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Carbon Sequestration Potential of Traditionally Managed Forest: Contributions to Climate Change Mitigation, Ethiopia

Samuel Tizazu Agidew[1], Alemayehu Hailemicael Mezgebe[2]

[1]*MSC, Adama Science and Technology University,Adama, Ethiopia*
[2]*PH. D Arba Minch University College of Natural SciencesBiology Department, Ethiopia*

Correspondence Author: Alemayehu Hailemicael Mezgebe, *PH. D, Arba Minch University, Arba Minch, Ethiopia*

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Abstract

Natural forests can sequester huge amount of carbon thereby contributing towards climate change mitigation efforts. The purpose of the study was to estimate the carbon sequestration potentials of traditionally managed Shawo sacred forest so that its role in climate change mitigation could be recognized and valorized. Both primary and secondary sources were used to achieve the objectives. The analysis of this study was carried out using both qualitative and quantitative techniques. Descriptive research design was employed. Systematic sampling method was used to collect data of biomass along transect lines having systematically established plots of different carbon pools. Results revealed the presence of 16 plant species in Shawo forest. The average Diameter Breast Height (DBH) and Height (H) value of the plants was 9.21 cm and 10.43 m, respectively. The total mean carbon density was 514.52 t/ha (1888.31 CO_2 equivalents). Of the total carbon pools, plants share was 385.39 t/ha (1414.39 CO_2 equivalents). Litter, herbs and grasses (LHGs) account 1.69 t/ha (6.21 CO_2 equivalents). The soil organic carbon (SOC) up to 30 cm depth was 127.44 t/ha (467.60 CO_2 equivalents). The overall forest area of the study site has sequestered an estimated amount of 66,887.6 tons of carbon (245,254.53 CO_2 equivalents). In conclusion, the community surrounding Shawo forest has unique traditional forest conservation practices. Hence, carbon finance programs that recognize and valorize the community climate change mitigation efforts need to be considered.

Keywords: Carbon Stock, Climate Change Mitigation, Indigenous Knowledge, *Shawo* Forest.

INTRODUCTION

The response of forests to alarmingly increasing atmospheric carbon dioxide concentrations is crucial for climate change mitigation. Forest ecosystems contain from 62% to 78% of the total terrestrial carbon (Ullah and Al-Amin, 2012). Forests, as a source and sink of carbon, form an important component in efforts to combat global climate change impacts (Calfapietra *et al.*, 2015). The world forest stores 289 Gt of carbon in their biomass alone (FAO, 2010). Tropical forests comprise the largest (44%) proportion of the world forest (FAO, 2010). The world tropical forests release approximately 425 million tons of carbon annually (Pan *et al.*, 2011). The tropical forests are subjected to severe degradation due to overpopulation, shifting cultivation and expansion of agriculture (Chakravarty *et al.*, 2012). Deforestation and degradation of tropical forests constitute the second largest source of anthropogenic emissions of carbon dioxide after fossil fuel combustion (van der Werf *et al.*, 2009).

The forest resources of Ethiopia store 2.76 billion tons of carbon (about 10 billion tons of CO_2 equivalents) in the Above Ground Biomass (AGB) (Moges *et al*., 2010). However, the forest resources in Ethiopia have experienced so much pressure due to the increasing need for wood products and conversion to agriculture.

If the deforestation continues at the present rate of about 2%, the existing 2.76 billion tons of stored carbon will be released to the atmosphere in 50 years (Ayalew *et al.*, 2006).

Indigenous conservation practices of forest resources in Southern Ethiopia are traditionally well developed. Forest patches of diverse fauna and flora with several benefits as traditional medicinal, the source of food and ritual activities are some among many. Therefore, assessing and exploring indigenous knowledge of forest conservation practices is important to maintain and enhance the benefits of ecosystem service and to promote sustainable management of the forest ecosystem (UNDP, 2014). The south-western part of Ethiopia accounts for 18% of the country's forest cover (Menker and Rashid, 2012). *Shawo* forest is one of the traditionally managed sacred forests. Assessment of carbon stocks and stock changes in forests are relevant to the world climate change impacts to deal with the UNFCCC and Kyoto Protocol report (Green *et al.*, 2007).

No research has been conducted on Shawo forest. The forest has never been studied, recognized and valorized so far. This study bridges the data gap so that it can contribute to sustainable forest resource management.

Objectives:
The main objective of the study was to estimate the carbon sequestration potentials of traditionally managed *Shawo* sacred forest so that its role in climate change mitigation could be recognized and valorized.
Specific Objectives: Specifically, the study was designed to:

- Estimate how much carbon was sequestered in different pools of the forest.
- Analyze the vegetation structure and diversity of *Shawo* forest

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Location: The study was conducted in *Shawo* forest, located in Dita *Woreda*, Southern Nation Nationalities and Peoples Regional State (SNNPRS). It is found between 37^o 24' 43" East to 6^o 16' 30" North. The altitude of the area ranges from 2185 m to 2278 m asl.

Figure 1: Location of study area: *Shawo* Forest

Soil and landscape: The soils are primarily clay or clay loams which have been evolving from volcanic rocks (basalt) and volcanic tuff in the higher altitudes of the study area. The dominant soil color is reddish brown to dark brown (FAO, 1990). The principal soil types are cambisols and nitosols. These soils are very shallow and agriculturally unproductive.
Climate: Based on fifteen years (1999-2014) climate data obtained from Hawassa Statistical Agency, the study area experiences a bimodal rainfall pattern. It has an average annual temperature of 16.7^{o}C with a mean minimum daily temperature of the coldest month and the mean maximum temperature of 8.0°C and 21.0°C respectively. The annual average rainfall of the study area is 1246 mm.
Vegetation: *Shawo* forest covers an area of 130 ha. It is a natural evergreen forest dominated by *Syzygium guineense* plant.
Population: According to the district administration data, the study area has a total population of 4199, of which 1973 are men and 2226 women. The majority of the inhabitants practiced Christianity, with 96.87% and 2.43% practiced traditional beliefs. More than 90% of the peoples spoke Gamo as a first language.

2.2. Data Collection and analysis

Site selection and sampling design: A systematic sampling method was used to take vegetation samples. Sample plots were laid along transect lines on the study area following reconnaissance. Fourteen parallel transect lines were laid to East direction with an interval of 150 m between the transect lines. The main sampling plots were laid on transect lines with 200 m interval each using the GPS navigation system and compass. The sample plots were laid 100 m away from the border to avoid edge effect. The first transect line and the first plot on each transect line were laid randomly. A total of 42 field plots were established on the transect line within the *Shawo* forest. The main quadrant has a square shape and a dimension of 20 m × 20 m. Within the main plot, dimensions of 4 m × 4 m (16 m^2) for sapling data collection, and 1m × 1 m (1 m^2) were nested to sample litters, grasses, and herbs (Bazezew *et al.,* 2015).

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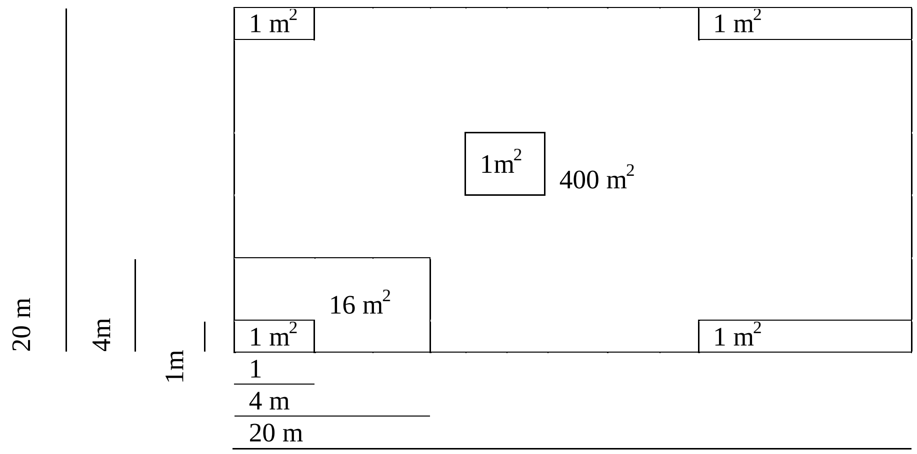

Figure 2: Quadrat design for filed data collection: (a) 20m X 20m main quadrat for Plants DBH> 5 cm, (b) 4m X 4m Plot for saplings (c) 1m X 1m for Soil, Liter Grass and Herbs nested five plots four plots in corner and one plot in middle of the main plots**.**

Field carbon stock measurement

Above ground biomass: All the plants in the main plots with a diameter at breast height (DBH) equal to or greater than 5 cm; and a height (H) greater than 1.3 m above the surface level was measured by using diameter tape and Suunto Clinometers, respectively (Lu, 2006). Plant DBH measurements were taken according to UNFCCC (2015) field manual recommendations. Plant specimen was collected, pressed and dried for further identification and checkup in Addis Ababa University. Sapling layer with a DBH less than 5 cm and H greater than 1.3 m were measured by Vernier Caliper in all nested quadrats (4 m^2) of the main plots.

Dead Leaf Litter, Herbs and Grass Sample Collection: The undergrowth layer, including seedlings, climbers, grasses, litter (twigs and leaves), were collected from five 1m × 1 m nested quadrats, at each corner and at the center of the main plot (Pearson *et al.*, 2005). The collected fresh weight of the litters, grasses, and herbs was recorded at the field. The collected sample from the five nested sub plots was evenly mixed and from that 100 grams was brought to the laboratory for analysis. Dead wood was not measured due to the nonexistence in sample plots.

Soil Sample Collection: Soil samples were collected from five points of the nested plot. Samples for bulk density and soil organic carbon content analyses were taken from the main plot (from 0-10, 10-20 and 20-30 cm soil depth) (Powers *et al*., 2011). Core sampler of height 10 cm and diameter 9.7 cm were used to sample for soil bulk density. The volume of the soil sample for each soil layer was determined from the height and radius of core sampler. A composite soil sample from the three-soil layer (0-10, 10-20 and 20-30) cm soil depth were taken to analyses soil organic carbon using soil Auger. All samples were placed in paper bags with the appropriate label.

Carbon Stock Biomass Estimation for Different Carbon Pools

Above ground biomass estimation: DBH and H values were recorded for all Plants (DBH value ≥ 5 cm) and saplings (DBH value < 5 cm) and H >1.3 m. The AGB was estimated using the regression equation developed for tropical forest and it has been used successfully in tropical forests, which has similar vegetation characteristics to *Shawo* forest. The estimation of sapling AGB was obtained from the regression equation (FAO, 2010). These equations are developed by considering tropical climatic zones (Chave *et al*., 2014). Additionally, Xu *et al*. (2015) compared this model with other biomass estimation models and has observed better accuracy than other models.

$$AGB = 0.0673 \times (p DBH^2 H)^{0.976} \quad \ldots\ldots (1)$$

Where, 5 cm < DBH and p= species wood density

The Saplings biomass (Bs) was estimated by allometric equation (2) shown below, which is DBH and H based having annual rainfall greater than 900mm (Visaratana and Chernkhuntod, 2004).

$$Bs = 0.0093 * DBH^2 * H^{0.9403} \quad \ldots\ldots (2)$$

The undergrowth biomass (vegetation with H value < 1.30 m), including seedlings, climbers, grasses, and others, were estimated directly using the harvesting method. The fresh weight was measured, and the dry weight was determined by oven-drying at 70 °C for 48 hours in the lab before weighting. The total dry weight of the biomass was calculated from the fresh weight using the equation below (Senpaseuth *et al*., 2009).

$$Total\ DW\ (kg.m^{-2}) = \frac{Total\ FW\ (Kg) x\ Subsample\ DW(g)}{Subsample\ FW(g) x\ Sample\ area(m^2)} \ldots\ldots (3)$$

Where: DW = the dry weight and
FW = the fresh weight.

The AGB was converted to carbon stock by multiplying 0.47 as a conversion factor (IPCC, 2007) using the equation below:

Above-ground carbon stock (AGCs) = 0.47 x AGB…………………………..…. (4)

Below Ground Biomass Estimation: it was made through a root-to-shoot ratio. For tropical rain forest, BGB is estimated about 20% of the ABG estimates (MacDicken, 1997).

Estimating of Litter, Herbs and Grass Biomass: The litter layer includes dead leaves, twigs, dead grasses, and small branches, fragments of organic material and dead wood with a diameter of less than 10 cm (Girma *et al*., 2014). Biomass carbon stock was estimated from sub-samples taken in the field. The total wet mass to oven dry mass was determined according to (Pearson *et al.*, 2005). The amount of biomass per unit area was calculated according to equation 5. LHGs Percentage of carbon was determined bythe loss on ignition (LOI) method (Allen *et al.*, 1986). The carbon density of LHGs was then calculated by multiplying biomass of LHGs per unit area with the percentage of carbon determined for each sample.

$$LHGsB = \frac{Wfield}{A} \times \frac{Wsub-sample\ (dry)}{Wsub-sample\ (fresh)} \times \frac{1}{1000} \qquad \ldots\ldots (5)$$

Where:
LHGsB = Litter, herb and gasses (biomass of litter t ha^{-1});
W field = weight of wet field sample of litter sampled within an area of size 1 m^2 in gm;
A = size of the area in which litter were collected (ha);
W sub-sample (dry) = weight of the oven-dry sub-sample of litter taken to the laboratory to determine moisture content (g), and
W sub-sample (fresh) = weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).

CLHGs = LHGsB × % C ………………………………………………………... (6)

Where, CLHGs is total carbon stocks in the dead litter, herbs, and grasses in the^{-1}
% C is the carbon fraction determined in the laboratory

Soil Carbon: The collected soil samples were oven-dried at 105 ^{0}C for 24 hours to remove the soil moisture so as to determine the organic matter and the bulk density (Gedefaw, 2015). To calculate Bulk density and soil carbon, the dried soil was washed and 2 mm sieve then the retaining builder dried again at 105 ^{0}C for 24 hours and subtracted from the dried weight of the soil. Then the dried soil weight was obtained, and bulk density was calculated using Equation (5) (Grossman *et al*., 2002). Also, the amount of soil carbon content (%C) of the sub-sample was measured in the laboratory using the Walkley-Black method. The soil carbon content was calculated by multiplying the volume percentage of the soil organic carbon in each soil horizon by the soil bulk density value (g cm^{-3}) and then multiplying the result by the soil depth (Black, 1965). Finally, the soil carbon content (the^{-1}) was calculated using Equation (5).

$$\text{bulk density}\left(\frac{g}{cm^3}\right) = \frac{\text{Massofoven} - \text{Dried soil}}{\text{Total Volume}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Soil carbon (t/ha) = Soil depth (cm) * soil bulk density (g/cm^3) X %C ……………… (6)

Total Carbon Stock
The total carbon density of the study area was determined by measuring and calculating carbon stock of all carbon pools in the *Shawo* forest and summing it up together.

Total Carbon Stock =AGB+LHGsB + BGB +SOC …........................... (7)

Data Analysis
Vegetation data analysis**:** The collected data was organized and recorded on the excel data sheet and analyzed using Statistical Package for Social Science (SPSS) software version 20. The height and diameter data were arranged in classes for applying the appropriate model of biomass estimation equation. Analysis of variance (one-way ANOVA) was used to determine statistically significant differences (at 0.05 level) of carbon stocks along different DBH, height and soil depth. The analyzed data were presented using descriptive statistics using charts, percentages, Tables, and Figures.
Soil pH**:** Soil pH was determined in a 1:2.5 soil to water suspension following the procedure outlined in Sahelemedhin and Taye (2000).

3. RESULTS

3.1. Analysis of Structure and diversity of *Shawo* Forest

In the current study, an average plant density of 499 indv. ha^{-1} was recorded (Table 1). The average DBH and H value for *Shawo* forest plants was 9.21 cm and 10.43 m respectively (Table 1). Out of the sixteen plant species, *Vernonia* sp. has an average DBH (50.86 cm) and H (23.62 m) (Table 1). The plant has stored the largest amount of average carbon density per individual (27.03 t $indv.^{-1}$) (Table 2).

Table 1: Species distribution of *Shawo* forest plants: Distribution and vegetation structure explained in terms of DBH Mean Height

Plant name	Family	No. of plant ha^{-1}	Mean DBH	Mean H	SD DBH	SD H
Echinopse giganteus	Asteraceae	89	2.7	2.4	0.61	0.48
Vernonia sp.	Asteraceae	32	50.86	23.6	44.2	18.41
Eucalyptus globulus	Myrtaceae	226	11.37	21.22	10.66	17.85
Croton macrostachyus	Euphorbiaceae	878	3.05	3.5	0.83	0.94
Ilex mitis	Aquifoliaceae	30	4.12	2.85	0	0
Vernonia myriantha	Asteraceae	342	2.35	3.06	0.59	1.32
Ocotea kenyensis	Lauraceae	29	2.2	1.57	0.282	0.09
Rubus sp.	Rubiaceae	2039	2	3.7	0.54	1.02
Embelia schimperi	Primulaceae	134	2.48	2.38	0.66	0.20
Maesa lanceolata	Primulaceae	804	2.8	3.5	0.8	0.94
Euphorbia abyssinica	Euphorbiaceae	496	11.37	21.22	10.66	17.85
Dombeya torrid	Malvaceae	30	2.3	1.6	0.31	0.12
Brucea antidysenterica	Simaroubaceae	938	2.36	2.6	0.611	0.76
Syzygium guineense	Myrtaceae	600	27.56	39.14	18.21	3.57
Juniperus procera	Cupressaceae	128	18.53	30.7	9.51	11.12
Maytenus gracilipes	Celastraeae	1190	2.4	2.38	0.67	0.78

3.2. Carbon Stock Potentials of Individual Plant Species

From the study, *Syzygium guineense* has stored the largest amount of mean carbon density per hectare (357.65 tha^{-1}) with storing capacity of 13.49 $tindv.^{-1}$) (Table 2). The plant was found to be the reservoir of 93.61% carbon density from the total carbon stock of *Shawo* forest. *Syzygium guineense* has the highest total AGB and BGB carbon with 298.04 and 59.61 t ha^{-1} respectively.

Table 2: Above and below ground biomass and carbon stock of plant speciesin the forest: AGBC and BGBC- above ground and below ground biomass carbon; TCS - total carbon stock; T. CO_2- total carbon dioxide equivalent; indv- individual

Plant name	x10^{-2}						% of share TCS of indv. Plant. ha^{-1}
	AGBC (t $indv^{-1}$)	BGBC (t $indv^{-1}$)	TCS ($tindv^{-1}$)	T CO_2 equivalent	% share of indv. plant	TCS of indv. Plant. ha^{-1}	
Echinopse giganteus	0.78	0.16	0.94	3.46	0.0196	0.63	0.00
Vernonia sp.	2252.66	450.53	2703.2	9920.73	56.364	587.99	1.52
Eucalyptus globulus	109.01	21.8	130.81	480.09	2.7276	231.27	0.60
Croton macrostachyus	1.42	0.28	1.71	6.27	0.0356	13.52	0.04
Ilex mitis	2.13	0.43	2.55	9.37	0.0532	0.47	0.00
Vernonia myriantha	0.76	0.15	0.91	3.34	0.019	2.93	0.01
Ocotea kenyensis	0.38	0.08	0.45	1.67	0.0095	0.3	0.00
Rubus sp.	0.67	0.13	0.8	2.93	0.0167	11.86	0.03
Embelia schimperi	0.67	0.13	0.8	2.95	0.0168	0.84	0.00
Maesa lanceolata	1.21	0.24	1.45	5.32	0.0302	331.79	0.86
Euphorbia abyssinica	95.76	19.15	114.91	421.71	2.3959	331.79	0.86
Dombeya torrid	0.33	0.07	0.4	1.47	0.0083	0.3	0.00
Brucea antidysenterica	0.64	0.13	0.77	2.83	0.0161	5.48	0.01
Syzygium guineense	1124.06	224.81	1348.87	4950.34	28.125	35778.9	92.77
Juniperus procera	405.51	81.1	486.62	1785.89	10.146	1266.26	3.28
Maytenus gracilipes	0.62	0.12	0.75	2.75	0.0156	1.1	0.00
Average	249	50	299	17601	6.25	2410.3	

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3.4. Distribution of plant species and their Carbon Stock Share

In the study area, plant species were categorized into ten DBH and H classes following (Healey *et al*., 2005; Bekele, 1994). From the ten categories of plant DBH, class1 has the highest density with 318 plant ha^{-1} (32%) (Table 3). While class 10 (>150 cm) was the least dominant, containing one plant ha^{-1} (0.10%). Unlike the highest plant density, the higher carbon stock was found in DBH class 3 with 128.75 tha^{-1} (33.4%) (Figure 3), and the lowest carbon stock was found in DBH class 1 with 1.14 the^{-1} (0.24%) of the total carbon stock density (Table 3).

Table 3: Above ground and below ground carbon stock variation within different DBH classes AGBC and BGBC- above ground and below ground biomass carbon stock; TCs-total carbon stock; TCs CO_2-total carbon stock carbon dioxide equivalent

DBH classes	Class Size in cm	No. of plants ha^{-1}	AGBC ($t\ ha^{-1}$)	BGBC ($t\ ha^{-1}$)	TCs ($t\ ha^{-1}$)	CO_2 Equivalent
Class 1	2-10	318	1.17	0.23	1.41	5.17
Class 2	11-20	256	41.76	8.35	50.11	183.90
Class 3	21-30	288	107.29	21.46	128.75	472.51
Class 4	31-50	87	62.27	12.45	74.72	274.23
Class 5	51-70	22	38.09	7.62	45.71	167.76
Class 6	71-90	4	8.51	1.70	10.21	37.49
Class 7	91-110	3	7.64	1.53	9.17	33.66
Class 8	111-130	5	30.50	6.10	36.60	134.33
Class 9	131-150	4	20.66	4.13	24.79	90.99
Class 10	>150	1	3.32	0.66	3.98	14.60
Total		988	321.22	64.24	385.46	1414.64

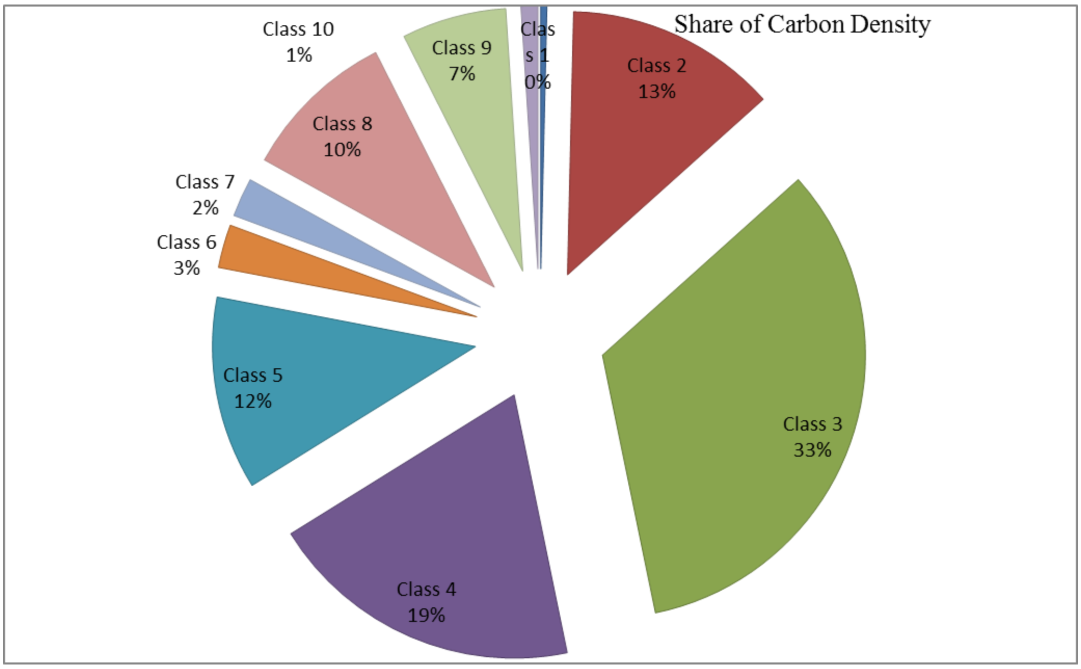

Figure 3: Percentage Share of Carbon density of the classes

Out of the ten H category of plant species class 8 has the highest plant density with 344 plants ha^{-1} which accounts for 34.89% of the total plant height class (Table 4). While plant height class 4 and class 5 were the least density with 2 plants ha^{-1} (0.415%). But class 3 did not exist in the study area (Table 4). Like plant density, the highest carbon density was found in plant height class 8. Plant height class 9 and class 7 were the 2nd and the 3rd, respectively (Table 4).

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Table 4: Above ground and below ground carbon stock variation within different height classes**:** AGBC and BGBC- above ground and below ground biomass carbon stock; TCs- total carbon stock; TCs- total carbon stock carbon dioxide equivalent. Carbon Stock in Different Carbon Pools of Shawo Forest.

Height classes	Class size in m	No. of plant (plant. ha^{-1})	AGBC ($t.ha^{-1}$)	BGBC ($t.ha^{-1}$)	TCs	CO_2 equivalent	Percentage share (%) of TCs
Class 1	(2-5]	287	0.72	0.14	0.86	3.15	0.22
Class 2	(5-10]	17	0.08	0.02	0.09	0.34	0.02
Class 3	(10-15]	0	0.00	0.00	0.00	0.00	0.00
Class 4	(15-20]	2	0.10	0.02	0.12	0.42	0.03
Class 5	(20-25]	2	0.13	0.03	0.16	0.58	0.04
Class 6	(25-30]	10	1.15	0.23	1.38	5.06	0.36
Class 7	(30-35]	80	19.31	3.86	23.18	85.06	6.01
Class 8	(35-40]	344	198.12	39.62	237.74	872.51	61.67
Class 9	(40-45]	189	87.99	17.60	105.59	387.53	27.39
Class 10	>45	33	13.68	2.74	16.41	60.23	4.26

In the study area, the mean carbon stock per plot for aboveground carbon pool was 321.22 tha^{-1} with CO_2 equivalent of 1179.13 tha^{-1} (Table 5). The average belowground carbon stock was found to be 64.26 ± 65.3 t ha^{-1} with CO_2 equivalent of 235.83 t ha^{-1} (Table 5).

Table 5: Mean biomass and carbon stock of AGB, AGC, BGB, BGC, LHGsB, LHGsC and SOC of *Shawo* forest**:** AGB & BGB – above ground and below ground biomass; LHGsB- litter, herbs and grasses biomass; TB- total biomass; AGC and BGC- above and below ground carbon; LHGsC- total litter, herbs and grasses carbon; SOC- soil organic carbon; TC-total carbon

Total No. of plots	Different Carbon pools								
42	AGB	BGB	LHGsB	TB	AGC	BGC	LHGsC	SOC	TC
Mean value (t ha^{-1})	683.59	136.72	2.59	822.9	321.29	64.26	1.69	127.44	514.68
% share	83.07	16.61	0.31	100.00	62.43	12.49	0.33	24.76	100.00

Soil organic carbon: The percentage of carbon content has decreased with increasing depth (Table 6). Similar to percentage carbon, soil organic carbon share has shown variation at different soil depth 56.19 ± 0.89 tha^{-1} (0 - 10 cm),44.06 ± 1.55 (10-20 cm) and 27.19 ± 1.35 (20-30 cm). The total average Soil organic carbon of the forest was estimated to be 127.44 t ha^{-1}. However, the variation was not statistically significance (p=3.07) at a 95% confidence interval (Table 6).

Table 6: Soil carbon stock at different soil depth in *Shawo* forest

Depth of soil (cm)	0-10	11-20	21-30	P-value
Soil pH	6.64	6.51	6.33	0.09
Bulk density (g cm^{-3})	0.73 ±0.118	0.80 ±0.194	0.82 ±0.137	0.00
Organic carbon (%)	7.67 ± 0.079	5.51 ± 0.146	3.33 ± 0.16	0.01
SOC (t $ha^{-1}depth^{-1}$)	56.19 ± 0.89	44.06 ± 1.55	27.19 ± 1.35	3.07

The test was done at 95% confidence interval (α = 0.05) SOC - soil organic carbon: t ha^{-1}

3.5. Carbon density in the three general carbon pools of *Shawo* forest

Total carbon stock density of plants, LHGs and organic soil were found to be 385.55, 1.69 and 127.44 t ha^{-1}, respectively (Table 5). The total carbon stock of *Shawo* forest which was 514.68 tha^{-1} (Table 5). Accordingly, maximum carbon stock was found in plant species with a carbon reservoir of 385.55 t ha^{-1} (74.91%) of the total carbon of the forest (Figure 2). The soil organic carbon stock was ranked as the second carbon reservoir (127.44 t ha^{-1} (24.77%)). LHGs biomass accumulated a small amount of carbon 1.69 t ha^{-1}, which accounts for 0.33% of the total carbon stocks of *Shawo* forest (Figure 4).

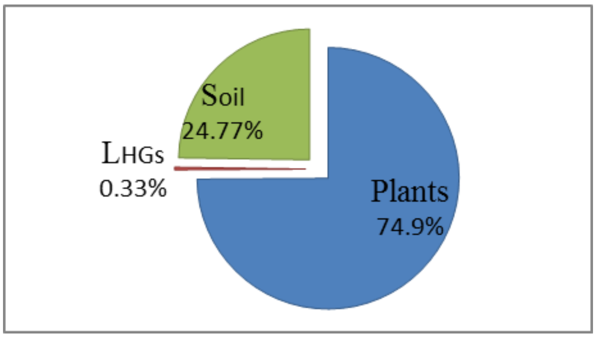

Figure 4: Share of total carbon stock (%) in different carbon pools

4. DISCUSSION

4.1. Carbon Stored in Each Individual Plant Species

In *Shawo* forest, even if the species density is higher in the lower class (climbers and saplings), the higher DBH and H class plant was the larger carbon. For instance, Plant DBH >21 cm contains 86.64% of the total carbon density share of the total carbon stock (Figure 3). Similarly, plant H > 25 m has stored 99.75% of the total above ground carbon stock of the studied area (Table 4). This shows that carbon stock density has a positive strong correlation with DBH (R^2=0.72) and H (R^2=0.63). As the DBH and H value increase, carbon density increase. Within the plant species of the study site, 94% total above ground carbon stock was stored by *Syzygium guineense*.

According to different literature, the global pattern above ground biomass in tropical forests ranges between 213-1173 t ha^{-1} (Murphy and Lugo, 1986). The average carbon stock of Sub-Saharan Africa is 143 t ha^{-1} (Ullah and Al-Amin, 2012). Accordingly, the *Shawo* forest carbon density iswithin the interval of tropical forest carbon stock interval. However, it was found to be above one-fold of the reported value of Sub-Saharan Africa above ground biomass carbon (321.29 t ha^{-1}). According to the total carbon, the current study result was relatively greater than that of some of the reported carbon stock studies of Ethiopian forests; Mount Zequalla forest (Girma *et al.*, 2014) and Humbo forest (Chinasho *et al.*, 2015) (Table 7). However, the present result is smaller to that of Egdu forest (Yohannes *et al.*, 2015) and Tara Gedam forest (Gedefaw, 2015) (Table 7). Nevertheless, the current study carbon stock result was more or less similar toAdaba-Dodola and Danaba Community forest Bazezew *et al.,2014*; Bazezew *et al.*, 2015) (Table 7).The variation might be due to the variation of the age of the plants, existing species,and management of the forests (Bazezew *et al.*, 2015). The use of an allometric model for biomass estimation might also help to explain for the difference in estimated value as explained that reliance on allometric equations could be one of the limitations resulting in large variations in such estimates (IPCC, 2003). Similarly, below ground biomass carbon stock in the studied area followed the same manner since it was a direct factor of above ground biomass (Brown, 2002).

Table 7: Comparison of carbon stock potential of the current result with other studies

Name	T ha^{-1}				
	AGBC	BGBC	LHGsBC	SOC	TCS
Adaba-Dodola CF Bazezew *et al.,2014*)	278.03	41.76	1.06	186.4	507.29
Danaba CF (Bazezew *et al.*, 2015)	278.03	41.76	1.06	186.4	507.29
Egdu forest (Yohannes *et al.*, 2015)	278.08	55.62	3.47	277.6	614.72
Humbo forest (Chinasho *et al.*, 2015)	30.77	14.46	12.55	168.2	225.98
MauntZequalla forest (Girma *et al.*, 2014)	273.2	47.6	6.5	57.6	348.8
Tara Gedam forest (Gedefaw, 2015)	306.66	61.52	0.9	274.3	643.11
Shawo forest (current study)	321.29	64.1	1.69	127.4	514.68

AGBC and BGBC- above ground and below ground biomass carbon stock; TCS-total carbon stock; LHDsBC- litter, herbs and grasses biomass carbon; CF- community forest

4.2. Carbon Stock in Different Carbon Pools of *Shawo* Forest

The mean carbon stock of leaf litter, herbs and grasses biomass was found to be less (1.69 t ha^{-1}) as compared to other forests such as Egdu forest (Yohannes *et al.*, 2015), Mount Zequalla forest (Girma *et al.*, 2014) and Humbo forest (Chinasho *et al.*, 2015) (Table 7). However, the result was more or less similar to evergreen forest (1.58 tha^{-1}) (Mohanraj *et al.*, 2011). This might be due to the presence of dominant evergreen plants (*Syzygium guineense)* which do not shed their leaves in dry seasons. The result of this study (1.69 tha^{-1}) was within the interval estimated for the tropical and sub-tropical forest (1.4 - 4.8 t ha^{-1}) (Chang *et al.*, 2010). the obtained result for LHGsBC result was nearly similar to that of Adaba-Dodola and Danaba Community forest (Bazezew *et al.*, 2015; Bazezew *et al.*, 2014). The variation might be due to litterfall biomass accumulation that may be associated with forest stand condition such as stand properties (Castilho et al., 2006). In the study site, the community uses the litter fall for fuel wood consumption this might be another factor for low LHGsB. From the LHGsB the majority was covered by litter falls in most case the herbs and grasses were absents in the sampled site. According to Bazezew et *al.* (2014), the absence of herbs and grasses might be due to huge closed canopies of making the growth unsuitable.

Soil Organic Carbon

About 32% of global soil carbon pool is in tropical soils (Lal, 2004). In the current study, the amount of soil organic carbon was 127.44 tha^{-1}) (Table 7). Though this is the second most stock of carbon in *Shawo* forest, it was found to be lower than other studies in another Ethiopian forest, Egdu Forest (Yohannes *et al*., 2015), Adaba-Dodola CF Bazezew *et al*.,2014), Tara Gedam forest (Gedefaw, 2015), Danab Community Forest (Bazezew *et al*., 2015), Humbo forest (Chinasho *et al*., 2015) (Table 7). However, the result was also greater than MauntZequalla forest (Girma*et al*., 2014) (Table 7). This might be rainfall and temperature variation of the studied area Bazezew*et al*., 2014). Also, in undisturbed forest ecosystems, most of the variation in SOC stocks could be significantly explained by variables (basal area, clay fraction and soil pH). Furthermore, SOC is strongly affected by ecosystem productivity, vegetation type, climate, clay mineralogy, soil pH, nutrient availability, soil aggregates and texture (Don *et al*., 2011; Chaplot *et al*., 2010; Lal, 2004; Sixet *al*., 2002).

Soil pH and forest SOC stocks have a high relationship; reflect how the soil biochemical environment is critically important for soil microbial communities that decompose organic matter (Hombegowda *et al*., 2016; Motavalli *et al*., 1995). The higher SOC stocks found in the acidic and basic soils. Unfavorable biochemical environment retards microbial communities that decompose the organic matter (Hombegowda *et al*., 2016; Six *et al*., 2002). At a near neutral soil pH, conditions were ideal for microbial communities. Accordingly, decomposition rates were high, resulting in SOC accumulation (Hombegowda *et al*., 2016). In the current study, a pH value of near neutral (6.64) was observed (Table 6). This might create a conducive condition for soil microbes to decompose effectively.

The bulk density of the soil in the current study was found to be 0.73 ± 0.12gcm^{-3}, 0.80 ± 0.19 gcm^{-3} and 0.82 ± 0.14 gcm^{-3} for soil depth of 0-10 cm, 10-20 cm, and 20-30 cm, respectively. In the studied area, the presence of low bulk density in the soil indicates that the soil has a high potential to accumulate a large amount of organic carbon. The bulk density of the soil was increased with in increasing soil depth significantly (P=0.004**). This might due to the presence of plant roots and large soil aggregates Bazezew *et al*., 2014; Yohannes *et al*., 2015; Lal, 2004; Six *et al*., 2002). Unlike bulk density, percentage carbon decrease with increasing soil depth significantly (P=0.006**) (Table 6). Which was similar to Danaba Community Forest result, this might be due to the accumulation and decomposition of litter fall in the tope soil.

The recorded values of Egdu Forest (Yohannes *et al*., 2015); Adaba-Dodola Community Forest Bazezew *et al.*,2014), MauntZequalla Forest (Girma *et al*., 2014), Tara Gedam forest (Gedefaw, 2015) and Danaba Community Forest studies showed a similar pattern with the present study. However, Humbo Forest SOC is greater than all referred in table 7(Table 7).

Unlike the current result, the soil is the largest carbon reservoir in the terrestrial ecosystem (Chinasho *et al*., 2015; IPCC, 2003; Lal and Bruce, 1999). But forest management and the existing condition of the forest greatly affect soil organic carbon. SOC is influenced through land use and management activities that affect the litter input (for example how much-harvested biomass is left as residue and SOM output rates, tillage intensity affecting microbial survival) and the estimates depth to which carbon is accounted, commonly 30 cm (IPCC, 2003; Lal and Bruce, 1999). Hence, in the current study, the above-ground biomass has two-fold greater than SOC. This might be due to the presence of mature *Syzygium guineense* (with better DBH and H value*)* in good density. The use of litter as fuel also affects the SOC (IPCC, 2003).

5. CONCLUSION

The traditionally managed *Shawo* forest was found to sequester much of its carbon on above ground portion. The woody nature of the dominant plant, *Syzygium guineense*, has the highest contribution to reserve the highest biomass of the total plant species. With total area coverage of 130 hectares, a remarkable contribution was observed by community effort. Hence, possibilities in carbon finance programs and other related benefits need to be considered. The traditional forest management Knowledge that pass-through generations have to be recognized to enhance the global climate change mitigation efforts. Such interventions would contribute towards sustainable conservation of the forest resource and encourage climate change mitigation effort.

6. REFERENCES

Allen, S. E., H. M. Grimshaw, and A. P. Rowland, 1986. Chemical Analysis. In: Moore, P. D. and S. B. Chapman, (eds). 1986. Methods in plant ecology. Blackwell Scientific Publications, London, UK, 285-344.

Ayalew, A., Bekele T., and Demissew S., 2006. The Undifferentiated Afromontane Forest of Denkoro in the Centeral Highland of Ethiopia: A Floristic and Structural Analysis. SinetEthiopia Journal of Science, 29(1): 45–56.

Bazezew, M.N., 2014. Carbon Stock in Adaba-Dodola Community Forest of Danaba District, West-Arsi Zone of Oromia Region, Ethiopia: An Implication for Climate Change Mitigation. MSc thesis, Addis Ababa University, Ethiopia.

Bazezew, M.N., Soromessa, T. and Bayable, E., 2015. Above- and Below-Ground Reserved Carbon in Danaba Community Forest of Oromia Region, Ethiopia: Implications for CO_2 Emission Balance. *American Journal of Environmental Protection*, 4(2): 75-82. doi: 10.11648/j.ajep.20150402.11.

Bekele, T., 1994. Phytosociology and Ecology of Humid Afromontane Forest in the Central Plateaus of Ethiopia. *Journal of Vegetation Science,* 5(1): 87- 98. doi: 10.2307/3235642.

Black, C.A., 1965. Hydrogen-ion Activity. In Methods of Soil Analysis Part II: Chemical and Microbiological Properties; *America Society of Agronomy*, 2: 771–1572.

Brown, S., 2002. Measuring carbon in forests: current status and future challenges. *Environmental Pollution,* 116(2002): 363-372.

Calfapietra, C., L. Barbati, B. Perugini, G. Ferrari, A.Guidolotti, A. Quatriniand P. Corona, 2015. Carbon stocks and potential carbon sequestration of different forest ecosystems, under climate change and various management regimes in Italy. Ecosystem Health and Sustainability, 1(8):1-9. doi: org/10.1890/EHS15-0023.

Castilho, C.V., Magnusson, W.E., Araujo, R.N.O., Luizao, R.C.C., Luizao, F.J., Albertina, P. and Higuchi, N., 2000. Variation in aboveground plant live biomass in a central Amazonian Forest: effects of soil and topography. JournalForestEcologyManagement, 234(2006): 85–96.

Chakravarty, S., K. Ghosh, C.P. Suresh, A.N. Dey, and G.Shukla, 2012. Deforestation: Causes, Effects and Control Strategies. In: Clement, A. and Okia, (Edts.)., (2012). Global Perspectives on Sustainable Forest Management, 65:1-28.

Chang, C., Wang, C., Chou, C. and Duh, C., 2010. The Importance of Litter Biomass in Estimating Soil Organic Carbon Pools in Natural Forests of Taiwan. *Taiwan Journal of Science,* 25(2), 171-80.

Chaplot, V., B. Bouahom, and C. Valentin, 2010. Soil organic carbon stocks in Laos: spatial variations and controlling factors, Global Change Biology16(4): 1380–1393. doi: org/10.1111/j.1365-2486.2009.02013.x.

Chave, J., M. Rejou-Mechin, Echain, A. Burquez, E. Chidumayo, M.S. Colgan, W.B.C. Delitti, A. Duque, T. Eid, P.M. Fearnside, R.C. Goodman, M. Henry, M. Martinez-Yrizar, W.A. H.C. Mugasha, Mullerlandau, M. Mencuccini, B.W., Nelson, A. Ngomanda, E.M. Nogueira, E. Ortiz-Malavassi, R. Pceisser, Ploton, P., M. C. Ryan, J.G. Saldarriaga, and G. V. IeIlledent, 2014. Improved allometric models to estimate the above ground biomass of tropical Plants. Global Change Biology.20(10): 3177-3190. doi: org/10.1111/gcb.12629.

Chinasho, A., T. Soromessa, and E. Bayable, 2015. Carbon stock in woody plants of Himbo forest and its variation along altitudinal gradients: The case of Humbo district, Wolaita Zone, Southern Ethiopia.International journal of environmental protection and policy, 3(4): 97-103. doi: 10.11648/j.ijepp.20150304.13.

Don, A., J. Schumacher, and A. Freibauer, 2011. Impact of tropical landuse change on soil organic carbon stocks a meta-analysis: Soil organic carbon and land-use change. *Global. Change Biology*, 17(4): 1658–1670. doi: 10.1111/j.1365-2486.2010.02336.x.

FAO, 1990. The State of Food and Agriculture. World and Regional Reviews Structural Adjustment and Agriculture. FAO Agriculture Series 23, United Nations, Rome.

FAO, 2010. Global Forest Resources Assessment, Country Report Ethiopia. FAO forestry paper 163. FAO, Rome, Italy.

Gedefaw M (2015) Estimation of Above and Belowground Carbon Stocks of Forests: Implications for Sustainable Forest Management and Climate Change Mitigation: A Case Study of Tara Gedam Forest, Ethiopia. J Earth Sci Clim Change 6: 286. doi: 10.4172/2157-7617.1000286.

Girma, A., T.Soromessa, and T. Bekele, 2014. Forest carbon stocks in woody plants of mount Zequalla Monastery and its variation along altitudinal gradient: implication of managing forests for climate change mitigation. Star journal, 3(2):132-140. doi: 10.4314/star.v3i2.17.

Green, R., B.Tobin, and M. O’Shea, 2007. Above and below ground biomass measurements in an unthinned stand of Sitka spruce (*Piceasitchensis*(Bong) Carr.). European Journal of Forest Research,126(2): 179−188. doi 10.1007/s10342-005-0093-3.

Grossman, R.B. and T.G. Reinsch, 2002. Bulk Density and Linear Extensibility: The Solid Phase: In Methods of Soil Analysis. Soil Science Society of America Madison: Madison, WI, USA, 201–225.

Healey, S.P., W.B. Cohen, Z.Yang, and O.N. Krankina, 2005. Comparison of Tasseled Cap-based Landsat data structures for forest disturbance detection. Remote Sensing of Environment. 97(2005): 301-310.doi:10.1016/j.rse.2005.05.009

Hombegowda, H.C., O.V. Straaten, M. Köhler, and D. Holscher, 2016. On the rebound: soil organic carbon stocks can bounce back to near forest levels when agroforests replace agriculture in southern India, Soil, 2: 13–23. doi: 10.5194/soil-2-13-2016.

IPCC, 2003. Good Practice Guidance for Land Use, land-Use Change and Forestry. In: Penman, J., M. Gytarsky, T. Hiraishi, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe, and F. Wagner, (Eds) (2003). Intergovernmental Panel on Climate Change (IPCC), IPCC/IGES, Hayama, Japan.

IPCC, 2007. Climate Change: The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC; Cambridge University Press: Cambridge, UK.

Lal, R. and J. Bruce, 1999. The potential of world cropland to sequester carbon and mitigate the greenhouse effect. *Environmental Science and Policy*, 2(1999) 177–185.

Lal, R., 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science, 304(5677): 623-1627. doi: 10.1126/science.1097396.

Lu, D., 2006. The potential and challenge of remote sensing-based biomass estimation. International Journal of Remote sensing, 27(7):1297–1328. doi: org/10.1080/01431160500486732.

MacDicken, K.,1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International, 1611 N. Kent St., Suite 600, Arlington, USA

Menker, H. and M.H. Rashid, 2012. Drivers of land-use change in the Southern Nations, Nationalities and People’s Region of Ethiopia. African Journal of Agriculture and Resource Economics,9(2): 148-164.

Moges, Y., Z. Eshetu, and S. Nune, 2010. Ethiopian Forest Resources: Current Status and Future Management Options in View of Access to Carbon Finances. Literature Review for Ethiopian Climate Research and Networking and the United Nations Development Program. Addis Ababa, Ethiopia.

Mohanraj, R., J. Saravananand S.Dhanakumar, 2011. Carbon stock in Kolli forests, Eastern Ghats India) with emphasis on aboveground biomass, litter, woody debris and soils. In: Elena, P. and Y.Serengil, (edts.), (2011). Biogeosciences and Forestry, 4: 61-65. doi: 10.3832/ifor0568-004.

Motavalli, P. P., C. A. Palm, W. J. Parton, E. T. Elliott, and S. D. Frey, 1995. Soil pH and organic C dynamics in tropical forest soils: evidence from laboratory and simulation studies. Soil Biology and Biochemistry, 27(12): 1589–1599. doi: org/10.1016/0038-0717(95)00082-P.

Murphy P. G., A. E. Lugo 1986. Ecology of Tropical Dry Forest Annual Review of Ecology and Systematics, 17: 67-88.

Pan, Y., A. R. Birdsey, F. Jingyun, H. Richard, P. E. Kauppi, A. W. Kurz, L.O. Phillips, 2011. A Large and Persistent Carbon Sink in the World's Forests. Science, 333(6045): 988-993.doi: 10.1126/science.1201609

Pearson, T., S. Walker, and S. Brown, 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, 19-35.

Powers, J.S., M.D. Corre, T.E. Twine and E. Veldkamp, 2011. Geographic bias of field observations of soil carbon stocks with tropical land-use changes precludes spatial extrapolation 108: 6318–6322.

Sahelemedhin, S. and B. Taye, 2000. Procedures for Soil and Plant Analysis. National Soil Research Center, EARO, Technical paper No.74, Addis Ababa, Ethiopia.

Senpaseuth, P., C. Navanugraha, and S.Pattanakiatron, 2009. The estimation of carbon storage in dry evergreen and dry dipterocarp forest in Sang Khom District, NongKhai province, Thailand. Environment and Natural Resources Journal, 7(2): 1-11.

Six, J., R.T. Conant, E.A. Paul, and K. Paustian, 2002. Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. Plant and Soil, 241(2): 155–176.

Ullah, M.R. and Al-Amin, 2012. Above- and below-ground carbon stock estimation in a natural forest, Bangladesh, Journal of Forest Science, 58 (8): 372–379.

UNDP, 2014. Social and Environmental standards, United Nations development program.

UNFCCC, 2015. Measurements for estimation of carbon stocks in afforestation and reforestation project activities under the clean. Development mechanism: a field manual.

Van der Werf G. R., D. C. Morton R. S. DeFries, J. G. J. Olivier, , P. S. Kasibhatla, R. B., Jackson, G. J. Collatz, and J. T. Randerson, 2009. CO_2 emissions from forest loss. National Goscience, 2: 737–738.

Xu, Y. J., S. B. Zhang, J. Franklin, P. Liang, Y. Ding, Z. Luo, D. Lu, Bao. and M. Jiang 2015. Improving allometry models to estimate the above and belowground biomass of subtropical forest, China. Ecosphere, 6(12): 289. doi: org/10.1890/ES15-00198.1.

Yohannes, H., T. Soromessa, M. Argaw, 2015. Carbon Stock Analysis Along Altitudinal Gradient in Gedo Forest: Implications for Forest Management and Climate Change Mitigation. American Journal of Environmental Protection, 4(5): 237-244. doi: 10.11648/j.ajep.20150405.14.