

RESEARCH ARTICLE

VARIATION OF CARBON STOCK IN SELECTED TREE SPECIES: IN GONCHA SISO ENESIE DISTRICT, ETHIOPIA

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ABSTRACT

There is now a lot of concern throughout the world about the rise in atmospheric carbon dioxide and how it could alter the climate. An efficient way to reduce elevated atmospheric carbon dioxide concentrations and help slow down global warming has been to expand the area covered by plantation forests. The aim of this study is to estimation of carbon stock variation and how they affect the biomass of selected tree species in the study area. A systematic sampling method was employed for this study. There were taken a total of 60 sample plots from this study area. To collect soil and litter samples, five 1 m² subplots were laid out inside the main plots. From *this study*, the carbon pools in *Cupressus lusitanica* species, such as aboveground carbon, belowground carbon, litterfall carbon, and soil organic carbon were 159.46±70.91, 41.46±18.44, 0.07±0.01 and 111.37±8.52 t C/ha, respectively. From *Eucalyptus globulus*, such as aboveground carbon (AGC), belowground carbon (BGC), litterfall carbon (LBC), and soil organic carbon (SOC), were 170.63±75.21, 44.37±19.55, 0.02±0.003, and 141.07±22.88 t C/ha, respectively. The total mean carbon storage of *Cupressus lusitanica* was 312.36±97.88 t C/ha, and that of *Eucalyptus globulus* was 356.09±117.64 t C/ha. This was equivalent to 1146.36±359.23 t C/ha CO₂ (gas) of *Cupressus lusitanica* and 1306.85±431.75 t C/ha CO₂ (gas) of *Eucalyptus globulus*. The over-all mean carbon storage of *Eucalyptus globulus* was higher than that of *Cupressus lusitanica* in all carbon pools, with the exception of litterfall biomass. The over-all carbon storage of the species from this research area can be characterized as intermediate when related to other research carried out elsewhere in the tropics.

KEYWORDS

Eucalyptus globulus, Cupressus lusitanica, carbon stock, plantation forest, Above and below ground biomass

1. INTRODUCTION

The destruction of forests around the world announcements carbon dioxide into the atmosphere, which underwrites to climate change (Nunes et al., 2020). Extended changes in the global average weather patterns have been referred to as climate change (Seneviratne et al., 2021). There is now a lot of concern throughout the world about the rise in atmospheric carbon dioxide (CO₂) and how it could alter the climate (Dar et al., 2015). An efficient way to reduce elevated atmospheric carbon dioxide (CO₂) concentrations and help slow down global warming has been to expand the area covered by plantation forests (Aba et al., 2017). According to a recent assessment, between 2005 to 2010, carbon reserves in forestry biomass declined by an assessed 0.5 gigatons per year (Köhl et al., 2015). Forfeiture of forest biomass over deforestation and forest dilapidation make up 12%–20% of yearly glasshouse gas emissions (Kumar et al., 2022). The buildup of carbon in the atmosphere is a global problem since it is the main driver of global warming and has a profound impact on ecosystems, aquatic characteristics, and ocean level rise. About four billion hectares of forest cover make about 31% of the world's land area, and its biomass alone stores 289 gigatons of carbon (FAO, 2011).

African forests contribute 21% of the global forest biomass carbon pool and store up to 630 kg of carbon per hectare annually, making them a vital vibration absorber for climate change (Katerere et al., 2009). Due to extensive deforestation, Ethiopia's forest cover decreased from 13.78% to 11.40% between 1990 to 2015 (FAO, 2015). Compared to other sub-Saharan African nations, where the average yearly deforestation rate was 0.8%, this one had a high rate of approximately 1% (FAO, 2010). The

aboveground carbon pools of tropical forests contain more carbon per unit area than any other type of land cover when they are in their natural state (Tyukavina et al., 2015). The active biomass of trees and understory plants, along with the dead mass of litter, woody debris, and soil organic matter, are the primary carbon reservoirs in tropical forest ecosystems. However, natural forests store more carbon above ground than any other vegetation (Borma et al., 2022). To combat global warming and effectively balance increasing atmospheric carbon dioxide (CO₂) concentrations, plantations forests were established (Bernal et al., 2018).

The global carbon cycle depends on how forests respond to growing atmospheric carbon dioxide (CO₂) concentrations (Xiao et al., 2021). Forests store more carbon than any other terrestrial ecosystem, storing over 70% of all soil organic matter and over 80% of all terrestrial above-ground carbon (Alemu, 2014). The burning of fossil fuels and the conversion of forests to agricultural land are the primary causes of the 3.5 pentagrams (10¹⁵ gramme or billion tones) of carbon that has accumulated in the atmosphere annually over the past century (Paustian et al., 2000). Deforestation, soil erosion, changes in land cover, and land use all have an impact on the carbon stock density in the forest ecosystem. Slope, altitude, and land use types all have an impact on the carbon reservoirs in the forest ecosystem (Assefa et al., 2017). Impact of slope on above- and belowground biomass, soil organic carbon, and total carbon in forest ecosystems (Yohannes et al., 2015). By accelerating carbon emissions, land use in the tropics has an impact on the worldwide carbon cycle. The density of soil organic carbon pool decreased by 20–50% when forests were converted to other land uses or land-living shelter into farmed land use types (Ahirwal et al., 2022).

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The properties of stand stage and tree species composition on carbon storage in forest ecosystems are appropriately taken into justification (Kaushal et al., 2021). According to with increasing stand age, more biomass is accumulated (Zhang et al., 2012). It has not been well studied how certain tree species affect the storage of carbon in Ethiopian plantation forests. There has been very little research in Ethiopia's forest carbon pool that takes into account the tree species and environmental conditions that influence carbon stock. Due to their rapid growth, species of plantation forests like *E. globulus* and *C. lusitanica* were essential to efforts to allay and familiarize to climate change over carbon requisitioning and storage. Additionally, by lessening the strain on ruminant natural forests, these quickly growing tree varieties were extremely important. This study was among the few that addressed these research gaps. This study offered experimental evidence towards deliberate these fast-rising tree species as a basis of carbon pools for founded climate alteration extenuation approaches in this research area, specifically in Goncha Siso Enesie District, and nationwide. For targeted species, the data can be applied as initial information for sustainable forest management. Additionally, the findings will aid in the understanding of carbon routine difference of the four mainly carbon pools such as, aboveground, belowground, litterfall, and soil organic carbon in species-specific plantations in Ethiopia, however, has not received much attention from the fast-growing tree species the targeted study area. The assessment Enhancing estimates of forests' potential to store carbon and providing the basis for national forest management depend on this data. Prior research conducted in Ethiopia and other tropical regions has shown a great deal of interest in assessing the quantity of carbon deposited in the soil and standing biomass of forest ecosystems (Negash and Starr, 2015). For foreign and district government, politicians, and other preservation administrations, this further illustrates the gap in the plantation forest's capacity to store carbon and provides some helpful information in current condition, including *E. globulus* and *C. lusitanica* tree species. This study addresses the information gaps regarding the estimation of carbon stock variation and how they affect the biomass of selected tree species in this research area. Specifically, to determine and contrast the carbon stock of selected plant species above and below ground, to calculate the carbon storage of litterfall under specific plant species, and to calculate the carbon stock of soil organic matter under specific plant species.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was conducted in the Goncha Siso Enesie District in Amhara, Ethiopia. It is far from 335 km from Addis Ababa and 155 km from Bahir Dar. The study area is situated at 10° 27' 36" and 11° 53' 52" north latitudes and 37° 12' 56", 38° 43' 45", 3° 55", and 38° 24' east longitudes with an average altitude of 2000 meters above sea level (m.a.s.l.) (Fig. 1)

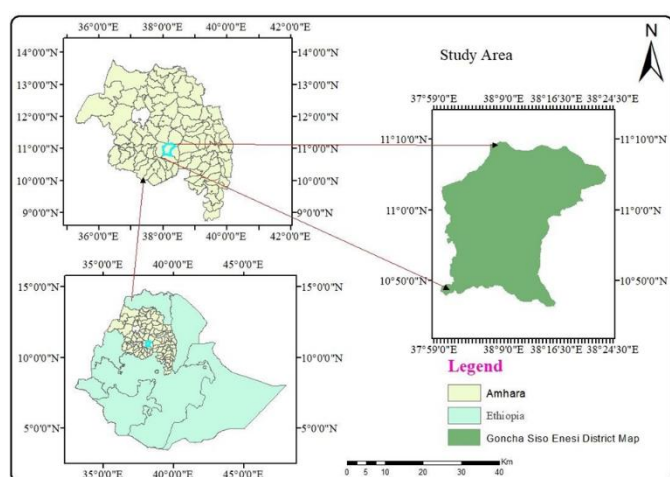


Figure 1: Map of the study area

2.1.1 Climate and Agro-ecological Condition

Agro-ecological conditions and climate are two of the most important variables in deciding if a given place is suitable for a given settlement. Highland or Dega (12%), Midland or Woyna Dega (48%), and Lowland or Kola (40%), are the district's three agro-ecological zones. Rainfall averages between 800 to 1800 mm annually. However, the unimodal rainfall pattern, which normally lasts from June to September, is erratic and insufficient, especially for timely-planted long-season crops. The temperatures of Woyna Dega and Dega were 18-25°C, as were the vegetation type, socioeconomic activities, and human agro-ecological conditions. The temperature gets very hot from March up to May, when it

risers above 25°C. Generally, according to the Woreda Office of Agriculture and Rural Development, the rainfall pattern of major crops stops during the time when most crops are in vegetative growth or at flowering stages (WoARD, 2019).

2.1.2 Study Site Selection

The selection of the study site was thoughtful; selected species were planted in nearby locations with comparable climatic, topographic, and edaphic conditions at the time of plantation, which is why the study site selection was deliberate. The Goncha Siso Enesie District plantations forest was chosen for the study because it offered the optimum location in this regard. The team leader of Natural Resources Management participated in an initial conversation to gain more knowledge about in this plantations forest. Finally, to estimation the biomass carbon storage variation and soil carbon stores of the target tree species were employed a well-defined boundary.

2.2 Sampling Design and Forest Inventory

For this investigation, systematic sample strategy stayed employed to demeanor the forest record in these plantation forests. Because it is easy to use in the field and yields more precise findings. It was found that the plot and the transect line were 50 and 100 meters apart, respectively. According to Genene et al. (2013) suggest that compared to circular plots, square plots can be more cost-effective, contain greater within-plot variance, and are more representative of the same area. As a result, square sample quadrants with dimensions of 10 m x 10 m (100 m²) were considered for plantation measurements. Five 1m x 1m (1m²) sub-sampling units were set up inside each 10m x 10m quadrat at the four corners and at the center of each square plot to collect soil and litterfall samples. To collect data on tree stands based on DBH and overall height of the trees, a wood inventory stayed carried out. Since tree diameter was the main predictor of carbon and biomass in the allometric equations selected for this investigation, it was measured. It employed to develop stand characteristics in conjunction with total tree height. In order to tolerate the demands of use in challenging circumstances, fieldwork equipment needs to be accurate and long-lasting.

Field measurements of four carbon pools, such as aboveground biomass, belowground biomass, litterfall biomass, and soil, were used to collect the primary data, including tree height and diameter, litterfall, and soil samples. The equipment needed was determined by the type of measurements (Pearson et al., 2005). In order to collect the data for this study, the following instruments were used: meter tape to measure sample plot distances; a clinometer to measure tree height; a caliper to measure tree diameter at breast height (DBH); an auger to collect sample soil; plastic bags to collect sample soil; a core sampler to sample soil for bulk density; and a Global Positioning System (GPS) to collect study site coordinates. Samples of bulk density up to a depth of 60 cm were collected using a core sampler.

2.3 Sample Size Determination

It is necessary to measure a sufficient number of sampling units to achieve the required level of precision, neither more nor less, in order to evaluation the biomass and carbon storage capacity of planted forests in a statistically and practically efficient manner (Thomas et al., 2015). Using the resources at hand, a practical method was taken to regulate the necessary amount of sample schemes (Woldemariam, 2015). According to a general rule, the smaller the sample size needed for a planting, the more precise the measurement and the more changeable the material (Thomas et al., 2015). A total of 60 sample schemes were taken from *C. lusitanica* and *E. globulus* tree species. The analysis suggested that thirty (30) sample plots for a single, similar estate site were required. Based on this, a total of 60 sample plots were taken from the study area (Picard et al., 2012).

2.3.1 Litterfall Sampling

The litterfall models stayed calm from sub-plot of 1 m x1 m in apiece scheme. At the corners and in the center of the main plot, five equal sub-quadrants of 1 m² each were established. Whole litterfall models in the sub-quadrants were composed by physical from each sub-quadrant. All of the litterfall inside the surround was calm and put in a flexible basket and a new mass was measured there with a digital balance. After weighed and coded, all samples were evenly mixed per sample plot to prepare a total of 60 composite samples (30 for each stand). From each plot 100 g of the composite samples were taken to the lab to determine the oven dry mass (Pearson et al., 2007). Then after the new mass grit, the model was taken for laboratory analysis, which was taken into the Bahir Dar Forest Development Office to estimate the oven-dry mass of the litterfall. The dead wood at the study sites did not exist; hence, dead wood was not estimated in the current study.

2.3.2 Soil Sampling

For the purpose of analyzing bulk density and soil organic carbon, soil models stayed engaged from each sample plot. Three types of variables must be known in order to acquire an accurate inventory of soil organic carbon stocks in mineral or organic soil: (1) depth; (2) bulk density (determined by calculating the oven-dried weight of soil from a known volume of tested material); and (3) the concentrations of organic carbon within the sample (Pearson *et al.*, 2005). For bulk density determination, soil sample was placid from sub-samples which were designed at the center of apiece model design (1mx1m). The models stayed engaged from quadrants 1mx1m (1m²) assigned in the four angles of the model schemes and from the one center of within (10 m x 10 m). After clearing away any fallen debris, soil samples were taken from a depth of 60 cm in two depth classes (0–30 and 30–60 cm) in order to determine SOC and bulk density, respectively.

Soil models stood obtained using a circle auger and a core sampler. Five equal weights of each sample from each quadrant were taken and mixed together homogeneously, and a composite subsample of 100 g of wet weight from each plot was given to the lab for analysis. Subsequently, using the Walkley-Black Procedure, the carbon fraction of each sample was calculated in the laboratory (Walkley and Black, 1934). Finally, the bulk density, organic carbon, and soil organic carbon were computed using this information. Also, using a core sampler that was carefully inserted into the soil to prevent compaction, identical quadrants of undistributed soil samples for bulk density determination were taken from the surface soil at the same time, from the center (Roshetko *et al.*, 2002).

2.4 Methods of Data Analysis

2.4.1 Aboveground Biomass

Estimation of AGB, the allometric equivalences established by Berhe *et al.* (2013) for *C. lusitanica* (Eq. 1) and Debela (2017) for *E. globulus* (Eq. 2) were employed.

$$AGB = 0.0319 * DBH^{1.8903} * H^{0.9194} \quad (1)$$

$$AGB = 0.479 * DBH^{2.2578} * H^{-0.374} \quad (2)$$

$$AGBC = AGB \times CF \quad (3)$$

2.4.2 Below Ground Biomass and Carbon Storage Estimation

Based on the AGB each stand, BGB of the stand were assessed. BGB was estimated by multiplying the above-ground biomass by 0.26, which represents the root-shoot ratio (Hangarge *et al.*, 2012).

$$BGB = 0.26 \times AGB \quad (4)$$

Where, BGB= below-ground biomass and AGB=above-ground biomass, the conversion factor for AGB is 0.26.

$$BGBC = BGB \times CF \quad (5)$$

2.4.3 Litter Biomass Carbon Storage Estimation

The litter samples were:

$$LB = \frac{W_{field}}{A} * \frac{W_{sub sample(dry)}}{W_{sub sample(fresh)}} * \frac{1}{10,000} \quad (6)$$

The carbon content of litter biomass was calculated by 0.37 of the dry weight of litter biomass per unit area (IPCC, 2006) and was estimated using the following formula:

$$CL = LB \times 37 \% \quad (7)$$

2.4.4 SOC Estimation

According to Pearson *et al.* (2007), to establish a precise inventory of the organic carbon stocks in the soil, the following parameters must be examined: organic carbon concentrations, soil bulk density (derived from an oven-dry weight of soil from a known volume of measured material), and soil depth to which carbon is estimated for (0–60 cm) are all factors. The same sampling sub-quadrats advised for litter sampling were used to obtain samples for soil carbon analysis. The soil samples were air dried, thoroughly mixed, and sieved through a 2mm mesh size sieve before being used for soil carbon measurement at the Amhara Design and Supervision Works Enterprise (ADSWE) center soil analysis of laboratory.

A cylindrical core sampler with a 5 cm diameter and 5 cm height was used to collect a soil sample and determine the volume of the core for soil bulk density analysis. Each plot had a soil sample taken from it in a pit that was 0–60 cm deep. So, using a metal soil corer sampler to dig the soil, two layers of 0–30 cm and 30–60 cm were chosen to be the most representative. The

freshly sampled soil obtained by bulk density cores was stored in a plastic bag, which was then labeled and sealed. The samples were then brought to the lab oven for oven drying, where the oven dry weight was measured (re-weighted) after drying for 48 hours at a constant temperature of 105°C to ascertain moisture content and bulk density (Pearson *et al.*, 2005). Samples were tested using the Walkley method to determine the percentage of organic carbon (Walkley and Black, 1934). The study suggested method was used to calculate the soil's carbon stock based on the bulk density and carbon content of the soil at a set depth (Pearson *et al.*, 2007). It is important to know the volume of the soil collected before computing SOC because doing so aids in computing bulk density.

$$V = h * \pi r^2 \quad (8)$$

Moreover, the bulk density of a soil sample was calculated as follows (Pearson *et al.*, 2007).

$$BD = \frac{W_{avdry}}{V} \quad (9)$$

The soil organic carbon stock pool was calculated using the formula (Pearson *et al.*, 2005):

$$SOC = BD * d * \%C \quad (10)$$

2.5 Total Carbon Storage

The total carbon storage has been estimated:

$$CT = AGC + BGC + CL + SOC \quad (11)$$

2.6 Data Analysis

The numerical information (DBH, height, fresh and dried litter weights, and soil weights) gathered from the field was entered into a computer and set up on an Excel data sheet for future study. A one-way analysis of variance (ANOVA) was carried out to check for significant differences in carbon storage between both targeted tree species of forest biomass and soil organic carbon across the two depth classes. When the analysis of variance (ANOVA) showed a significant difference among the different factors taken into consideration at (P < 0.05), a mean separation for each treatment was made by the Tukey least significant different comparison method. All statistical tests were performed using Statistical Package for Social Science (SPSS) version 27.1. Descriptive statistics were used to summarize the frequency and density of each tree species in the sample plot of the study area, the DBH and height of trees, and the mean, standard deviation, minimum, and maximum value of carbon storage in different carbon pools of the study area, while one-way ANOVA and an independent T-test were used to determine the statistical significance of carbon storage variation along selected tree species.

3. RESULTS AND DISCUSSION

3.1 Stand Characteristics for the Studied Species

This study showed that the mean value results of the tree biomass determining parameters such as height (H) and diameter at breast height (DBH). The total mean height (m) and DBH (cm) of *E. globulus* and *C. lusitanica* significantly differed at (P < 0.05) (Table 1).

Table 1: Stand characteristics for the target tree species (Mean ± SD)

Stand character	<i>C. lusitanica</i>	<i>E. globulus</i>	P- value
Age	41 years	41 years	
DBH (cm)	21.41 ± 4.46	38.03 ± 9.52	<0.001
H (m)	27.70 ± 4.99	50.16 ± 5.47	<0.001

These results showed that the total mean height and DBH of *Cupressus lusitanica* was lower than *Eucalyptus globulus* (Table 1). This variation in species features, although it was planted in the same year and in the same agro-ecological zones, could be the cause of this difference. *Eucalyptus* tree can reach heights of 40–55 m, and sometimes 70 m, with a diameter of 2 m in Ethiopia (Bekele *et al.*, 2007). while *C. lusitanica* trees can reach heights of up to 35 m in environments that are favorable for them (Orwa *et al.*, 2009). But in this study area, the height of *E. globulus* reaches 60–70 m, and the height of *C. lusitanica* was 35–45 m.

3.2 Aboveground Biomass and Carbon Storage Estimation

This result showed that the presence of species variation affects the carbon storage of different pools in the forest stand (Fig.2). The aboveground carbon content of the two species at the same age showed a significant difference (p=0.001).

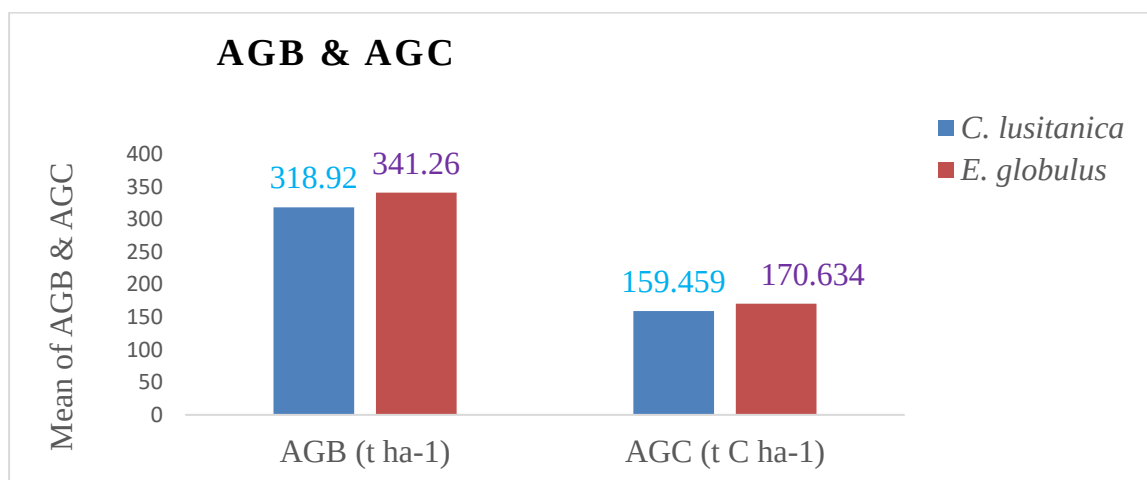


Figure 2: The mean of aboveground biomass (AGB) and aboveground carbon (AGC) of two species

The ecosystems have significant potential variation in both short-term and long-term carbon storage (Houghton, 2005). This study showed, the variation in carbon storage among various tree species varied, and those that have been found to have high carbon storage. The current study results include assessing carbon stock at the targeted species and are crucial aimed at determining the function of forest ecologies in managing local and worldwide carbon emissions. From this finding, *E. globulus* stored a larger amount of Aboveground biomass carbon storage than *C. lusitanica*. This difference might be due to the presence of larger trees in DBH in *E. globulus* and difference in aboveground tree biomass estimator (allometric equation). According to Moges, (2011) the amount of carbon assessed in a particular forest is impacted by the various types of representations used for biomass assessment. Based on this AGB of species depends on their DBH; this could be due to the DBH difference between the two species that affects carbon storage. The other scenario could be the type of species difference. The older trees with a large DBH value will have a large AGB. As the age of trees increases, biomass also increases (Mamo, 2007). These are considered sources of variation in carbon storage (Tefera and Soromessa, 2015).

The current total mean AGC storage of *C. lusitanica* was significantly higher as compared to other studies AGC storage of (158±66.6 Mg C/ha) in the baseline study in Kenya (98.4±44.4 Mg C/ha) in Kenya, (39.05 t C/ha) in Wondo Genet, Ethiopia (128.1 t C/ha) in Addis Ababa (89.7 t C/ha) in the Gamo zone in southern Ethiopia and lower than (184.80 t C/ha) in Chilimo dry Afromontane forest, central Ethiopia and (180.14 Mg/ha) in Chato

Afromontane forest, western Ethiopia (Iticha, 2017; Omoro et al., 2013; Patula and Oeba, 2016; Yirdaw, 2018; Yilma and Derero, 2020; Mada et al., 2022; Tesfaye et al., 2020). *E. globulus* was significantly lower than (221±143.2 Mg C/ha) in the baseline study in Kenya (205.07 Mg/ha) in Chato Afromontane forest, western Ethiopia and (287.8 t C/ha) in Addis Ababa and higher than (67.5 t C/ha) in other study areas of Ethiopia and (59.3 t C/ha) in the Gamo zone in southern Ethiopia (Mada et al., 2022; Omoro et al., 2013; Iticha, 2017; Yilma and Derero, 2020; Tefera and Soromessa, 2015).

These variations may be the result of differences in tree ages, species height, and DBH range of trees, management practices, the environment, and the different allometric equations used. Another differences in structural parameters such as tree diameter, ecological area, topography (Yilma and Derero, 2020). Generally, the difference may be that the majority of Ethiopia's plantation forests' carbon storage are assessed using general allometric equations without taking into consideration the value of species-specific equations as a whole or the differences in species. However, applying a species-specific allometric equation to estimate carbon stocks produces better and more dependable results than a generic equation, particularly in less diversified plantation forests.

3.3 Belowground Biomass and Carbon Storage Estimation

From this finding, there stood a significant difference in belowground carbon content between the two tree species ($P=0.001$) (Fig.3).

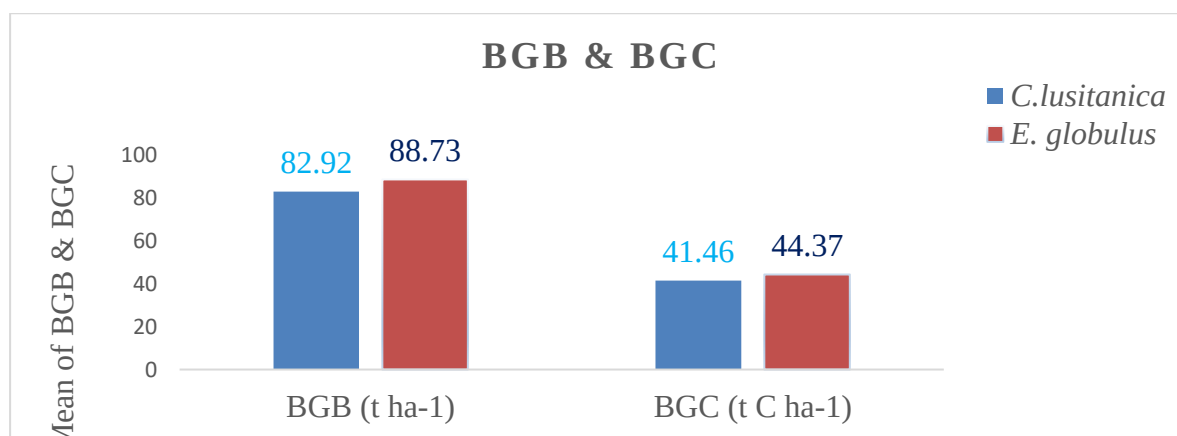


Figure 3: Mean value of belowground biomass and belowground carbon of the two species

From these results belowground carbon stock (BGC) of *E. globulus* was higher than *C. lusitanica*. These study, compared with other studies, the over-all mean BGC storage of *C. lusitanica* was higher from (39±17.8 t C/ha) in the baseline study in Kenya, (10.15 t C/ha) in Wondo Genet, Ethiopia, (17.9 t C/ha) in the Gamo zone in southern Ethiopia, and lower than (43.23 Mg/ha) in Chato Afromontane forest, western Ethiopia, and (54.5 t C/ha) in Addis Ababa (Yilma and Derero, 2020; Omoro et al., 2013; Mada et al., 2022; Yirdaw, 2018; Iticha, 2017). The results of *E. globulus* was lower than (72±46.0 t C/ha) in the baseline study in Kenya, (122.5 t C/ha) in Addis Ababa and (49.22 Mg/ha), in Chato Afromontane forest, western Ethiopia and higher than (11.9 t C/ha) in the Gamo zone in

southern Ethiopia (Mada et al., 2022; Omoro et al., 2013; Iticha, 2017; Yilma and Derero, 2020). The variation was due to the fact that, compared to the smallest trees, changes caused by larger trees have a greater capacity to produce larger amounts of below-ground biomass.

3.4 Litterfall Biomass and Carbon Storage Estimation

According to these findings, the biomass of litterfall was calculated using the carbon storage and total mean biomass of *C. lusitanica* and *E. globulus*. There was a significant difference noticed in the two tree species at the 95% confidence interval ($P < 0.001$) (Fig.4).

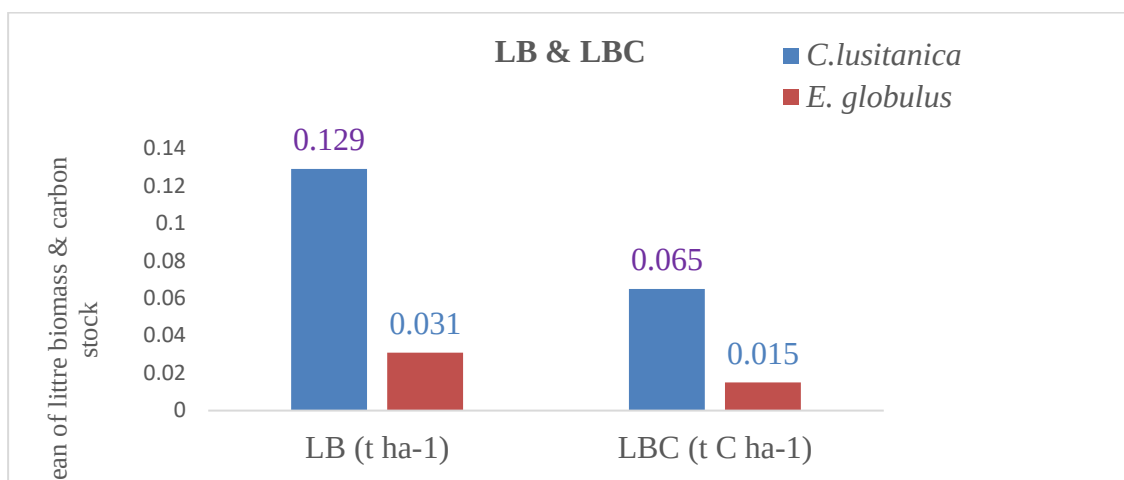


Figure 4: The mean value of litterfall biomass and litterfall carbon stock of the two tree species

Compared to *E. globulus*, *C. lusitanica* had a slightly greater mean litter biomass carbon storage. This difference might be due to *E. globulus* litterfalls for fuel wood being easier to collect by the local community and the consumption of fuel where it is common in that area compared with *C. lusitanica*. The current study, compared with other studies, the litter carbon storage value of *E. globulus* was higher than (0.0031 t C/ha) in the Gamo zone in southern Ethiopia and lower than (3.25 Mg/ha) in the Chato Afromontane forest, Western Ethiopia (Iticha, 2017; Mada et al., 2022). The result of *C. lusitanica* was higher than (0.007 t C/ha) in southern Ethiopia and lower than (2.10 Mg/ha) in the Chato Afromontane forest, Western Ethiopia (Iticha, 2017; Yirdaw, 2018). From these different tree species and, thus, different forest types, come various amounts of litterfall value (Nave et al., 2022).

3.5 Soil Organic Carbon Stock (SOC)

From these results, the soil organic carbon storage of the two species was not showed significant difference ($P=0.093$) (Table 2).

Depth of soil (cm)	Species	BD (g/cm ³)	OC (%)	SOC (t/ha)
0-30		1.08 ± 0.05	2.12 ± 0.09	68.62 ± 5.78
30-60	<i>C. lusitanica</i>	1.14 ± 0.03	1.25 ± 0.06	42.76 ± 2.75
0-60		2.22 ± 0.08	3.37 ± 0.15	111.37 ± 8.52
0-30		1.16 ± 0.02	2.42 ± 0.46	84.02 ± 15.29
30-60	<i>E. globulus</i>	1.12 ± 0.08	1.72 ± 0.33	57.06 ± 7.59
0-60		2.27 ± 0.09	4.15 ± 0.79	141.07 ± 22.88

The results for bulk density were in opposition to the concentration (%) and stock of soil organic carbon. This outcome was corroborated by (Sheikh and Tiwari, 2013). This indicates that the SOC dropped as soil

depth rose. The buildup of dead and rotting logs and decomposed forest litter over the floor was the primary cause of this variation, which was caused by the presence of greater organic matter at the top soil layer. These differences were comparable to those discovered in a research by (Sheikh and Tiwari, 2013). A number of factors, including soil properties, forest management techniques, litter inputs, decomposition rates, and root turnover, influence soil organic carbon (Jandl et al., 2007). In the global carbon cycle and the forest's carbon stores, soil organic carbon is essential (Sundarapandian et al., 2015). According to reports, *C. lusitanica* (86.1 kg/ha) and *E. globulus* (87 kg/ha) in Ethiopia are found within the range of soil organic carbon stock (0–40 cm) depth (Abate, 2004). This discrepancy could result from variations in planted forests, soil microorganisms' rate of mineralization, climate, and soil type (Lal, 2004).

The low carbon content beneath *C. lusitanica* in the 0–60 cm soil depth in comparison to *E. globulus* suggests a poor inflow of fresh litter. According to this data, the top layer (0–30 cm) of both plantation stands had a much greater SOC than the lower layer (30–60 cm). The land use history of the

stands where it was growing may be the cause of this discrepancy. Because of the constant supply of litter, lower rate of disturbance, minimal impact of erosion, and lower temperature beneath the closed forest canopy, which may slow down decomposition and favour an extension of the residence time of soil organic matter, the upper layers have a higher SOC than the lower depth (Erskine et al., 2002). These findings showed that the soil at the study site contained a significant level of organic matter. The greater mean SOC stock may be the result of high SOM and quick litter breakdown, which maximizes carbon storage (Wolde et al., 2014).

3.6 Total Carbon Stock from Plantation Forests

The finding of this research showed that AGC, BGC and SOC of *E. globulus* species were higher than those of *C. lusitanica* and lower than LBC (Table 3).

Stand	AGC (t C ha ⁻¹)	BGC (t C/ha)	LC (t C/ha)	SOC (t C/ha)	TBC (t C/ha)
<i>C. lusitanica</i>	159.459	41.46	0.065	111.37	312.36
<i>E. globulus</i>	170.63	44.37	0.015	141.07	356.09

The capability of plants to absorb CO₂ through photosynthesis may be the reason for the discrepancy in this discovery, where there is more carbon storage in the forest. In accordance with the report of (Omoro et al., 2013) in Kenya, which claimed that the *C. lusitanica* woodland ecosystem had the biggest reservoir of soil organic carbon. Nevertheless, this outcome runs counter to Abate's findings.

(2004), who discovered that the biomass of standing trees had a significant carbon content, but the soil had a tiny amount of organic carbon. Variations in the soil depth at which the data was gathered (0–30 cm) may be the cause of this little value. The variations are caused by how the forest is managed, and they could also be explained by the use of various allometric models for biomass measurement. Therefore, one of the main constraints resulting in significant changes in such estimates could be the reliance on allometric equations.

According to this study, forests that are maintained for greater carbon storage have the greatest potential for sequestering carbon and offer important mitigation alternatives. Nonetheless, research demonstrated that there were variations in species type and species-specific biomass allometric equations among the exotic species, which could be caused by the carbon content of aboveground, belowground, litterfall, and soil carbon storage. Differences in the allometric equation, tree species kinds, and the existence of greater diameter trees at breast height in *E. globulus* could all be contributing factors to the variation.

4. CONCLUSION AND RECOMMENDATIONS

This study uses DBH and total tree height as independent variables to determine the biomass and carbon store of the two targeted tree species. The outcome reveals which of the targeted tree species is most sequestered. Compared to the *C. lusitanica* stand, the *E. globulus* stand had a much higher total mean carbon storage. Nonetheless, *C. lusitanica*'s litterfall carbon storage was marginally greater than *E. globulus*'s. According to the current finding, the total mean carbon stock of *C. lusitanica* was

312.36±97.88 t C/ha and *E. globulus* was 356.09±117.64 t C/ha. These findings suggest that species-to-species heterogeneity in carbon storage variation occurs. This study result indicates that, *C. lusitanica* and *E. globulus* are important in storing carbon stock in their biomass and soil. Finally, it could be concluded that *E. globulus* has stored more carbon than *C. lusitanica*. Hence it has a considerable role in mitigating the climate change by sequestering carbon dioxide and to earn income from the current carbon marketing system in addition to its direct economic benefit plantation forests. Large-scale plantations of *E. globulus* and *C. lusitanica* have been established throughout Ethiopia, so comparable studies on carbon resources would be advantageous to both the local community and the nation. The development and implementation of allometric equations that are country-specific should be the main subject of future study. Knowledge of how this component affects the biomass and soil carbon pools for scientific advancement, more topographic aspect-related research will be required. The findings of this study indicate that more research will be required in this area because they do not address the role that plantations of the *C. lusitanica* and *E. globulus* species play in mitigating climate change. In addition to above-ground, below-ground, and soil carbon storage, fine roots can also hold carbon in plantation forests. So, in this study carbon storage in fine root was not included. Therefore, further study should concentrate on estimating the amount of carbon in this carbon pool.

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