)

4.2 Carbon Stocks in Different Carbon Pools

4.2.1 Above Ground Biomass Carbon Stock

The study revealed that majority of carbon stock in the study area was contributed by soil organic carbon, followed by tree biomass, whereas very little biomass carbon stock was found in the leaf litter, herbs and grass biomass for both natural and plantation forests (Table 7). The average carbon storage of AGB in natural and plantation forests was 195.34 $t.ha^{-1}$ and 111.07 $t.ha^{-1}$ respectively.

Table 1: Carbon stocks in different carbon pools

Forest Type	TAGB	TBGB	TTB	AGBC	BGBC	CLHGs	SOC	TC
Petros site natural forest	390.67	101.58	492.25	195.34	50.79	1.56	325.97	573.66
Plantation forest (K2Pl, PPl and DPl)	222.12	57.76	279.89	111.07	28.88	1.38	273.11	414.44

TAGB, TBGB–Total Above and Below Ground Biomass respectively; TTB–Total Tree Biomass, AGBC, BGBC–Above and Below Ground Biomass Carbon respectively; CLHGs– litter, herbs and grasses carbon; SOC–Soil Organic Carbon; TC–Total Carbon and K2Pl, PPl, DPl–Kuke2, Petros and Degaga site plantation forest respectively.

4.2.2 Below Ground Biomass Carbon Stock

The average carbon storage of BGB of natural and plantation forest was 50.79 $t.ha^{-1}$ and 28.88 $t.ha^{-1}$ respectively (Table 7). Analogous to AGBC, the natural forest's BGBC was about 1.76 times of plantation forests.

4.2.3 Litter, Herbs and Grasses Carbon Stock

The carbon stock of the leaf litter, herbs and grasses was 1.56 $t.ha^{-1}$ and 1.38 $t.ha^{-1}$ for natural and plantation forests respectively (Table 1)

4.2.4 Soil Organic Carbon Stock

The estimated mean soil carbon stock recorded was 325.97 $t.ha^{-1}$ and 273.11 $t.ha^{-1}$ for both ecosystem types-natural and plantation forest respectively (Table 1).

4.2.5 Total Carbon Stock

The total carbon stock was the sum of the above ground carbon, below ground carbon, LHGs carbon and soil organic carbon. Accordingly, 573.66 $t.ha^{-1}$ and 414.44 $t.ha^{-1}$ of TC were recorded in natural and plantation forests respectively (Table 7).

As shown on the Table 8, maximum and minimum (AGBC and BGBC) carbon was recorded under natural forest with the value of 582.73 and 151.1 $t.ha^{-1}$ in plot no 10 and 15.35 and 3.99 $t.ha^{-1}$ in plot no 30 from all ecosystem types respectively. There was a statistically significant difference between natural and plantation forest in relation to carbon storage.

Table 2: Plots location of Maximum and Minimum AGB and BGB Carbon of selected study site

Plot no	Natural forest Petros Site		Plantation Forest Kuke2 Site		Petros Site		Degaga Site	
	AGBC	BGBC	AGBC	BGBC	AGBC	BGBC	AGBC	BGBC
P1	518.38	134.78	126.46	32.88	178.01	46.28	110.87	28.83
P2								
	141.43	36.77	256.29	66.63	99.70	25.92	64.08	16.66
P5	400.02	104.00	231.77	60.26	69.87	18.17	227.85	59.24
P8	565.28	146.97	71.95	18.71	46.61	12.12		
P10	582.73	151.51	65.68	17.08	75.99	19.76		
P11	445.28	115.77	46.61	12.12				
P30	15.35	3.99						

AGBC, BGBC– Above and Below Ground Biomass Carbon respectively

4.3 Species Wise Carbon Pools of Natural and Plantation Forest

4.3.1 Natural Forest

A total of 11 tree species were recorded in the natural forest. Among these *Croton macrostachyus* was the most dominant species. Regarding carbon store, *Podocarpus falcatus* and *Croton macrostachyus* stored high density of carbon with 107.46 $t.ha^{-1}$ (55.01%) and 61.06 $t.ha^{-1}$ (31.26%), respectively that accounts 86.27% of the Munesa natural forest (Petros site). *Podocarpus falcatus* had the highest total above and below ground biomass carbon with 107.46 $t.ha^{-1}$ and 27.94 $t.ha^{-1}$, respectively. The lowest carbon was recorded for *Prunus africana* with 0.05 $t.ha^{-1}$ and 0.01 $t.ha^{-1}$of above and below ground carbon stock respectively (Table 3).

Table 3: Biomass carbon stock of natural forest tree species

S/no	Tree Species Name	Number of trees	Above Ground Carbon		Below Ground Carbon		Total Tree Biomass Carbon	
			AGBC ,$t.ha^{-1}$	%	BGBC , $t.ha^{-1}$	%	TTBC , $t.ha^{-1}$	%
1.	*Podocarpus falcatus*	130	107.46	55.01	27.94	55.57	135.40	55.57
2.	*Croton macrostachyus*	200	61.06	31.26	15.88	31.57	76.93	31.58
3.	*Celtis africana*	21	16.94	7.67	4.40	7.75	21.34	7.75
4.	*Ficus vasta*	2	4.68	2.39	1.22	2.42	5.89	2.42
5.	*Cordia africana*	4	1.58	0.81	0.41	0.82	1.99	0.82
6.	*Olea capensis subsp. marocarpa*	8	1.33	0.68	0.35	0.69	1.68	0.69
7.	*Albizia gummifera*	8	0.92	0.47	0.24	0.47	1.16	0.47
8.	*Grewia bicolour*	4	0.73	0.37	0.19	0.38	0.92	0.38
9.	*Ziziphus mauritiana*	2	0.30	0.15	0.08	0.15	0.37	0.15
10.	*Ficus sur*	12	0.29	0.15	0.07	0.15	0.36	0.15
11.	*Prunus africana*	2	0.05	0.02	0.01	0.02	0.06	0.02
	Total	393	195.34	100.00	50.79	100.00	246.12	100.00

AGBC, BGBC, TTBC- Carbon in Above Ground Biomass, Below Ground Biomass and Total Tree Biomass respectively

4.3.2 Plantation Forest

Four tree species were recorded in plantation forest. *Cupressus lusitanica* was the most dominant one. *Cupressus lusitanica* and *Eucalyptus grandis* stored high amount of carbon with AGBC of 65.25 $t.ha^{-1}$ (58.75%) and 31.88 $t.ha^{-1}$ (28.7%), respectively that accounts 87.45% of the Munesa plantation forest. Whereas BGBC was 16.97 and 8.29 $t.ha^{-1}$ for *Cupressus lusitanica* and *Eucalyptus grandis* respectively. The lowest carbon stored was recorded for *Croton macrostachyus* with 1.12 $t.ha^{-1}$ and 0.29 $t.ha^{-1}$of above and below ground carbon stock respectively (Table 4)

Table 4: Biomass carbon stock of plantation forest tree species

S/no	Species name	Number of trees	Above Ground Carbon		Below Ground Carbon		Total Tree Biomass Carbon	
			AGBC, $t.ha^{-1}$	%	BGBC $t.ha^{-1}$	%	TTBC $t.ha^{-1}$	%
1	*Cupressus lusitanica*	839	65.25	58.76	16.97	58.76	82.22	58.76
2	*Eucalyptus grandis*	210	31.88	28.7	8.29	28.7	40.17	28.7
3	*Pinus patula*	24	12.82	11.54	3.33	11.54	16.15	11.54
4	*Croton macrostachyus*	2	1.12	1.01	0.29	1.01	1.41	1.01
	Total	1075	111.07	100	28.88	100	139.95	100

AGBC, BGBC, TTBC- Above Ground Biomass, Below Ground Biomass and Total Tree Biomass Carbon respectively

4.4 Comparison of Present Study with Other Studies in the Country

The findings of the present study are compared with other similar researches in the country (Table 5). The mean of AGB and BGB carbon of the present study is larger than those studies conducted in Ethiopian country. It was greater than that of Selected Church Forest (Tullu *et al*., 2013), Menagesha Suba State Forest (Mesfin, 2013), Chilimo Forest (Teshome and Ensermu, 2013b) and Humbo Forest (Chinasho *et al*., 2015). But it was less than that of Egdu Forest (Adugna *et al*., 2013), Danaba CF (Bazezew *et al*., 2014), Arba Minch ground water Forest (Belay *et al*., 2014), Tara Gedam Forest (Mohammed *et al*., 2014), Gedo Forest (Hamere *et al*., 2015), Ades Forest (Kidane *et al*., 2015) and Woody Plants of Mount Zequalla Monastery Church (Abel *et al*., 2104) for natural forest. This variation might come from variation of age of the trees, its DBH and height, existing species type, and forest management. The large and small AGB carbon might be also due to species diversity. The other basic reason for this variation might be the use of different allometric model for biomass estimation. Lasco *et al*. (2000) also concluded that, using different allometric equations could be one of the limitations resulting in large variations in such estimates.

Table 5: Comparison of present study with other study in the country

S/no	Place of Study	Cover. Area, ha	AGBC $t.ha^{-1}$	BGBC $t.ha^{-1}$	LHGs $t.ha^{-1}$	SOC $t.ha^{-1}$	TC $t.ha^{-1}$
1.	Egdu Forest(Adugna *et al*., 2013)	486	278.08	55.62	3.47	277.56	614.73
2.	Danaba CF (Bazezew *et al*.,2014)	5,437	277.83	41.65	1.06	186.4	506.94
3.	Selected Church Forest (Tulu, 2011)	3.71	122.85	25.97	4.95	135.94	289.71
4.	Menagesha Suba State Forest (Mesfin, 2011)	3,418	133.00	26.99	5.26	121.28	286.53
5.	Arba Minch Ground Water Forest (Belay *et al*., 2014)	2120	414.70	83.78	1.28	83.80	583.56
6.	Tara Gedam Forest (Mohammed *et al*., 2014)	475	306.36	61.52	0.90	274.32	643.1
7.	Gedo Forest (Hamere *et al*.,2015)	5000	281	56.1	0.41	183.69	521.2
8.	Chilimo Forest (Teshome and Ensermu, 2013b)	2500	90.25	17.32	0.39	109.40	217.36
9.	Humbo Forest (Chinasho *et al*.,2015)	200	60.58	28.36	12.55	168.2	269.69
10.	Mount Zequalla Monastery Church (Abel *et al*., 2014)	9600	237.75	47.6	6.49	57.62	349.46
11.	Ades Forest (Kidane *et al*.,2015)	618	259.17	52.19	2.34	271.69	585.39
12.	Munesa Forest (present study)						
	a) Natural forest	2,000	195.34	50.79	1.56	325.97	573.66
	b) Plantation forest	567.62	111.07	28.88	1.38	273.11	414.44

AGBC, BGBC, CLHGs and TC –Above-Ground Biomass Carbon, Below-Ground Biomass Carbon, Carbon in Litter, Herbs and Grasses and Total Carbon respectively

When comparing the value of carbon stored in LHGs of Munesa forest with other previously studied findings in our country, Munesa forest could stored more carbon than that of Chilimo Forest, Gedo Forest, Tara Gedam, Arba Minch Ground Water and Danaba CF by (75.26, 73.72, 42.31, 17.95, 32.05%), respectively of natural forest. But it was less than that of Egdu Forest, Selected Church Forest, Ades Forest, Menagasha Suba State Forest, Humbo Forest and Woody Plants of Mount Zequalla Monastery by (122.44, 217.31, 50, 237.18, 704.49 and 316.03%). The main reason for this variation might be type of tree species produced leaf, tree age, and seasonal variation and etc.

SOC of the study area was higher than the above mentioned Ethiopian forests (Table 5) of Menagasha Suba State Forest, Selected Church Forest, Woody Plants of Mount Zequalla Monastery Church, Arba Minch Ground Water Forest, Tara Gedam, Ades Forest, Egdu Forests, Danaba Community Forest, Gedo Forest, Chilimo Forest and Humbo Forest by (62.79, 58.3, 82.32, 74.29, 15.85, 16.65, 14.85, 42.82, 43.65, 66.44 and 48.40%), respectively for natural forest. But it was lower than that of Ades Forest and Egdu Forests. The main reason for this variation might be tree types, rainfall and temperature variation of the studies might have contribution for this variation. Besides, mountainous manifestation of the study area might cause early run off litter, herbs and grasses which contributed to soil organic matter in decomposition.

V. CONCLUSIONS & RECOMMENDATIONS

Conclusions

The result of the study showed that natural forest ecosystem stored more carbon than plantation forest in all carbon pools (i.e. AGBC, BGBC and CLHGs). Under natural forest, there is high above and below-ground biomass carbon accumulation. Because, most of tree species, namely *Croton macrostachyus* and *Podocarpus falcatus* which are found in the natural forest ecosystem are many in numbers and has high DBH class and Height. As a buffer zone to natural forest, plantation forest is more subjected to exploitation by the local community, since the trees are very tall, straight and suitable for many purposes.
Similarly, in the case of litter, herbs and grasses, natural forest accumulates high mean litter, herbs and grasses than plantation forest ecosystem. This is due to high litter fall and growth of herbs and grasses easily under natural forest that play a great role in storing large amount of carbon. Age, tree species and sites were key determinants of amount of carbon sequestered.

Munesa forest was the reservoir of potentially high amount of carbon stock as compared to similar areas in the tropics like in tropical Africa, Asia and Latin America. At this time, the Munesa forest has the capacity to store 573.66 $t{\cdot}ha^{-1}$ and 414.44 $t{\cdot}ha^{-1}$ of carbon by natural and plantation forests respectively. This is helping in mitigating climate change by sequestering 2103.42 $t{\cdot}ha^{-1}$ and 1519.61 $t{\cdot}ha^{-1}$ of C equivalents for natural and plantation forest, respectively. Therefore, it can be concluded that natural and plantation forests of the study area are crucial to mitigate the climate change as they sink high GHGs from the atmosphere.

Recommendations & Future Works

The potential role of forest in storing carbon to reduce the buildup of greenhouse gases in the atmosphere is now well recognized almost by everybody. A number of alternative approaches to utilize forest management for carbon storing can be applied. These include forest protection, the management of forests for carbon and joint products to generate both carbon and timber as products. Establishing plantation forests dedicated to carbon sequestration and livelihood improvement through the products of the forests. Therefore, based on the conducted research study, the following recommendation has been made.

- The study was conducted for selected sites of Munesa forest due to lack of money and shortage of time. It is better if other studies should be done on the whole coverage area of the forest by using satellite images with the help of GIS to know its carbon storage potential.
- Adequate understanding on climate change issues and more powerful methods to implement cost/benefit analyses of forest-based GHG mitigation should be made.
- The carbon sequestration should be integrated with $REDD^+$ and CDM carbon trading system of the Kyoto Protocol. Hence possible to get monetary benefit of carbon dioxide mitigation which can be helpful for the sustainability of the forest;
- Existing timber harvesting should be done in a sustainable manner without disturbing the young trees to grow and increase its biomass. Surrounding communities should focus only on dead trees to fulfill the demand of firewood and charcoal production;
- In this research, quantification of carbon was done by non destructive method for tree biomass. So, it is better if other study should be done by using destructive method and comparing the result;
- Studying carbon sequestration and organizing the data for the Ethiopian country is mandatory to know the amount of country emission and offset of CO_2 in the city which helps the country to plant more trees to compensate it.

REFERENCES

[1] Abel Girma, Teshome Soromessa and Tesfaye Bekele, "Forest carbon stocks in woody plants of Mount Zequalla Monastery and it's variation along altitudinal gradient: Implication of managing forests for climate change mitigation". *Sci. Technol. Arts Res. J*. **3(2):**132-140, 2014.

[2] Broadmeadow, M. and Robert, M., "Forests, Carbon and Climate Change": The UK Contribution. Forestry Commission Bulletin 125. Forestry Commission, Edinburgh, 2003.

[3] Cai, S., Kang, X. and Zhang, L., "Allometric models for aboveground biomass of ten tree species in northeast China, *Ann. For. Res*. **56(1):** 105-122, 2013.

[4] Cairns, M.A., Olmsted, I., Granados, J. and Argaez, J., "Composition and aboveground tree biomass of a dry semi-evergreen forest on Mexico's Yucatan Peninsula", *Forest Ecology and Management* **186:** *125-132*, 2003.

[5] Chaffey, D. R., "Southwest Ethiopia forest inventory project": a reconnaissance inventory of forest in southwest Ethiopia. Ministry of Oversea Development, Land Resources Development Centre, Project Report **31:** 1-316, 1979.

[6] Chave, J. C., Andalo, S., Brown, M., Cairns, J., Chambers, D., Eamus, H., Folster, F., Fromard, N., Higuchi, T., Kira, J.P., Lescure, B., Nelson, H., Ogawa, H., Puig, B. and Yamakura, T., "Tree allometry and improved estimation of carbon stocks and balance in tropical forests", *Oecologia* **145:** *87-99*, 2005.

[7] Chave, J., Andalo, C., Brown, S., Cairns, M., Chambers, J., Eamus, D., Folster, H., Fromard, F., Higuchi, N. and Kira, T., "Tree allometry and improve estimation of carbon stocks and balance in tropical forests", *Oecologia* **145:** 87-99, 2014.

[8] Chave, J., Coomes, D. and Jansen, S., "Towards a worldwide wood economics spectrum", *Ecology Letters*, **12:** 351–366, 2009.

[9] Chidumayo, E.N. "Changes in miombo woodland structure under different land tenure and use systems in central Zambia", *Journal of Biogeography*, **29:** 1619–1626, 2002.

[10] EFAP, "Ethiopian Forestry Action Plan MoNRDEP, Addis Ababa, Ethiopia", volume **I**.14p. and volume **II**. pp. 21-34, 1994.

[11] Gorte, R. W. "Carbon Sequestration in Forests, Congressional Research Service", CRS Report for Congress, (Eggleston, H. S., Buendia, L. and Miwa, K. edn). Prepared for Members and Committees of Congress. Greenhouse Gas Inventories Programme. CRS Publishing, USA, Pp. 1-23, 2009

[12] IPCC, "The intergovernmental panel on climate change", A special report on land-use, land-use change and forestry. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 2000.

[13] IPCC, "Good Practice Guidance for Land Use, Land Use Change and Forestry", **In:** Institute for Global Environmental Strategies, Penman, j., Gytraskym. J., Hiraishi, T., Krug, T., Kruger, D., Pippatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F., (eds), IPCC National Greenhouse Gas Inventories Programme, Hayama, Kangawa, Japan, 2003.

[14] IPCC, "IPCC Guidelines for National Greenhouse Gas Inventories", Volume 4. Prepared by National Greenhouse Gas Inventories Program, Institute for Global Environmental Strategies (IGES) Publishing, Japan, 2006.

[15] IPCC, "Facts on climatic change", A summary of the 2007 assessment report of IPCC. Cambridge University Press, Cambridge, UK, 2007.

[16] Kebede Seifu "Estimating Land Cover/Land Use Changes in Munessa Forest Area Using Remote Sensing Techniques", M.Sc. Thesis. Swedish University of Agricultural Sciences, Skinnskatteberg, Sweden, 1998.

[17] Kirschbaum, M.U.F. "The carbon sequestration potential of tree plantations in Australia", **In:** Environmental Management, Eldridge, K.G., Crowe, M.P and Old, K.M. (eds.), The Role of Eucalypts and Other Fast Growing Species, Forestry and Forest Products, **20:**77-89, 1996

[18] Lundgren, B. "Soil studies in a montane forest in Ethiopia. Research Notes Nr11. Department of Forest ecology and Forest Soils, Royal College of Forestry, Stockholm, 1971.

[19] Pearson, T., Walker, S. and Brown, S. (2005). Source book for land-use, land-use change and forestry projects. Winrock International and the Bio-carbon fund of the World Bank.Arlington, USA.

[20] Subedi, B. P., Pandey, S.S., Pandey, A., Rana, E.B., Bhattarai, S., Banskota, T.R., Charmakar, S. and Tamrakar, R. "Guidelines for measuring carbon stocks in community managed forests", ANSAB, ICIMOD, FECOFUN, NORAD. 79 pp, 2010.

[21] Tesfaye Bekele, "Plant Population Dynamics of *Dodonea angustifolia and Olea europea subsp. Cuspidate* in dry Afromontane Forest of Ethiopia". Acta Universtitatis upsaliens Upssala, Sweden, 2002.

[22] Teshome Soromessa, "Ecological Phytogeography: A Case Study of *Commiphora* Species: *Science, Technology and Arts Research Journal* **2(3):** 93-104, 2013.

[23] Teshome Soromessa, Demel Teketay and Sebsebe Demissew. "Ecological study of the vegetation in Gamo Gofa zone, Southern Ethiopia", *Tropical Ecology* **45(2):** 209-221, 2004

[24] Teshome Soromessa, Ensermu Kelbessa, Afework Bekele, Getinet Masresha, Desalegn Ejigu, Melese Yihune and Fisseha Itanna, "Current Status and Significance of Faunal and Floral Diversity of the Simien Mountains, Northern Ethiopia". A poster presented on December 30-31, 2011 during the conference on Thematic Research, 2011.

[25] Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J. and Dokken, D.J. "Land Use, Land-Use Change, and Forestry, Intergovernmental Panel on Climate Change (IPCC), Special report. Cambridge University Press, UK. 375pp, 2000.

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