



Diversity and Carbon Storage Potential of Farmland Trees in Mattu District, Southwestern Ethiopia

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Abstract

*Trees on farmland contribute significantly to conserving biodiversity and combating climate change by sequestering carbon. However, the diversity of these species and their potential for carbon storage in biomass and soil have not been extensively studied. This study aimed to assess the diversity of trees and estimate their carbon storage capacity in Mattu District, southwestern Ethiopia. The research was based on a tree inventory across 24 plots of dimension 40 m × 50 m, and the soil was taken from subplots of 1 m × 1 m within the main plots. The study identified 21 tree species from 13 families, revealing high species diversity ($H' = 2.67$) and evenness ($E = 0.83$). The two most dominant tree species were *Cordia africana* and *Croton macrostachyus*. The mean carbon stocks were 183.1 tons/ha in aboveground biomass, 49.8 tons/ha in belowground biomass, and 195 tons/ha in soil organic carbon. These values equate to a total carbon storage of 427.9 tons/ha, equivalent to sequestering 1,570.4 tons of carbon dioxide. These results emphasize the crucial role of scattered trees on farmland in mitigating climate change as carbon sinks. The study strongly recommends that the district agricultural office prioritize protecting these tree species from further degradation.*

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INTRODUCTION

Trees scattered throughout farmlands are vital in mitigating climate change because they sequester greenhouse gases through the process of photosynthesis and retain the carbon stored in their biomass (Komal et al., 2022). Consequently, agricultural landscapes are increasingly recognized globally as important carbon sinks that can offset emissions by accumulating carbon in vegetation and soil (Tesfay et al., 2022). Considering the global deforestation rate of about 151,000 square kilometers each year, integrating forestry into agricultural zones is one of the most impactful ways to sequester carbon (Gebrewahid & Meressa, 2020).

In Ethiopia, farmland is land that is primarily used for agricultural activities, such as crop cultivation and livestock rearing (Bishaw et al., 2013). Farmland trees, on the other hand, are trees intentionally planted or naturally grown on agricultural land (Maryo et al., 2023). These trees are part of an agroforestry system, which integrates crops, livestock, and trees for management on the same land. Agroforestry systems have great promise, as they can sequester approximately 1.4 tons of carbon per hectare annually in soil (Enkossa et al., 2023). Their significance is recognized in climate agreements, including the Clean

Development Mechanism (CDM) and REDD+ programs (IPCC, 2007).

Agricultural landscapes constitute the predominant category of land use in Ethiopia, expanding to 38.5 million hectares by 2020, or almost 34% of the entire land area (Maryo et al., 2023). These systems are important for the country because they aid in the sustenance of millions of people, and they store significant amounts of soil organic carbon (Bishaw et al., 2013). A well-known method that enhances the carbon sequestration capability of such regions is the practice of retaining trees on farms and on the borders of the property. Research conducted on semi-arid parts of East Shewa showed that farmland trees had a distinct composition, featuring higher densities around homesteads and boundaries (Endale et al., 2016). Likewise, an investigation conducted in western Tigray showed that scattered trees in cultivated land conserved up to 31 Mg C ha⁻¹, thus verifying their ecological value (Gebrewahid et al., 2018). Understanding this opportunity, the CRGE (Climate Resilient Green Economy) initiative of the government of Ethiopia encourages tree planting in cereal croplands to enhance climate resiliency and carbon capture (Maryo et al., 2023).

Despite growing scholarly attention, the linkage among woody tree species richness and carbon sequestration potential in Ethiopia remains insufficiently explored at a regional scale, necessitating more in-depth investigation (Enkossa et al., 2023; Manaye et al., 2021; Kassa et al., 2022; Tesfay et al., 2022). Earlier works focused on tree diversity within parkland agroforestry systems (Gebrewahid & Meressa, 2020), assessed different farming systems (Enkossa et al., 2023; Manaye et al., 2021), and looked at variation in carbon stocks with elevation and management (Birhane et al., 2020; Gebrewahid et al., 2018; Maryo et al., 2023). The species, age, management techniques, and local climatic circumstances all affect a tree's capacity to store carbon (Enkossa et al., 2023). Such diversity highlights the necessity of undertaking targeted empirical studies for different locations in order to answer the questions and have the outcome adaptable to the country. Nevertheless,

Sci. Technol. Arts Res. J., July. –Sep, 2025, 14(3), 107-120
there is limited knowledge on the diversity of woody plants and carbon storage in agricultural-dominated landscapes of the southwestern highlands of Ethiopia, particularly in the Mettu district. Reliable scientific information on this locality is limited, to the best of the authors' knowledge. To address this identified knowledge gap, this empirical investigation was designed to examine the diversity of farmland tree species and quantify their capacity for carbon storage. The evidence from this study will inform approaches for sustainable land management, which can address deforestation, carbon emissions, and biodiversity.

Statement of the problem

Mitigation and adaptation to climate change are central to the ongoing worldwide ecological discourse, with the reduction of forest degradation and emissions of carbon from tropical vegetation cover changes representing a major challenge to preserving biodiversity and addressing climate change (Rahman et al., 2017). Including trees in agricultural areas is globally recognized for its essential part in storing carbon to lessen the effects of climate change. In Ethiopia, where vast agricultural landscapes suffer from significant soil degradation and declining carbon sink capacity, these trees are a vital yet overlooked resource. Despite their potential to support national climate goals, farmland trees are often cleared for fuel, construction, and agricultural expansion in the study area. The problem is exacerbated by a systemic underestimation of their value; researchers and policymakers often ignore their contribution to carbon stocks, leading to a failure to protect this essential environmental asset.

Although some studies (Gebrewahid & Meressa, 2020; Birhane et al., 2020; Manaye et al., 2021; Kassa et al., 2022; Enkossa et al., 2023; Jegora et al., 2025) have examined tree species diversity and carbon storage in certain regions of Ethiopia, a significant shortage of local, context-specific data remains. Because trees' capacity to store carbon varies greatly depending on species, climate, and management, regional studies are essential for making accurate policies. This study

directly addresses a significant knowledge gap because no previous scientific research has measured the variety of woody species and their capacity to store carbon in the Mattu District. This study aims to provide the area's first empirical data, creating a scientific baseline to inform land use planning, support climate mitigation strategies, and demonstrate the value of preserving trees on agricultural land.

Research questions

This study was carried out to respond to these three main research inquiries:

1. What is the diversity and spatial distribution of tree species within the farmlands of the study area?
2. How much carbon is sequestered in the aboveground and belowground biomass of tree species on farmlands?

3. How much carbon is stored within the soil profile of the farmland areas?

MATERIALS AND METHODS

Research site

This research was undertaken in the Mattu District, situated in the Illubabor zone of Ethiopia (Figure 1). The study district is geographically situated between longitudes 35°34'E and 35°37'E and latitudes 8°13'N and 8°16'N, having an altitude between 1,500 and 2,500 meters above sea level. The district, which covers an area of 68,723 hectares, is characterized by the use of agroforestry, a practice that combines trees with crop cultivation and other farming activities. As reported by the Central Statistical Agency (CSA, 2013), Mattu District had an estimated population of 85,739, comprising 43,727 males and 42,012 females.

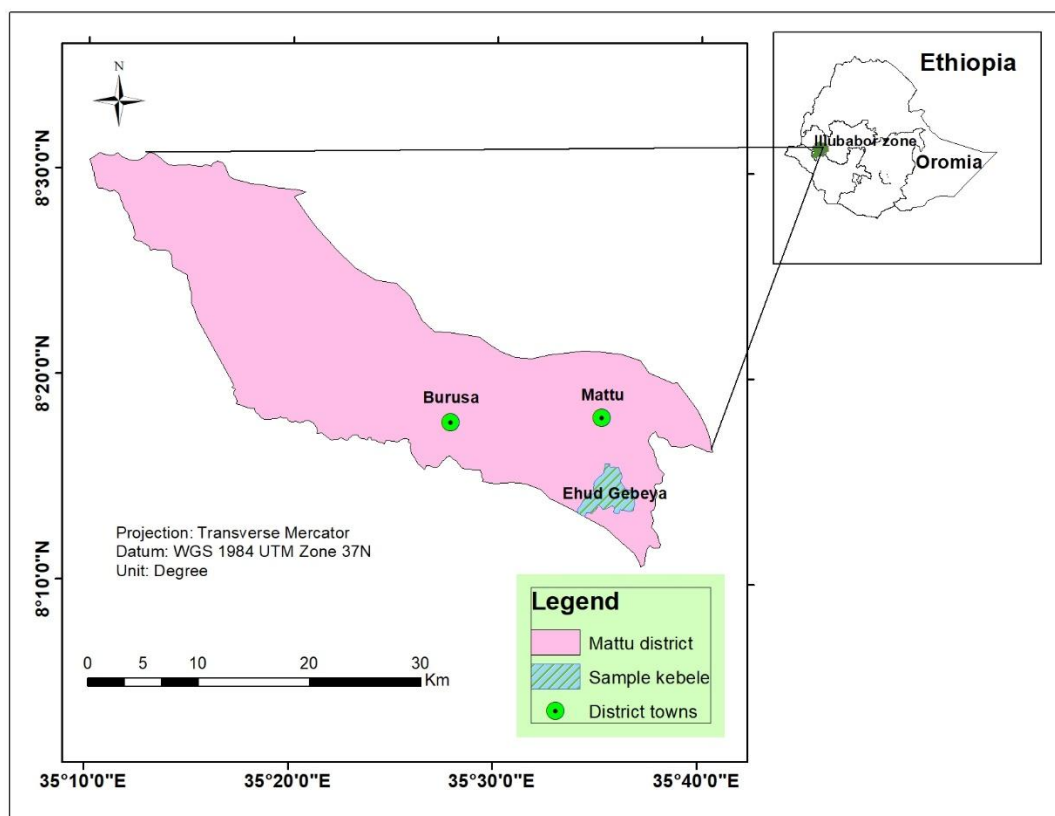


Figure 1. Study the district map and sample kebele location

The study area, known as the wettest highlands in Ethiopia, is characterized by diverse landscapes and receives an average of 1,408.6 mm of precipitation

annually and has an average temperature of 19.67°C (Desta et al., 2025). The predominant farming system in the study area involves a

combination of coffee cultivation in mixed forests, cereal production, and livestock rearing. The local economy and its smallholder farmers are heavily reliant on coffee, which is the region's principal cash crop and a vital source of income (Desta et al., 2025). Over 90% of local farmers practice farmland agroforestry, which is a dominant feature of the research area. Afromontane moist forest is the research area's native vegetation, while the farmlands include species like *Sapium ellipticum*, *Croton macrostachyus*, *Cordia africana*, *Albizia gummifera*, *Grevillea robusta*, *Millettia ferruginea*, and *Acacia abyssinica*.

Farmland tree species inventory

Tree species inventories were carried out in the chosen farmlands using a systematic sampling design across 24 rectangular plots, each measuring 40 m × 50 m, to document species richness, diversity, density, and spatial distribution following the research methodologies of Enkossa et al. (2023) and Jegora et al. (2025). The study used transects separated by 300 m, with plots established at 200 m intervals along each one. All trees with a diameter at breast height (DBH) ≥ 5 cm were measured at 1.3 meters above ground level using a clinometer. Smaller trees were excluded from the study because they are routinely cleared through farm management activities. Species identification was performed in the field by recording local names with the help of knowledgeable community members. In accordance with the published volumes of the Flora of Ethiopia and Eritrea, plant samples of any species that were not identifiable on the farmland were collected and sent to the National Herbarium of Ethiopia for professional taxonomic identification (Edwards et al., 2000). Because dead wood and litter biomass were so insignificant in the farmlands, they were not included.

Soil Sampling

Soil samples were collected from the top 30 cm of each plot to measure soil organic carbon (SOC). Using an auger and core sampler, five subsamples were extracted from a central 1 m × 1 m area in a "X" pattern of sampling, as outlined by Gebrewahid

Sci. Technol. Arts Res. J., July. –Sep, 2025, 14(3), 107-120 et al. (2018). The five subsamples were thoroughly mixed to create a single composite sample for each plot. A total of 24 composite samples were prepared and sent to the Bedelle Soil Laboratory Center for analysis. The laboratory determined the soil's bulk density and organic carbon content. The calculation of bulk density was based on the oven-dried mass of the soil per unit of volume. This value was then used, along with the lab-measured carbon concentration and sample volume, to determine the final soil organic carbon (SOC) content of the farmlands.

Statistical analysis

In order to assess biodiversity, the study used three main ecological metrics: the Shannon-Wiener diversity index (H'), evenness (E'), which gauges the relative abundance of those species, and species richness (S), which counts the number of distinct species. Because it offers a single, all-inclusive number that takes into account both species richness and evenness, the Shannon-Wiener index was very significant. One major benefit of adopting the Shannon-Wiener index is that sample size has no discernible impact on it. This guarantees that diversity estimates continue to be reliable and consistent across many domains (Kent & Coker, 1992). The following formula was used to determine the Shannon-Wiener diversity index:

$$H' = -\sum P_i \ln P_i \quad (1)$$

where H' represents the Shannon-Wiener diversity index and pi represents the proportion of individuals found in the ith species, and ln is the natural logarithm base e.

The evenness index (E) indicates the uniformity of individual distribution across various species, and it was determined by dividing the observed diversity by the maximum possible diversity (Kent & Coker, 1992), using the following formula:

$$E' = \frac{H'}{\ln(S)} = \frac{H'}{H_{Max}} \quad (2)$$

where E denotes evenness, H' max = Ln(S), and S is the total number of species in the sample, and H' is the Shannon diversity index. According to Whittaker (1972), species evenness, which

evaluates the species balance in a particular sample region, is represented by the numbers 0 and 1.

Tree density and Frequency

To assess the spatial distribution of trees, we calculated tree density as a measure of how crowded or sparse the vegetation was on the farmlands following Jegora et al. (2025). This metric was assessed by dividing the total quantity of trees in a quadrant by its area. The final value was standardized and expressed as the number of stems per hectare in order to give a precise, comparable tree concentration number. Additionally, the relative frequency of each species was calculated to understand its prevalence compared to others (Enkossa et al., 2023). To do this, the frequency of a single species was expressed as a percentage of the frequency of all species combined. This calculation highlights which species are the most dominant in the surveyed landscape. It can be calculated using the following formula:

$$\text{Tree density} = \frac{\text{Number of individuals of a tree species}}{\text{Area of plot (ha)}} \quad (3)$$

The percentage of a species' occurrences in plots compared to the total number of plots sampled is known as its frequency. It goes from 0%, which means the species is not found in any plots, to 100%, which means the species is found in every plot (Kent & Coker, 1992). It can be calculated as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of plots where the species occurs}}{\text{Total number of plots}} \times 100 \quad (4)$$

Tree biomass and carbon stock estimation

The allometric equation developed by Kuyah et al. (2012a) is suitable for use across various ecosystems, as it incorporates key variables such as diameter, height, and wood density, while also exhibiting a low prediction error. Additionally, this model was specifically designed for trees and shrubs found in agroforestry systems or on farmland. Consequently, the equation developed by Kuyah et al. (2012a) was utilized to calculate aboveground biomass, as presented below:

$$\text{AGB} = 0.091 \times \text{dbh}^{2.472} \quad (5)$$

where dbh is the stem diameter at breast height in centimeters and AGB is the aboveground biomass of living trees expressed in kilos. Assuming that carbon makes up 50% of the AGB, the aboveground biomass carbon was calculated (IPCC, 2007). Accordingly, the aboveground carbon content was calculated by multiplying the AGB by 0.5, as described by Kuyah et al. (2012a).

$$\text{AGBC} = \text{AGB} \times 0.5 \quad (6)$$

Where AGBC is aboveground carbon, and AGB is aboveground biomass.

Similar to the approach for aboveground biomass via allometric relations based on stem diameter, the belowground biomass can be estimated from the proximal roots at the stem base, and belowground biomass is the least researched or measured carbon pool because of the difficulty in measuring or modeling the stock (Woldemariam, 2015). Belowground biomass was estimated using the equation developed by Kuyah et al. (2012b). The equation is as follows:

$$\text{BGB} = 0.490 \times \text{AGB}^{0.923} \quad (7)$$

Where BGB is below-ground biomass and AGB is above-ground biomass. Then, the model developed by MacDicken (1997) was used to transform the biomass of underground trees into carbon.

$$\text{BGC} = \text{BGB} \times 0.5 \quad (8)$$

Where BGBC is the below-ground carbon, and BGB is the below-ground biomass.

Soil organic carbon estimation

The method outlined by Pearson et al. (2005) was used to calculate the bulk density of soil, which is necessary to determine soil organic carbon.

$$V = h \times \pi r^2 \quad (9)$$

The following formula was used to determine the bulk density of a soil sample. This calculation required the soil volume (V, in cm³), which was determined using the height (h, in cm) and radius (r, in cm) of the core sampler.

$$\text{BD} = \frac{W_{av,dry}}{V} \quad (10)$$

The bulk density (BD) for each plot was determined using the average air-dry weight of the

soil sample (Wav, dry) and the volume of the core sampler (V). This BD value was then used to calculate the soil carbon stock according to the following formula:

$$\text{SOC} = \%C \times \rho \times d \quad (11)$$

Where SOC represents the soil organic carbon stock per unit area (ton/ha), %C is the percentage of carbon content, d is the soil depth in centimeters, and ρ (rho) denotes the bulk density in grams per cubic centimeter (g/cm^3).

Total carbon stock and CO₂ equivalent estimation

The total carbon stock per hectare was calculated by summing the carbon stock in the AGBC and BGBC and SOC pools using the equation from Pearson et al. (2005).

$$\text{TCS} = \text{AGBC} + \text{BGBC} + \text{SOC} \quad (12)$$

The total carbon stock (TCS ton/ha) was determined by summing the carbon stocks from the aboveground (AGBC), belowground (BGBC), and (SOC) pools. Subsequently, the total carbon dioxide equivalent (TCO_{2e}) sequestered in the farmland was calculated by multiplying the TCS by the CO₂ to C molecular weight conversion factor of 3.67 (44/12), as established by Pearson et al. (2007).

$$\text{TCO}_{2e} = \text{TCS} \times 3.67 \quad (13)$$

Where TCO_{2e} is the total metric tons of carbon dioxide equivalent and TCS is the total carbon stock (ton/ha).

RESULTS AND DISCUSSIONS

Results

Tree species composition

The results of the tree species composition recorded from the studied farmland are presented in Table 1. A total of 21 species belonging to 13 families were identified and documented across an area of 4.8 hectares. This diversity highlights the richness of woody tree species present in the research location and suggests the potential ecological importance and functional roles of these species within the farmland ecosystems. Euphorbiaceae was the most dominant family with four species (19%). Fabaceae and Moraceae were the second dominant families, each with three species (14.3%). Boraginaceae was the third dominant family with two species (9.5%). The fourth most abundant families were Meliaceae, Melianthaceae, Myrtaceae, Oleaceae, Podocarpaceae, Proteaceae, Simaroubaceae, Sinopteridaceae, and Ulmaceae, each denoted by a single species (4.8%). All of the tree species recorded in the sampled farmland parcels were trees, which indicates that trees exhibit greater diversity than shrubs. This may be attributed to their ecological adaptability, their many uses by local farmers, and their cultural and economic importance in the area. Additionally, shrubs may have been removed due to agricultural activities.

Table 1

Tree species composition and abundance grouped by family

Family	Species	Abundance (%)
Fabaceae	<i>Acacia abyssinica</i>	14.3
	<i>Albizia gummifera</i>	
	<i>Millittia ferruginea</i>	
Euphorbiaceae	<i>Bridelia micrantha</i>	19
	<i>Croton macrostachyus</i>	
	<i>Euphorbia abyssinica</i>	
	<i>Sapim ellipticum</i>	
Moraceae	<i>Ficus sycomorus</i>	14.3
	<i>Ficus sur</i>	
	<i>Ficus vasta</i>	

Table 1 continues

<i>Boraginaceae</i>	<i>Cordia africana</i> Lam	9.5
	<i>Ehretia cymosa</i>	
<i>Melanthaceae</i>	<i>Bersema abyssinica</i>	4.8
<i>Simaroubiaceae</i>	<i>Brucea antidysenterica</i>	4.8
<i>Ulmaceae</i>	<i>Celtis africana</i> Burm	4.8
<i>Myrtaceae</i>	<i>Eucalyptus camaldulensis</i>	4.8
<i>Proteaceae</i>	<i>Grevillea Robusta</i>	4.8
<i>Oleaceae</i>	<i>Olea welwitschii</i>	4.8
<i>Podocarpaceae</i>	<i>Podocarpus falcatus</i>	4.8
<i>Sinopteridaceae</i>	<i>Polyscias fulva</i>	4.8
<i>Meliaceae</i>	<i>Trichilia dregeana</i>	4.8

Tree species diversity, richness, and evenness in the studied farmlands

The average Shannon diversity index (H') for woody species among scattered trees on farmland was (2.67 ± 0.31), with a corresponding evenness index (E') of (0.83 ± 0.01). This suggests that farmland with scattered trees still maintains a significant portion of biodiversity, contributing to ecological services such as microclimate regulation, soil fertility improvement, and habitat provision. However, the studied farmland had a lower diversity index compared to other similar forests in southwestern Ethiopia due to higher exposure to anthropogenic activities such as selective tree felling, incidents of fire, grazing, and agricultural expansion, as observed during the transect walk in these study forests. The diversity and evenness indices highlight the importance of

conserving the trees on farmland, considering both their floristic diversity and the impacts of human disturbance. Mean tree species richness was (4.3 ± 0.31) per sampled plot, with this value exhibiting variability across the different farmland locations. Some plots had very few trees, while others contained a greater number of species. This indicates that tree species diversity, richness, and evenness differed among the studied farmlands, likely due to variations in land management practices, ecological conditions, and the extent of human disturbance.

Tree species density and frequency

Tree density

The results of tree species density in the studied farmlands, highlighting the ten most dominant species, are presented in Table 2.

Table 2

Density of ten dominant tree species

Scientific name	No of trees	Tree density/ha	Percent
<i>Cordia africana</i>	21	105	20.19
<i>Croton macrostachyus</i>	21	105	20.19
<i>Albizia gummifera</i>	10	50	9.62
<i>Millittia ferruginea</i>	9	45	8.65
<i>Sapim ellipticum</i>	6	30	5.77
<i>Acacia abyssinica</i>	6	30	5.77
<i>Ficus sur</i>	4	20	3.85
<i>Ehretia cymosa</i>	3	15	2.88
<i>Brucea antidysenterica</i>	2	10	1.92
<i>Bersema abyssinica</i>	2	10	1.92

The results showed that the two most common tree species were *Cordia africana* and *Croton macrostachyus*, each contributing 21 trees and accounting for 105 tree tons/ha and 20.19% of the total tree population, respectively. Other significantly represented species include *Albizia gummifera* (50 trees/ha, 9.62%) and *Millettia ferruginea* (45 trees/ha, 8.65%). Moderately distributed species, such as *Sapium ellipticum* and *Acacia abyssinica*, account for 30 tree tons/ha (5.77%). Less common species, such as *Ficus sur*, *Ehretia cymosa*, *Brucea antidysenterica*, and *Bersama abyssinica*, contribute smaller shares with densities ranging from 10 to 20 trees tons/ha. The high population densities of *Cordia africana* and *Croton macrostachyus* suggest that these species likely have a major influence on the surrounding ecology. They may influence microclimatic regulation, soil fertility, and fauna support.

Frequency

In the farmlands under study, the most common tree species was *Croton macrostachyus*, present in 17% of the area, within 12 plots out of the total sample plots. *Cordia africana* followed with 16.18%. Other commonly encountered species included *Albizia gummifera* (10.3%), *Millettia ferruginea* (8.8%), *Acacia abyssinica* (5.9%), *Sapium ellipticum* (5.9%), and *Ficus sur* (5.9%). Conversely, however, the species with the lowest occurrence were found in only 1.5% of the plots. These species included *Trichilia dregeana*, *Bridelia micrantha*, *Ficus vasta*, *Bersama abyssinica*, *Euphorbia abyssinica*, *Polyscias fulva*, *Podocarpus falcatus*, and *Olea welwitschii*.

Biomass, carbon stock, and CO₂ equivalent

The results revealed that the maximum aboveground biomass (AGB) value was 53.6 tons/ha, while the minimum was 3.2 tons/ha. This variation could be due to variation in tree density, species composition, size, and age of individuals, as well as management practices such as selective retention or removal of trees by farmers. The mean AGB value was 365.8 tons/ha. The higher AGB values indicate areas with relatively dense tree

Sci. Technol. Arts Res. J., July. –Sep, 2025, 14(3), 107-120

cover and greater biomass productivity, whereas the lower values reflect farmlands with sparse vegetation or limited tree species growth. Similarly, the estimated aboveground biomass carbon (AGBC) stock of the studied farmland ranged from 1.6 to 26.8 tons/ha, with an average value of 183.1 tons/ha. Furthermore, the maximum aboveground carbon dioxide equivalent (CO₂e) value was estimated to be 105.69 tons/ha, while the minimum value was estimated to be 5.87 tons/ha. This considerable range highlights the disparity in biomass density and carbon storage capacity under the various plots. The mean CO₂e value for the AGBC was 671.97 tons/ha, emphasizing the potential of these farmlands for storing carbon in aboveground biomass as a strategy to combat climate change.

The belowground biomass (BGB) recorded from the sampled farmland plots ranged from 1.01 to 13.72 tons/ha. The mean BGB across the studied farmland was 99.5 tons/ha. Regarding belowground carbon (BGC) stock, the maximum value recorded in the farmland was 6.9 tons/ha, while the minimum was 0.5 tons/ha. The average BGC stock for the studied farmland was 49.8 tons/ha. Estimated belowground carbon dioxide equivalent (CO₂e) values also varied, ranging from a maximum of 25.32 tons/ha to a minimum of 1.84 tons/ha. The mean belowground CO₂e value across the sampled farmland was 182.76 tons/ha.

Biomass carbon stocks of the dominant tree species

Table 3 presents the carbon storage capacities of ten tree species, ranked from highest to lowest based on their AGC values. *Sapium ellipticum* has the highest carbon stock at 30.93 tons/ha and 7.97 tons/ha of BGC. *Cordia africana* follows closely behind with 27.67 tons/ha of AGC and 7.45 tons/ha of BGC. *Ficus vasta* ranks lowest among the top ten, with 3.26 tons/ha of AGC and 0.92 tons/ha of BGC. The values show a gradual decline across species, highlighting variability in carbon storage potential. The analysis further revealed that *Sapium ellipticum* and *Cordia africana* were dominant carbon sequesters, likely due to their large size and

high abundance. These findings suggest the need for regular monitoring and assessment of the AGBC of these tree species to track changes over time and evaluate the effectiveness of management interventions. In contrast, although rare species contribute less to total biomass carbon, they make an essential contribution in maintaining overall tree diversity, ecological resilience, and the genetic pool

Sci. Technol. Arts Res. J., July. –Sep, 2025, 14(3), 107-120 necessary for long-term ecosystem stability. Therefore, prioritizing conservation strategies that balance the protection of dominant, carbon-sequestering species with the preservation of rare, less abundant species is essential. This integrated approach provides immediate benefits in terms of carbon storage and ensures the long-term conservation of biodiversity.

Table 3

Potential biomass carbon stock of the top ten tree species

Scientific name	AGC ton/ha	BGC ton/ha
<i>Sapim ellipticum</i>	30.93	7.97
<i>Cordia africana</i>	27.67	7.45
<i>Ficus sur</i>	23.68	6.42
<i>Albizia gummifera</i>	21.33	5.61
<i>Croton macrostachyus</i>	16.56	4.88
<i>Olea welwitschii</i>	13.77	3.48
<i>Millittia ferruginea</i>	5.24	1.62
<i>Bridelia micrantha</i>	4.16	1.15
<i>Trichilia dregeana</i>	4.14	1.13
<i>Ficus vasta</i>	3.26	0.92

Soil organic carbon and CO₂ equivalent

SOC stocks across the sampled farmlands ranged from 109 to 305 tons/ha, with an average of 195 tons/ha. This variability can be attributed to differences in land management practices, tree density, and species composition. It can also be attributed to site-specific factors, such as soil type, texture, fertility status, slope, and micro-topography. All of these factors influence the rates at which organic matter is stabilized and decomposed. Consequently, the estimated carbon dioxide equivalent (CO₂e) ranged from 400.1 to 1,119 tons/ha, with an average of 715.65 tons/ha. This significant soil carbon stock accumulation is driven by the breakdown of other organic materials

and plant leftovers. This process facilitates carbon and nutrient cycling, supporting the robust microbial communities and plant growth observed in the ecosystem.

Total carbon stock and CO₂ equivalent

The TC stock for the sampled farmland was 427.9 tons/ha. This figure represents the sum of AGBC and BGBC storage and soil organic carbon storage. As shown in [Figure 2](#), soil organic carbon was the largest contributor at 195 tons/ha, while belowground biomass was the smallest at 49.8 tons/ha. Converted to carbon dioxide equivalent (CO₂e), the total for the studied farmland was 1,570.4 tons/ha, with individual pools ranging from 182.76 to 715.65 tons/ha.

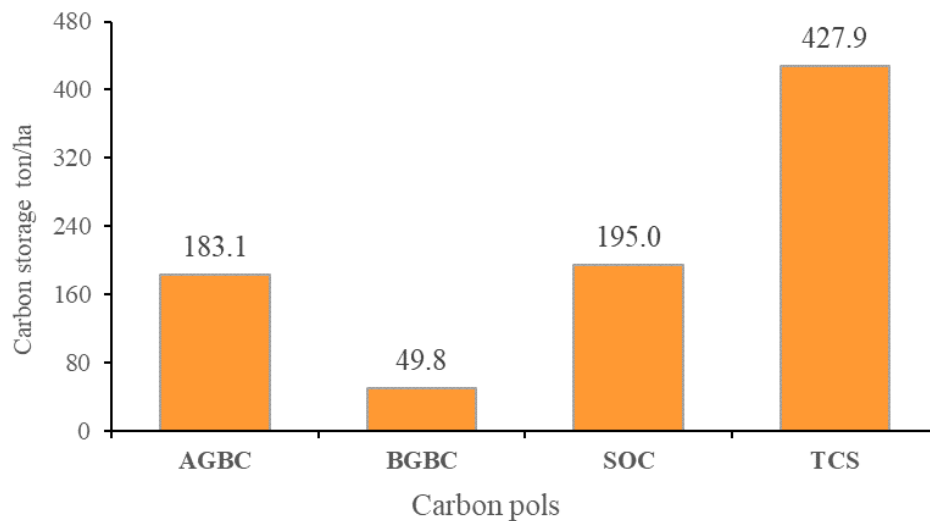


Figure 2. Carbon storage potential of farmland trees

Discussions

Diversity of tree species

According to [Olawoyin et al. \(2020\)](#), tree species diversity is critical for regulating water cycles, mitigating climate change, and sequestering carbon. This study revealed that agricultural landscapes in the area are predominantly populated by indigenous trees, which have significant potential for conserving biodiversity. Notably, the total quantity of recorded tree species and families was greater than in other land-use systems in Ethiopia ([Gebrewahid & Meressa, 2020](#); [Manaye et al., 2021](#)). This greater diversity could be ascribed to a combination of elements, such as unique farmland conservation practices, soil conditions, and geographical location. One key factor appears to be lower human disturbance. Because the study area is in a forest-rich region with ample wood resources, there is less pressure on scattered farm trees for firewood, charcoal, construction materials, or livestock grazing.

The present study recorded significantly higher Shannon diversity and evenness indices and tree species richness than other recent studies in Ethiopia, including those on agroforestry parklands in the north ([Gebrewahid & Meressa, 2020](#); [Manaye et al., 2021](#)) and landscapes in the southeast ([Mengistu & Asfaw, 2016](#)). These differences can be attributed to several interacting factors. First, the study area has favorable climatic

conditions, including consistent year-round rainfall (1,836 mm annually on average) and moderate temperatures (12.4°C–27.8°C). Second, a combination of socio-ecological factors drives diversity, which is perhaps more significant. These factors include farmers' preferences for commercially valuable or forage-producing trees, specific plot-level management practices, larger landholding sizes that support more trees, and comparatively low population density as compared to other elevated agroecologies. According to [Enkossa et al. \(2023\)](#), a mix of environmental elements, including soil and climate, as well as sustainable land management techniques, affects the diversity of tree species.

Carbon stocks in tree biomass and soil

Increased tree species diversity on farmland is known to enhance carbon storage potential, with a greater variety of species boosting carbon stocks in both biomass and soil ([Jegara et al., 2025](#)). Our findings strongly support this, revealing significantly higher carbon stocks at the farmland level than in previous studies. Specifically, we recorded aboveground biomass carbon (AGBC) at 183.04 tons/ha, belowground biomass carbon (BGBC) at 49.72 tons/ha, and soil organic carbon (SOC) at 195 tons/ha. These values far exceed those reported for parklands in northern Ethiopia (AGBC: 21.43 tons/ha; BGBC: 9.70 tons/ha) by [Manaye et al. \(2021\)](#) and are higher than the carbon stocks

found in southwestern Ethiopian agroforestry systems (Jegora et al., 2025). This enhanced carbon storage is likely driven by the positive effect of species richness on ecosystem productivity, possibly through facilitation, whereby certain species improve soil fertility for others (Ruiz-Benito et al., 2014). Furthermore, the exceptionally high soil carbon content is likely the result of superior local land management practices, including effective soil and water conservation methods and crop residue management techniques. From a practical standpoint, species with high inherent carbon storage, such as *Sapium ellipticum*, *Cordia africana*, and *Croton macrostachyus*, are identified as crucial assets for climate mitigation.

CONCLUSIONS

This study examined the diversity of tree species in farmlands and their carbon storage potential in the Mettu District of the Illubabor zone, southwestern Ethiopia. The study revealed a higher level of diversity among the woody plant species across the sampled farmlands. The Shannon diversity index and evenness values indicated a moderately high level of woody species diversity with a relatively balanced distribution of individuals among species. In terms of both density and frequency, *Cordia africana* and *Croton macrostachyus* emerged as the most dominant species, together accounting for over 42% of the total tree population. Other species, such as *Albizia gummifera*, *Sapium ellipticum*, and *Millettia ferruginea*, also had a moderate to significant presence, contributing to the ecological complexity of the farmlands. Frequency analysis revealed a mixture of common and rare species. This suggests that rare species, including *Trichilia dregeana*, *Bridelia micrantha*, *Ficus vasta*, *Bersama abyssinica*, *Euphorbia abyssinica*, *Polyscias fulva*, *Podocarpus falcatus*, and *Olea welwitschi*, highlight the importance of prioritizing conservation efforts.

Further, carbon stock assessments revealed significant variation among sites, primarily due to differences in tree density and species composition. On average, the largest portion of carbon storage was found in the soil, followed by aboveground and

Sci. Technol. Arts Res. J., July. –Sep, 2025, 14(3), 107-120 belowground biomass. Together, these carbon pools contributed to a substantial total carbon stock across the farmland. The estimated carbon dioxide equivalent further demonstrated these farmlands' considerable potential to sequester greenhouse gases and support climate change mitigation. In conclusion, the farmlands in the research area support a diverse and rich tree composition with high biomass production and carbon storage potential. Dominant species, such as *Sapium ellipticum* and *Cordia africana*, serve as vital carbon sinks. The substantial soil carbon pool further reinforces the role of these agricultural landscapes in mitigating greenhouse gas emissions. These findings underscore the importance of sustainably managing and conserving farmland trees to preserve biodiversity and enhance ecosystem services.

Recommendations

The following policy suggestions are put out in light of the study's main findings:

Conservation efforts should prioritize dominant and high carbon-storing tree species such as *Cordia africana* and *Sapium ellipticum*, given their substantial contribution to carbon sequestration and ecosystem services.

In order to increase the diversity of species, the productivity of biomass, and the resilience of agroecosystems, farmers should be encouraged to incorporate a variety of tree species into their farmlands.

There is a need to provide incentives and policy support for farmers who plant or maintain native, multipurpose tree species that provide environmental and livelihood benefits.

Further studies on litter and dead woody biomass stocks could be useful in improving estimates of total carbon stocks in farmland ecosystems.

CRedit authorship contribution statement

Kemiso Shashura: Conceptualization, investigation, methodology, and formal analysis
Solomon Tadesse: Supervision, writing-review & editing

Data availability

The data for this study are available upon reasonable request to the corresponding author.

Declaration of competing interest

No potential conflicts of interest were reported by the authors.

Ethical approval

Permission was obtained from local farmers to conduct the tree inventory on their private land.

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