Full Length Research Article

Woody Species Diversity and Carbon Stock Estimation of Dorze Ayira Natural Forest, Gamo Zone, Southern Ethiopia

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Abstract

Forests play a significant role in mitigating climate change by sequestering CO_2 from the atmosphere. This study was aimed to investigate woody species diversity and to estimate the carbon stock potential at Dorze Ayira Natural Forest at Chencha District, Gamo Zone, Southern Ethiopia. Systematic sampling techniques were used to collected vegetation data from twenty 20m×20m quadrats. Aboveground carbon and belowground carbon were estimated using allometric equations. Additional 1m×1m subplot was laid for literal and soil samples data collection using destructive methods. A total of 26 woody species represented by 25 genera and 19 families were identified. The mean aboveground biomass and carbon density were 50.87±9.98 and 23.91 ± 4.69 t/ha, respectively. On the other hand, the mean belowground biomass and carbon density were 10.18 ± 1.996 and 4.78 ± 0.94 t/ha.. The average sum of all carbon pools in the study area was 91.74t/ha. The corresponding average CO_2 equivalents of all carbon pools was 336.69 ton/ha. The mean leaf literal, herb and grass biomass and carbon stock were estimated to be 2.96 ± 0.49 and 1.39 ± 0.23 t/ha, respectively. Furthermore, the mean soil organic carbon was 60.95±13.49 ton/ha (0-10cm, 10-20cm and 20-30cm depth). The result of the current total carbon stock capacity of Dorze Ayra forest revealed its contribution to climate change mitigation. Therefore, the forest needs more protection and due attention to reduce its current anthropogenic pressures.

Keywords: Allometric equations; Biomass; Carbon stock; Diversity

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1. Introduction

Forests are known to play important role in regulating the global climate (Chavan and Rasal, 2010; Jordan *et al*., 2009). The response of forests is crucial for the global carbon cycle as they have huge potential in sequestering and storing more carbon than any other terrestrial ecosystem (Sundquist *et al*., 2008). Forests can sequester large amounts of carbon in several ways including as carbon sinks in the standing forest, in wood products, and in avoided emissions when wood is used as a substitute for more fossil fuel consuming products such as steel, concrete and brick (IPCC, 2007; UNFCCC, 2015).

Forest cover in Ethiopia has been declining due to anthropogenic activities such as uncontrolled expansion of agriculture, overgrazing, and illegal harvesting of the forest products (MoFED, 2011). As a result of this environmental degradation leads to desertification and its manifestations are eventually becoming the overriding cause for the loss of biodiversity (NBSAP, 2005; Friis *et al*., 2010).

The forest of study area is remnant natural forest patch which is composed of various flora and fauna (Temesgen Dingamo *et al*. 2018). However, the forest is neighbored by dense population whose livelihood is heavily dependent on forest resources. Even though the area is protected by indigenous forest management practices, illegal selective tree cutting and cattle grazing are still the major problems for the sustainability of the forest. In addition, there is no prior research in the area regarding woody species diversity and carbon stock estimation of the forest. Therefore, the present study was conducted to investigate woody species diversity and estimate carbon stock potential.

2. **Materials and Methods**

2.1. Description of the study area

The study area, Dorze Ayira kebele is located 525 kms away from Addis Ababa and 285 kms away from Hawassa at 06^{0}14’:57’’N latitude and 037^{0}34’35’’E longitude (Figure 1). It is highland agro ecological Zone at altitudinal range between 2450 to 2595 masl. The Dorze live primarily in the southern region of the country, the villages near the town of Chencha and Arba Minch located in the Gamo Zone. Weaving is a primary profession for many Dorzes.

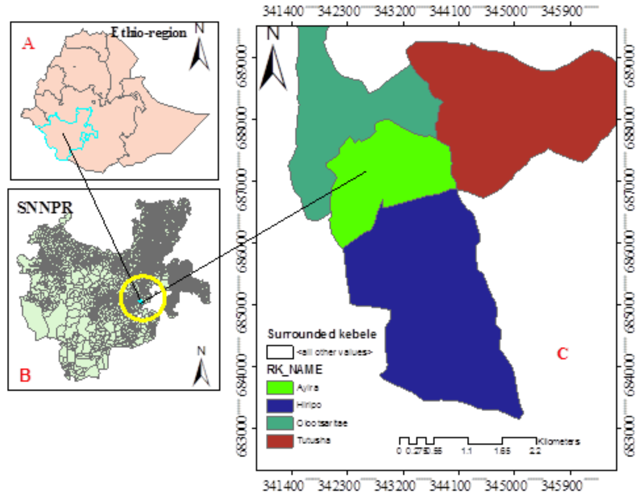

Figure 1. Location map of the study area (Source: Arc GIS 10.2)

The study area is known by bimodal rainfall type. Maximum and minimum mean annual rainfall of the study area during 2008-2018 was 202 mm and 52 mm and the maximum and minimum mean annual temperature was 24^0C and 11.8^0C, respectively.

A total number of populations in Dorze Ayira kebele is 811 of which 321 are females and 490 are males (Chencha Woreda Agriculture Office, 2010). Based on the data obtained from the Woreda Agricultural Office, about 67.04% of the total area is agricultural lands which covered by annual and perennial crops. The natural forest area covered 6.67 % (20 ha) of the Dorze Ayra kebele.

Ayira natural forest is a forest patch which composed of various flora and fauna (Temesgen Dingamo *et al*., 2018). Most common tree species are *Galiniera saxifraga*, *Dombeya torrida, Schefflera volkensii*, *Nuxia congesta*, *Vernonia myriantha*, *Hagenia abyssinica*, *Ilex mitis***,** *Syzygium guineense*, *Bersama abyssinica* and *Croton macrostachyus*. Shrubs and herb are *Phytolacca dodecandra*, *Rubus apetaluss* and *Rumex abyssinicus.* While animals are Anubis Baboon, Warthog, Colobus monkey etc.

2.2 Sampling design

The study site was stratified into different vegetation types. Four transect lines were laid and quadrats were laid at regular interval apart (b/n 50m) and all transect lines were roughly parallel to each other (100m). A total hectare (ha) of the study area is 20 ha and its potential 30 quadrats, out of total potential

20 quadrats (20 m × 20 m) were used for investigated woody species and carbon stock measurement. In each quadrat list of woody species, height (H≥ 2.5m), DBH ≥5 cm at breast height (1.3m) were collected as well as LGHs. Similarily, soil sample data were collected from 1*1m sub-plot using caliper, diameter tape, and Suuntoo clinometer. The data collection period was from December 2018 to January 2019. Square quadrats were selected since they are more advantageous by including more of within-plot heterogeneity, and thus be more representative than the circular quadrats of the same area (Brown, 1997). Thus, nested quadrats having 20m x 20m (main quadrats) and 1m x 1m (sub-pots) were used in this study.

2.3 Vegetation data collection

Vegetation data were collected from 20×20 main quadrats. Data were collected from each quadrat trees and shrubs. Height and diameters at breast height (DBH) of all woody plant species DBH ≥ 5 cm and height (H≥2.5m) was measured. Individuals having a DBH less than 5 cm were counted. The diameters at breast height (DBH) of all the woody plant at 1.3 meter above the ground was measured using a Caliper and tape meter. While the tree was on a slope, measurements were always on the uphill side; when tree was leaning, the DBH tape was wrapped according to the tree's natural angle (not straight across, parallel to the ground). In some parts when it is impossible to measure the fork was taken. Traditionally forestry dictates that forked stems are measured as two separate trees but when the focus is on biomass, it is more accurate to measure as a single tree (Holly *et al.*, 2007). Heights of trees were measured using Clinometer and adjusted bamboo stick.

Plant specimens were collected pressed and dried as well as identified at the field by expertise and unknown wood plant species were taken to the National Herbarium (ETH), Addis Ababa University. In each quadrat altitude and geographical coordinates were measured using Garmin eTrex GPS.

2.4. Carbon data collection methods

2.4.1 Aboveground biomass (AGB)

The DBH (at 1.3 m) and height of individual trees were measured in each 20*20 quadrats using caliper and marking each tree with colored rope to avoid double counting. Each tree was recorded individually, along with its scientific name, local name and collection code. Trees on the border were included, only if > 50% of their basal area fallen within the quadrat (Figure 2).

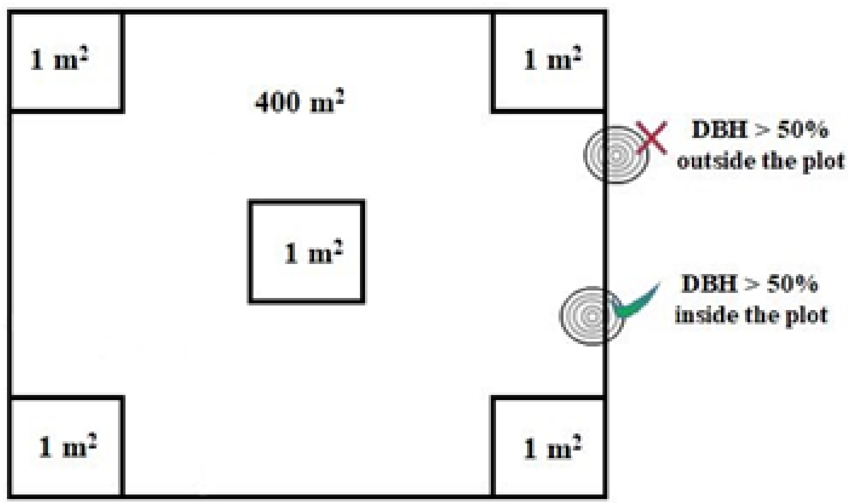

Figure 2: Nested plot design for sampling carbon pools

2.4.2 Belowground biomass (BGB)

Belowground biomass estimation was used 1:5 root-to-shoot ratio value AGB (MacDicken, 1997). Hence, BGB was calculated as 20% of aboveground tree biomass.

2.4.3 Standing Deadwood

Standing dead trees were categorized in to two: category-1 forest standing tree with no leaves and category-2 for standing dead tree with bole (trunk) only (Pearson *et al*., 2007). For category-1 the same measurement as live tree was used and category-2, diameter at the bottom and top of the bole were measured using diameter tape and caliper while the height was measured using stick.

2.4.4 Leaf Litter, Herbs and Grasses (LHG)

LHG found within 1m x 1m sub-plots from the four corners and at the center of the main plot were destructively collected to the ground using harvesting Sickle and then weighed inside a paper bag using digital beam balance. This weight was recorded as fresh weight of leaf literal, grasses and herbs for each sub-plot. Then, approximately 100g of a composite sub sample, which was evenly mixed from the five sub-plots, was properly packed with labeled paper bag and taken to the laboratory to determine percentage of carbon (% C) in the body represented by % of C.

2.4.5 Soil Organic Carbon (SOC)

Soil samples were collected from five places from the center and the four corners of the main plot using soil sampler and shovel cleaned surface of the ground . Core sampler (Auger) was used to take soil samples up to 30cm depth as recommended by IPCC (2006). The depth was divided into three layers: 0– 10cm, 10 – 20cm and 20 – 30cm. This helped to identify at what depth % C and bulk density were more concentrated. The fresh weight of each soil samples from the three layers were weighed using digital beam balance with 0.1g precision. Then composite sub- samples, approximately 100g, from the five sub-plots were taken to the laboratory by packing with labeled plastic bags. Then, soil organic carbon and bulk density were estimated following IPCC (2006).

2.4.6 Data Analysis

After the vegetation, data collection was completed and it was analyzed using R-software. Carbon stock density at the different carbon pools were analyzed using allometric equation for AGB and SPSS Version 20.0.

3. Results

3.1 Plant species diversity

A total of 26 woody species representing 25 genera and 19 families were identified in Dorze Ayra forest. Of the total, 19 species (73.08%) were trees, 5 species (19.23%) were shrubs, and 2 species (7.69%) were liaas (Figure 3). Euphorbiaceae was the most dominant family in terms of species number represented by three (15.79 %) species and Rubiaceae, Rosaceae, Araliaceae, Celastraceae and Myrsinaceae were represented by two species (10.53 %).

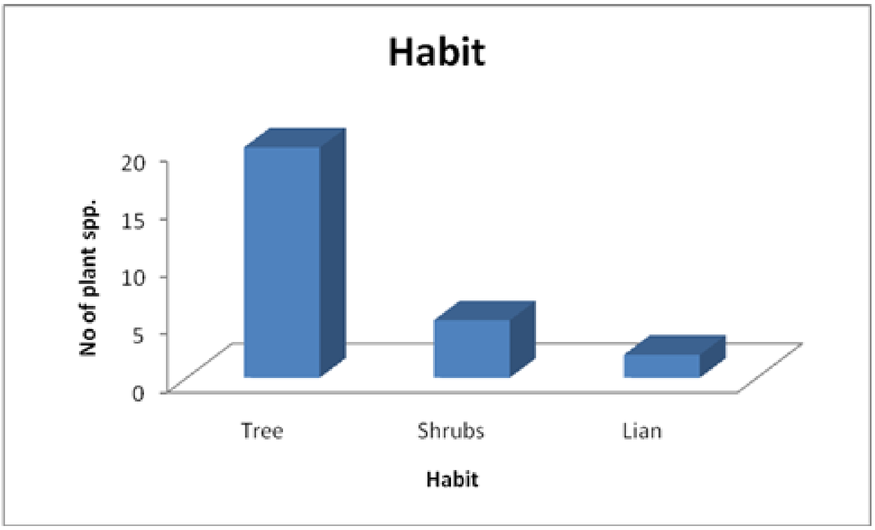

Figure 3: Distribution of plant species by their habits

3.2 Estimating different Carbon pools

The study revealed that the mean aboveground biomass and carbon density was 50.87±9.98 and 23.91 ± 4.69 t/ha, respectively. Crospondingly, the maximum and minimum aboveground biomass estimated were 149.63 and 0.53 ton/ha while the the maximum and minimum aboveground carbon were 70.33 ton/ha and 0.25 ton/ha (Figure 4). Furthermore, the corresponding CO_2 equivalents were 478.21 ton/ha (Table 1).

Table 2: All carbon pools of the study area

	N	Minimum	Maximum	Mean		Std. Deviation
				Statistic	Std. Error	
Plots	20	1.00	20.00	10.5000	1.32288	5.91608
AGC	20	.25	70.32	23.9105	4.69128	20.98002
BGC	20	.05	14.06	4.7830	.93792	4.19452
CO_2Eqv.	20	.92	258.09	87.7560	17.21677	76.99573
LGHC	20	.32	4.14	1.3913	.23156	1.03556
DWC	20	.00	1.14	.0855	.05885	.26317
SOC	20	.00	190.65	60.9510	13.49084	60.33285
Valid N (list wise)	20					

Key: AGC- aboveground carbon, BGC-belowground carbon, CO_2Eqv.-carbondioxide equivalent, LGHC-leaf literal, grass and herb carbon, DWC-dawn deadwood carbon, SOC- soil organic carbon

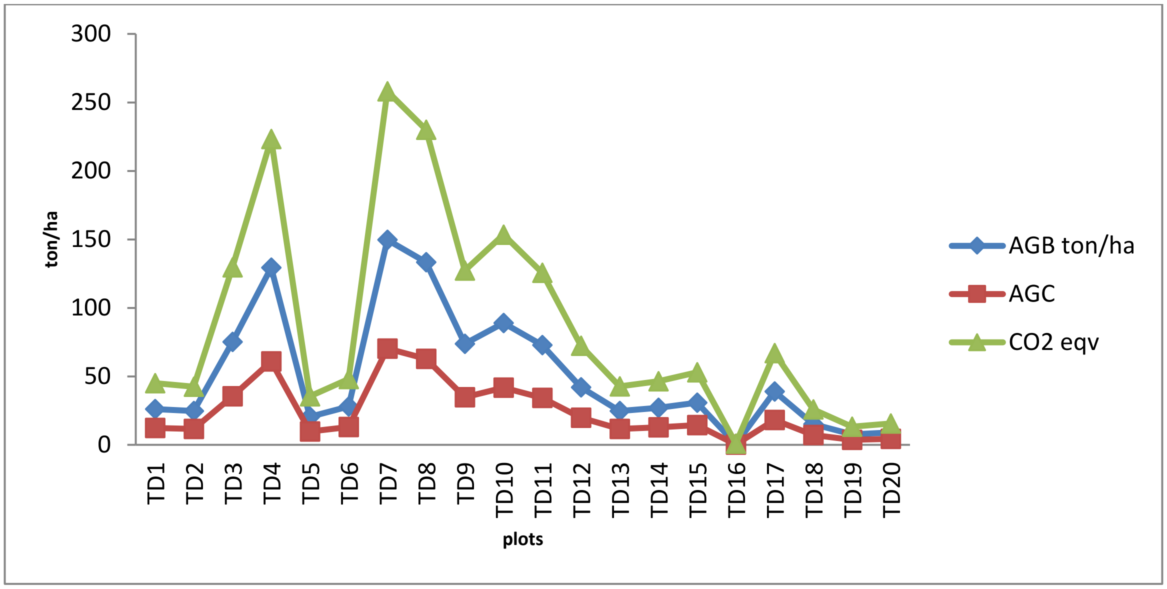

Figure 4: Aboveground biomass, carbon stock and CO_2 equivalent estimation per plot

The mean belowground biomass and carbon density was 10.18 ± 1.996 and 4.78 ± 0.94 t/ha, where as the maximum and minimum belowground biomass and belowground carbon estimated were 29.92 ton/ha and 0.11 ton/ha, and 14.06 ton/ha and 0.05 ton/h, respectively. Consequently, the corresponding equivalents were 351.03 ton/ha.

In the present study, dead wood was found only in 3 plots (plot 1, 18 and 19). Thus, carbon stock DWC was 2.28, 0.29, 0.28, respectively and correspondingly, CO_2 equivalent was 7.34, 1.05, 1.01 (Table 2). The mean LHGs biomass and carbon stock estimated were 2.96 ± 0.49 and 1.39 ± 0.23 t/ha, respectively.

Table 2: Biomass, carbon stock and CO_2 equivalent estimation of dead wood of the study area

Quadrat	Scientific name	DWB Kg/plot	20%	DWB ton/ha	DWC ton/ha	CO2.eqv ton/ha
1	*Ilex mitis*	793.53	158.71	3.98	1.87	6.84
	Maytenus arbutifolia	173.76	34.75	0.87	0.41	1.5
19	*Ilex mitis*	121.72	24.34	0.62	0.29	1.05
18	*Maytenus arbutifolia*	116.97	23.39	0.6	0.28	1.01

Maximum and minimum LHG biomass and carbon stock density were 8.81 ton/ha and 0.7 ton/ha, and 4.14 ton/ha and 0.33 ton/ha, respectively (Figure 5). Thus, the estimated maximum and minimum CO_2 equivalent were 15.2 and 1.21 ton/ha, in that order.

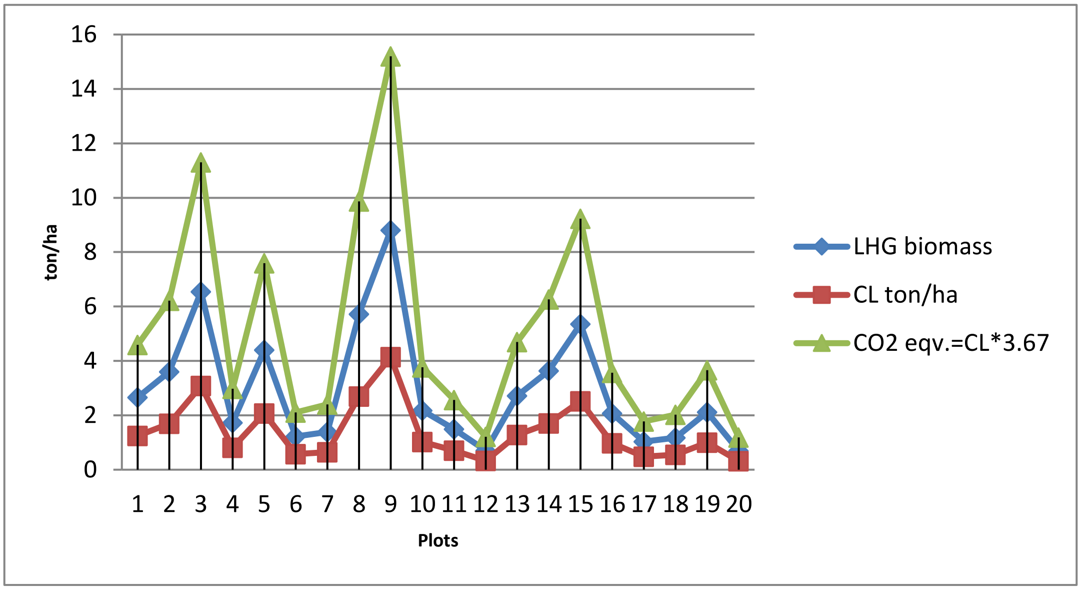

Figure 5: Biomass, carbon stock density and CO_2 equivalent of LGHs

The mean SOC density was 60.95±13.49 ton/ha with the maximum and minimum SOC density of 190.65 and 44.38 ton/ha, respectively. The corresponding CO_2 equivalent was 699.69 ton/ha in the study area. The mean soil bulk density was 1.61, 0.85 and 0.99 g cm^{-3} (0-10cm, 10-20cm and 20-30cm) depth, respectively. Mean soil bulk density of the study area was 1.15g cm^{-3} op, medium and bottom layers of soil,crospondingly. Finally, the sum total carbon stock of above ground carbon, below ground carbon, leaf litter, herbs, and grass, dead wood and soil organic carbon pools present in Table2.

Table 3: The sum total carbon stock of the study area

	AGC	BGC	LGHC	Dead wood	SOC	Total
Average	23.91	4.78	1.39	0.71	60.95	91.74

4. Discussion

In the present study, a total of 26 species were identified. In comparison with other similar natural forest areas in the country, the species richness in Dorze Ayra natural forest is less. For instance, Tesfaye *al*. (2013) has identified 183 woody species in Jibat Humid Afromontane Forest, West Shewa Zone. Furthermore, Melese and Wendawek (2016) have identified 54 woody species in the Lammo natural forest Tembaro District. However, the present study finding visa-vis species composition is very close to Biruk's (2018) study that he has identified a total of 29 woody species belonging to 24 families in Gezha Natural Forest, Bonke District. Poor forest management practices, agricultural expansion, overgrazing, selective tree cuttings and fire wood collection are presumable causes for reduced species composition. Different studies also revealed the aforementioned causes as major anthropogenic pressures that could affect species composition in a typical forest ecosystem (Feyera and Demel, 2003; Teshome et al., 2004; Mohammed, 2011)

The mean total carbon estimated in the present study was 91.74 t/ha. Murphy and Lugo (1986) revealed that tropical dry and wet forests AGC ranged between 30-273 ton/ha and 213- 1173 ton/ha, respectively. Thus, as tropical wet forest, mean total carbon estimated in the study area is lower. This might be due to the size of the forest, lower species composition and age of trees (Wei *et al*., 2013). Moreover, Lasco and Pulhin (2012) found that the use of different allometric equations for biomass estimation contributed to the variation of carbon stock estimates. The present study result is also lower than the mean aboveground and belowground biomass carbon of natural forest of Bangladesh (110.94 mt.ha-1) (Ullahand Al-Amin, 2012), and the secondary forest of Congo (167.93 mt.ha-1) (Ekoungoulou *et al*., 2014). The present study result is generally lower than similar studies in Ethiopia.

The mean LHGs carbon stock estimated in the study area was 1.39 ± 0.23 t/ha. IPCC (2003) study indicated LHGs carbon stock estimated for tropics and boreal conifer forest was 2-55 t/ha and 2-16 t/ha.. Thus, as compared to these estimates the study area LGHs is lower. Anthropogenic pressure primarily fire wood collection might be the cause for less ground vegetation that ultimately reduce LHGs biomass. However, relatively similar findings were reported by Alem (2015) and Mohammed (2013), as 1.5 t/ha (in selected public parks) and 0.9 t/ha (Tara Gedam Forest), respectively.

The IPCC (2006) guideline provided a global range of SOC values from 20 to 300 t/ha. FRA (2005) also reported the global average SOC in a depth of 30 cm is 73t/ha. Thus, 60.95 ± 13.49 t/ha estimated in the present study is within the range indicated above. As compared to similar studies conducted in the country, the present study showed similarity as well as differences. Paudel *et al.*

(2015) revealed that high decomposition rate and age of the forest are determinant factors for SOC content.

In the present study, fallen dead wood was occurred only in three plots. This might be an indication that the study area forest is not matured forest. Besides, fire wood collection may also contribute for the lower proportion of dead wood in the study area. Accordingly, compared to FRA (2005) study estimated 2.0 t/ha in Southeast Asia, the present study result (0.086 t/ha) is lower.

5. Conclusion and Recommendations

Investigation of floristic composition and carbon stock estimation in the forest is important for their management, conservation, and sustainable utilization. Woody species diversity of the study area was 26 and low compared with other studies due to size of forest. Carbon density in the different carbon pools varies. For example the mean AGC stock and BG carbon stock of the study area was lower than studies in other parts of Ethiopia and soil carbon pool was the highest carbon reservoir than others pools. In general, currently mean carbon density of the Dorze Ayira natural forest had the capacity to store 91.74 t/ha of carbon. Therefore, appropriate management plan is required for their conservation and sustainable utilization. Adequate awareness regarding wise use of this natural resource should be given to the whole surrounding society that will be saved some multipurpose trees and high carbon sequestrated individual plant species from extinction in the locality. Finally, it should be integrated with global CDM and REDD+ strategy to provide the respective monetary incentive for the area as well as to stick with the current strategy of the country, CRGE, to strength the protection of the forest resources.

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