WOODY SPECIES COMPOSITION, STRUCTURE, AND DIVERSITY OF PARKLAND AND COFFEE-BASED AGROFORESTRY SYSTEMS, HABRO DISTRICT, EASTERN ETHIOPIA

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ABSTRACT

Agroforestry practices in eastern Ethiopia are renowned for their multifunctional landscapes, contributing significantly to biodiversity conservation and enhancement. However, there is a lack of comprehensive studies on the diversity and structure of woody species within coffee-based and parkland agroforestry systems documented in a single study. This research aimed to evaluate the composition, diversity, and structure of woody species in these agroforestry systems. Conducted in the Habro district of eastern Ethiopia, the study involved randomly selecting sixteen plots for each agroforestry system. Inventory assessments of woody species were carried out using 40×40 and 20 m*20-meter plots for parkland and coffee-based systems respectively, and 5×5-meter plots for coffee shrubs. For trees with a diameter at breast height (DBH) of ≥2.5 cm, measurements of tree heights were taken. The study computed basal area, stem density, diameter, and height class distribution to characterize the structure of woody communities, and species diversity was also assessed. The findings revealed a total of 57 woody species across 31 families. Specifically, 38 woody species were recorded in parkland agroforestry, while 43 species were found in coffee-based agroforestry systems. Significant differences were observed in species diversity indices and structural parameters between the two agroforestry systems. The Shannon diversity index and richness were higher in coffee-based agroforestry compared to parkland systems. Additionally, the density and basal area of woody species were greater in coffee-based systems than in parkland agroforestry. Overall, both agroforestry systems were found to conserve a significant number of woody species, highlighting their potential to contribute to biodiversity conservation and informing future agroforestry management strategies in national programs.

Keywords: Agroforestry systems, Biodiversity, Habro district, Species richness

INTRODUCTION

Rapid growth of agricultural production is one of the most serious threats to forest biodiversity. (Nair *et al.*, 2010). The loss of forests and forest degradation in the tropical region contribute significantly to the world's most severe environmental concerns, including biodiversity loss and climate change (Strassburg *et al.*, 2010). Ethiopia is currently experiencing several kinds of environmental degradation, which are the gradual deterioration of biological (flora and fauna) and physical (soil, water, microclimate, etc.) land resources, as well as biodiversity loss (Abdella *et al*., 2022). However, some evidence indicates sustainable farming approaches, such as agroforestry, utilize and protect biodiversity, enhance environmental quality, and control expansion in agriculture into native forests (Brown *et al*., 2018).

Traditional agroforestry practices vary by region in Ethiopia. Some agroforestry approaches include coffee shade tree systems, scattered trees on fields, home gardens, woodlots, farm border practices, and trees on grazing pastures (Molla & Kewessa, 2015). A land-use system incorporating tree species with higher woody plant density will store more carbon in biomass (Rahayu *et al.,* 2004).

Parkland's agroforestry establishment is based on traditional agricultural practices, such as selectively clearing natural vegetation to leave only desired woody species on the land when developing crop fields (Bekele, 2018). Traditional agroforestry parkland systems help biodiversity conservation by preserving tree species on farms and reducing strain on natural forests (Vodouhe *et al.,* 2011).

The coffee-based agroforestry system is one of the most structurally complex and versatile of the agroforestry practiced in Ethiopia for centuries. Its upper layers are dominated by over-shade trees (fruit trees and timber trees) and are usually managed together with other perennials such as coffee (*Coffee arabica*) and enset (*Enset ventricosum*) and annuals that form a continuous vegetation (Betemariyam *et al*., 2020; Gezie, 2019). Various studies of coffee cultivation techniques have reported multiple functions of the system to protect regional indigenous tree species, provide habitat for other species, act as a biological corridor between protected areas, and alleviate resource use pressures on protected areas (Bhagwat *et al.,* 2008; Mcneely & Schroth, 2006).

Agroforestry was a traditional production system in Ethiopia a thousand years ago. However, traditional agroforestry knowledge is inconsistently established and is often excluded from national policies (Abayineh & Belay, 2017). Agroforestry systems, as an integral part of diverse farming landscapes, can play an important role in conserving and enhancing biodiversity and reducing pressure on natural forests (Eike *et al*; 2014; Jose & Bardhan, 2012). However, there is little literature on agroforestry activities in Ethiopia and they are more concentrated in the southern and southwestern regions of Ethiopia (Tesfaye *et al*., 2013; Mulugeta *et al.,* 2020; Yikunoamlak *et al.,* 2018; Mengistu *et al.,* 2020) and some studies in the northern part of the country (Haileselasie & Hiwot, 2012; Ashenafi *et al*., 2021; Yikunoamlak & Esayas, 2020). Few studies have been published in eastern Ethiopia. Most of the reports studied in eastern Ethiopia focus on agroforestry plant diversity (Ahmed *et al*., 2021; Husen & Tibebu, 2019) its contribution (Semu, 2018), and carbon storage potential (Tessema & Kibebew, 2019). However, the study of tree species diversity of coffee-based and park forestry systems in a single document has not been well-researched in the eastern region of the country. The study aimed to answer what is the tree species composition of the park and coffee-based agroforestry of the study area. Therefore, the objective of this study was to evaluate the diversity and structure of woody plant species in parkland and coffee-based agroforestry systems in the Habro district, Western Hararghe, Ethiopia

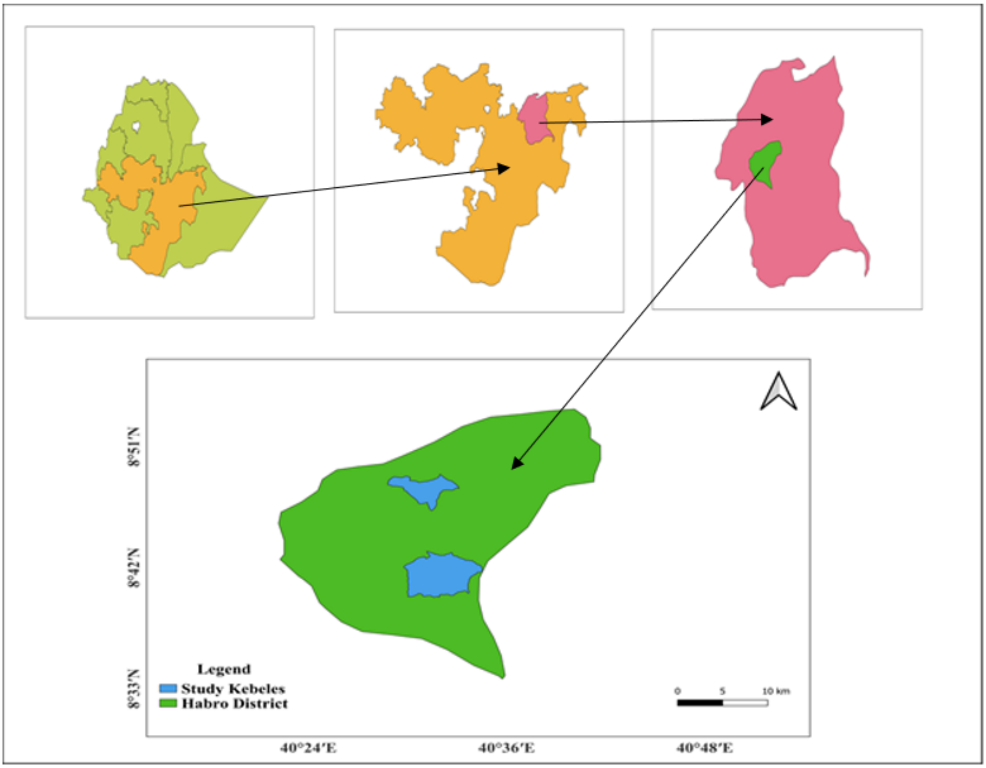
MATERIALS AND METHODS

Description of the study area

Location

The study area, Habro is one of the twelve Districts found in the west Hararghe Zone of Oromia Regional State, Ethiopia. It is 410 km southeast of Addis Ababa and 78 km from Chiro town, the capital of West Hararghe Zone. It is geographically located between 8° 34' 12"N to 8° 54' 36"N and 40° 20' 24" E to 40° 41' 24" E (Fig. 1). The district is composed of 32 rural kebeles and 5 urban kebeles. Gelamso town is the administrative seat of the district.

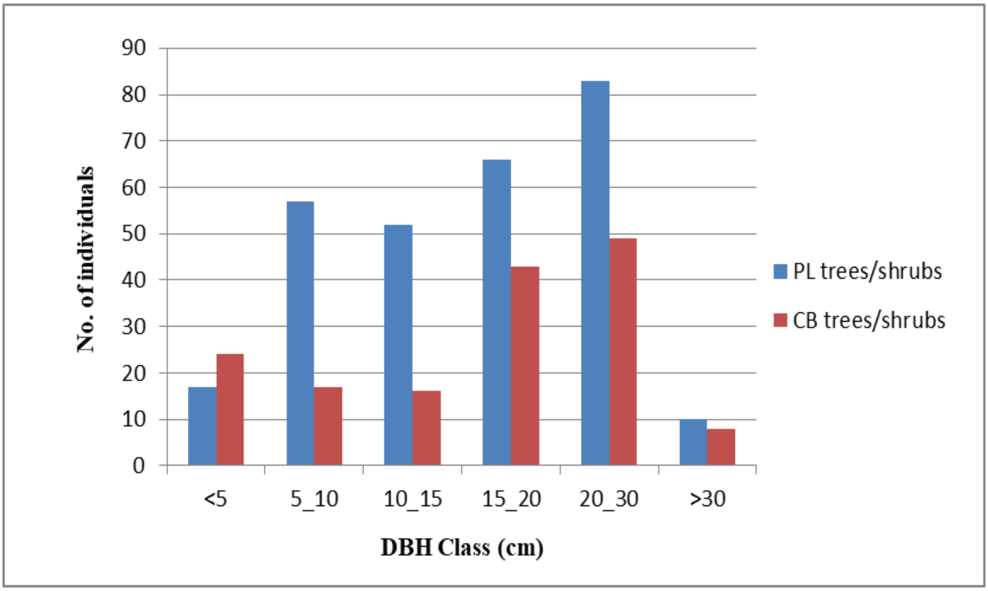
Fig. 1: Map of the study area



Agroecology and soil type

The elevation of the district ranges from 1600 to 2400 m.a.s.l. The district is characterized by plateaus, mountains, hills, plains, and valleys. The district is generally classified into three Agro-ecologies: the lowland, the midland, and the highland which constitute 5 %, 80 %, and 15 % of the total area of the district, respectively (HDoANRO, 2014). Climatically Habro district has a mean minimum and mean maximum temperature of 13.4 °C and 26.8 °C, respectively, and receives mean monthly rainfall of (80 mm) and mean annual rainfall of 959.7 mm (Fig. 2). Rainfall type is bimodal, erratic, and uneven. The five major soil types in Habro District include Vertic Luvisols, Rendzic Leptosols, Haplic Luvisols, Eutric Vertisols, and Eutric (Mengesha *et al.*, 1990).

Fig. 2: Diameter class distribution of woody species in Parkland and Coffee-based AF of study area



Land use type

The existing land use system of the Habro district consists of 33.7 % cultivated area of which 10.3 % is under perennial crops, 22.9 % pasture, and 1.7 % forest and shrub and bush lands, while the rest is accounted for barren, settlement area and others. Mixed crop-livestock agriculture is the major farming system throughout the Woreda. The main crops grown in the area are cereals such as teff (*Eragrostis tef*), maize (*Zea mays*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), haricot bean (*Phaseolus vulgaris*) and sorghum (*Sorghum bicolor*), and cash crops such as coffee (*Coffea arabica*), khat (*Catha edulis*), pepper (*Capsicum species*) and onion (*Alluim cepa L.*) (HDoANRO, 2014). the major agroforestry system practices in hararghe, include parkland agroforestry practice, home garden agroforestry, Trends of alley cropping with chat with maize and sorghum agroforestry, and coffee-based agroforestry practice (Diriba & Dekeba, 2022).

Population

The District has a population of about 265,942 of which 126,488 were females (CSA, 2020). Young, economically active, and old age populations accounted for 45.3 %, 52.4 %, and 2.3 %, respectively. The average family size for rural areas was 4.76 persons. The crude population density of the district is estimated at 357.9 persons per km^2.

Sampling Design

Habro District was selected as the study area by considering the extensive presence of parkland and coffee-based agroforestry practices. A preliminary reconnaissance survey was done to determine the study area/kebeles. Key informants, especially development agents, elders, and woreda natural resource-skilled professionals, were working to identify study sites (kebeles) with parklands and coffee-based agroforestry systems based on land accessibility, resources, and time. As a sampling structure, an overall 32 farmlands/plots for the woody species assessment of parkland and coffee-based agroforestry practices were randomly chosen from two kebeles (Garedew *et al.*, 2019; Tadesse, 2015).

Vegetation Data Collection

As a result, a woody species inventory was conducted on the farmlands of chosen households in the kebeles. For coffee-based agroforestry, woody species diversity, a quadrat measuring 20 m × 20 m (400 m^2) was put out, (Fikrey *et al*., 2022). For parkland agroforestry, an area quadrat size of 40 m × 40 m (1600 m^2) was employed to assess woody species (Reta *et al*., 2021). Because of the low density of trees in a large sample plot area was used since it was less likely to get woody species from small plots in this land use (Tolera *et al*., 2008).

The data obtained included the name of the species, the diameter of the tree at breast height, tree height, tree diameter at stump height, and plot position with GPS. The woody species in each sample plot with a diameter at breast height of ≥ 2.5 cm were measured. At each sampling point, the number of individuals per plot, DBH, height, and DSH of live trees were measured and recorded with a caliper and hypsometer (Macdicken, 2015). The diameter at stump height of all coffee shrubs (d at 40 cm) and 2.5 cm in plots were counted. In multi-stemmed coffee plants (1 to 9 stems per plant), each stem was measured by a caliper, and the equivalent diameter of the plant was calculated as the square root of the sum of the diameters of all stems per plant, following (Snowdon *et al.*, 2002) as below:

$$De = \sqrt{(D_1{}^2 + D_2{}^2 + \cdots D_n{}^2)} \quad \text{Eq. 1}$$

where De is the diameter equivalent (at breast or stump height), and di is the diameter of the i^{th} stem at the breast or stump height.

Tree species were identified in the field with the help of people familiar with the local flora. Species have been given scientific names based on useful trees and shrubs published in Ethiopia (Bekele tesemma, 2007).

Data Analysis

Diversity Analysis

The species diversity in parkland and coffee-based agroforestry was determined by applying species richness, the Shannon diversity index, the Simpson diversity index, and Shannon evenness, (Kent & Coker, 1992). Species richness refers to the overall number of species in a system (Krebs, 1999).

Shannon diversity index was calculated as:

$$H' = -\Sigma \text{pi} \ln \text{pi} \quad \text{Eq. 2}$$

where; H' = Shannon diversity index,

Pi = proportion of individuals found in the i^{th} species or the number of individuals of one species/total number of individuals in the samples.

Values of the index (H') usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (Kent & Coker, 1992).

Simpson's diversity index (D) was calculated as:

$$D = 1 - \left(\frac{\sum n(n-1)}{\sum N(N-1)}\right) \quad \text{Eq. 3}$$

where D = Simpson's index
n = the total number of organisms of a particular species
N = the total number of organisms of all species

Simpson's diversity index gives relatively little weight to the rare species and more weight to the most abundant species. It ranges in value from 0 (low diversity) to a maximum of (1-1/S), where S is the number of species (Krebs, 1999). It is moderately affected by sample size.

The evenness of a population was calculated as;

$$E = \frac{H'}{H\,max} = \frac{H'}{\ln S} \quad \text{Eq. 4}$$

where, E = Evenness
H ′ = Calculated Shannon-Wiener diversity
H max = ln(S) [species diversity under maximum equitability conditions]
S = the number of species

The higher the value of E, the more even the species is in their distribution within the sample

Structural Analysis

Basal area

The basal area is the cross-sectional area of woody stems at breast height. It measures the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in an area. Basal area was calculated for each woody species with diameter ≥ 2.5 cm as:

$$BA = \frac{\pi(DBH)2}{4} \quad \text{Eq. 5}$$

where, π = 3.14
BA = basal area (m^2)
DBH = diameter at breast height (cm)

Density

The density of woody species is one of the most essential structural criteria to consider while analyzing data. Density was computed by weighing up all stems from all areas and converting them to hectare units.

$$\text{Density} = \frac{\text{Total number of individual species}}{\text{sample area (ha)}} \quad \text{Eq. 6}$$

$$\text{Relative density} = \frac{\text{Number of individual species}}{\text{Total number of individual}} * 100 \quad \text{Eq. 7}$$

$$\text{Relative dominance} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} * 100 \quad \text{Eq. 8}$$

$$\text{Frequency} = \frac{\text{Area of the plot in which species occurs}}{\text{Total number of sample plot}} \quad \text{Eq. 9}$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} * 100 \qquad \text{Eq. 10}$$

Importance Value Index

The importance value index (IVI) indicates the importance of species in the system and it was calculated with three components (Kent and Coker, 1992). The importance value for each woody species is the sum of relative density, relative dominance, and relative frequency.

IVI = Relative density + Relative dominance + Relative frequency

Statistical Analysis

First, all data was evaluated for normality (using the Kolmogorov-Smirnov test). The extent and variance in tree/shrub diversity and structure were described using mean and standard deviation. An independent T-test ($\alpha = 0.05$) was used to compare diversity and structure across each AF system. The statistical analysis was performed using the SPSS Statistics software (version 26).

RESULT AND DISCUSSION

Woody species composition

A total of 57 woody species were recorded in the two AF systems (Appendex 1). Of the 57 woody species recorded, parkland agroforestry practices contributed 38 woody species, 43 species were recorded in coffee-based agroforestry practices, and 24 woody species were common for both AF practices. All recorded woody species belonged to 31 families. From the overall woody species family categorization, Fabaceae, Myrtaceae, Rutaceae, and Sapindaceae were the most dominant families, representing 14, 4, 4, and 3 species, respectively.

The total number of woody species in the study area was higher than 55 woody species reported for traditional agroforestry practices in the Dellomenna district of south-eastern Ethiopia (Molla & Kewessa, 2015); 32 woody species were observed across three agroforestry practices in the Wolayta zone of southern Ethiopia (Mikrewongel Tadesse, 2015); and additionally, it surpassed the number of 50 woody species documented in a coffee-based agroforestry system in eastern Uganda (Negawo & Beyene, 2017). In contrast, the species composition observed in the study area was lower compared to other studies. For example, it was less than the 83 species reported in Nicaragua (Méndez *et al.*, 2001), 59 species documented in the Kachabira district, Southern Ethiopia (Legesse & Negash, 2021), and the extensive count of 289 woody plants found in sub-urban areas of Sri Lanka (Kumari, 2009). Such differences in agroforestry practices exist Farmers maintain many tree and shrub species for environmental services like soil and water conservation. Most of the woody species retained by farmers in parklands and coffee-based agroforestry were remnants of the natural vegetation, which covered the area before the settlements appeared. Afterward, planting of both native and exotic species occurred, mostly in coffee-based and in some parklands.

Woody Species Diversity

In the study area, the evenness and Simpson index of woody species exhibited a significant difference among agroforestry practices ($p < 0.05$). These indicate variations in species distribution and dominance. However, the species richness and Shannon-Wiener index did not show a significant difference among the agroforestry practices ($p < 0.05$), suggesting a similar level of diversity across the different practices (Table 1). The species richness and Shannon diversity index of coffee-based AF practice were slightly higher than those of parkland AF practice. This result is due to coffee is traditionally grown in more complex systems in Eastern Ethiopia, that integrate multiple species of trees and shrubs. These systems often include a mix of shade trees, fruit trees, and other crops, enhancing overall biodiversity, which is associated with farmers' interest in growing trees that have high commercial, food, and forage values around houses rather than planting trees in parkland agroforestry systems and may be attributed to better and intensive management by family labor, in particular women and children.

Table 1: Mean ±SE. value of woody species richness, Shannon-Wiener index, Simpson index and evenness of Parkland and coffee-based AF system

AF practice	Richness plot^{-1}	Shannon plot^{-1}	Simpson plot^{-1}	Evenness plot^{-1}
parkland AF	6.56±0.38	1.77±0.05	0.8±0.01^{a}	0.93±0.01
coffee-based AF	7.56±0.38	1.78±0.06	0.31±0.02^{b}	0.95±0.01
p value	0.08	0.87	< 0.001	0.04

The mean Shannon index, Simpson index, and species richness of the parkland agroforestry practice were lower than previous studies on Ethiopia and West Africa (Misgana *et al*., 2020; Nikiema, 2005; Gebrewahid & Meressa|, 2020), The lower species richness and diversity of the study areas in parklands agroforestry associated with increased the demand for agricultural land and wood for fuels and timber product. On the other hand, the mean Shannon index and species richness of the coffee-based agroforestry practices in our study were higher than those reported by (Tesfay *et al.,* 2022) in Southern Ethiopia and (Mengistu & Asfaw, 2016) in Dallo Mena District, South-East Ethiopia. The difference might be due to variations in management practices, dominant species type, soil condition, and geographical location. This implies that intensive management systems need to be implemented in the diversification of land use types with diverse woody species composition.

The Important Value Index (IVI) of all woody species of the AF systems in the study area is listed in descending order (Appendex 2 and 3). In the coffee-based agroforestry practice, the species that exhibited the highest IVI were *Coffea arabica, Erythrina abyssinica, Casimiroa edulis, Cordia africana,* and *Faidherbia albida.* Similarly, within the parkland agroforestry systems, the woody species with the highest IVI were *Cordia africana, Eucalyptus camaldulensis, Faidherbia albida, Croton macrostachyus,* and *Milletia ferruginea*. On the other hand, seven tree/shrub species, namely *Ehretia cymosa*, *Grewia bicolor, Grevillea robusta, Justicia schimperiana, Acacia brevispica, Ficus vasta,* and *Dodonea angustifolia,* were found to be only in one plot (Table 2).

Table 2: Top five woody species with the highest importance value index (IVI) of two AF systems, in Habro District, Eastern Ethiopia

AF practices	Scientific Name	Importance value index (IVI) (%)
Coffee-based AF	*Coffea arabica*	156.73
	Erythrina abyssinica	15.71
	Casimiroa edulis	13.54
	Cordia africana	12.42
	Faidherbia albida	8.84
Parkland AF	*Cordia africana*	49.15
	Eucalyptus camaldulensis	26.57
	Faidherbia albida	23.59
	Croton macrostachyus	21.95
	Milletia ferruginea	17.47

The structural parameters of woody species for each size class are shown in (Table 3). The independent T-test (n = 16) showed that the mean stem density and basal area of tree species except coffee shrubs for parkland were significantly different (P<0.05) from coffee-based AF practice. However, the height and DBH showed no significant difference among AF practices (P<0.05).

Table 3: Mean (SE) DBH, DBS, Height, Basal area (BA) and stem number (density) of tree and coffee shrubs of two AF systems

Parameter	AF System	Tree	Coffee	Total
Avag. DBH (cm)	Parkland	16.89 ± 0.65^{a}		-
	Coffee-based	16.97 ± 0.94^{a}	7.21 ± 0.07	-
Avag. Height (m)	Parkland	7.51 ± 0.36^{b}		-
	Coffee-based	7.87 ± 0.44^{b}	3.62 ± 0.04	-
Density ha^{-1}	Parkland	112.06 ± 5.58^{a}		112.06 ± 5.58^{a}
	Coffee-based	245.31 ± 13.92^{b}	2000 ± 40.66	2245.31 ± 41.2^{b}
Basal Area $m^2\ ha^{-1}$	Parkland	3.11 ± 0.22^{a}		3.11 ± 0.22^{a}
	Coffee-based	7.03 ± 0.84^{b}	8.4 ± 0.2	15.43 ± 0.88^{b}

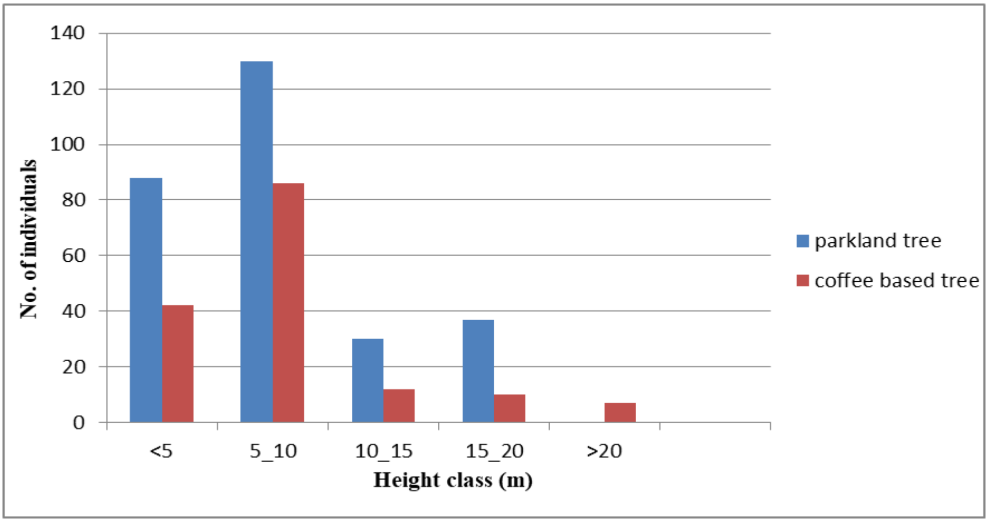
Coffee-based AF practice showed the highest stem number (density/ha) and basal area/ha for tree species compared to parkland agroforestry practice (Table 3). This is due to farmer's day-to-day activity to maximize the land use efficiency to increase their income. The mean density of woody species in the parkland agroforestry practice exceeded the findings of previous studies (Legesse & Negash, 2021; Misgana *et al.*, 2020) In the Kachabira district of southern Ethiopia and gindeberet district respectively. However, in the coffee-based agroforestry practice, the mean density of shade trees and coffee shrubs was lower compared to research conducted in the Moist Mid-Highlands of Southern Ethiopia by (Tesfay *et al.*, 2022) and (Mulugeta *et al.*, 2020) in the Mana district of southern Ethiopia.

Therefore, the mean density of woody species in the parkland agroforestry practice exhibited higher values compared to previous studies, while the mean density of shade trees and coffee shrubs in the coffee-based agroforestry practice showed lower values compared to other research findings.

The mean basal area of tree and coffee shrubs in the coffee-based AF system was higher than the result reported by (Tesfay *et al*., 2022) in the Moist Mid-Highlands of Southern Ethiopia But lower than the result shown by (Betemariyam *et al*., 2020) in Mana district southern Ethiopia and (Tesfay, 2020) was reported in southeastern Rift- valley Landscapes, Ethiopia. This is due to Variations in climate, soil fertility, altitude, and rainfall can influence the growth and productivity of trees and coffee shrubs. Other studies have also shown that stand structure was influenced by the diversity of woody species, and management practices, such as planting density, pruning, and crop management, can impact the growth and basal area of trees and shrubs.

The distribution of population structure for the AF systems has an inverted U-shape (bell shape), which shows a high number of intermediate DBH and height classes, but a very low number in the small and large height and DBH classes (Figures 2 and 3). This indicates a poor reproduction and recruitment of species, which may be associated with the overharvesting of seed-bearing individuals, hampered regeneration could be attributed mainly to grazing. Disturbance was also common in the *Cordia africana*, *Eucalyptus camaldulensis*, and *Faidherbia albida* communities in the form of selective cutting for charcoal making and construction wood. Besides, these species were commonly preferred for fuel wood and construction.

Fig. 3: Height class distribution of woody species of Parkland and Coffee-based of AF systems of study area



CONCLUSIONS

This study provides a comprehensive assessment of woody species composition and diversity across parkland and coffee-based agroforestry practices. The result shows that the woody species composition of the study area was comparatively higher in both parkland

and coffee-based agroforestry practices and focused on the conservation of dominant indigenous woody species such as *Cordia africana, Croton macrostachyus, Faidherbia albida,* and *Erythrina abyssinica.* Coffee-based agroforestry practice was found to have a relatively higher number of species and diversity compared to the parkland agroforestry practice. Most structural parameters such as tree density and basal area were significantly different by AF and coffee-based AF practices are relatively higher in terms of basal area and density. Quantifying and understanding the woody species diversity helps to design and develop biodiversity conservation and climate change mitigation strategies.

Based on the findings the following recommendations are forwarded to contribute to AF systems toward biodiversity conservation:

- Some native tree species were found to be rare in the current study area. Therefore, a special conservation priority coupled with wise utilization of woody species including *Ehretia cymosa, Grewia bicolor, Dombeya torrid,* and *Justicia schimperiana* should be done by the community,
- Illegal exploitations, deforestation of native woody species, and unmanaged grazing have threatened the system. Hence, this calls for integrated action between local, regional, and national gov't with communities to control the problem.

Finally, in our study area different AF systems are practiced so further research should be done on soil properties, management, and the role of tree species in agroforestry.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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APPENDIX

Appendix 1: List of woody plant species recorded in both AF systems of our study areas

No.	Scientific Name	Local Name	Family	Habit
1	Acacia abyssinica	Lafto	Fabaceae	Tree
2	Acacia brevispica	Kontir/Amazaze	Fabaceae	Tree
3	Acacia seyal	Wachu	Fabaceae	Tree
4	Accacia saligna	Akacha saligna	Fabaceae	Tree
5	Acecia tortilis	Tedecha	Fabaceae	Tree
6	Albizia gummifera	mukaarba	Fabaceae	Tree
7	Albizia scimperiana	Muka arta	Fabaceae	Tree
8	Allophylus abyssinicus	Seho	Sapindaceae	Tree
9	Annona muricata	Hambeshok	Annonaceae	Tree
10	Annona senegalensis	Gishta	Annonaceae	Tree
11	Balanites aegyptiaca	Badano	Balanitaceae	Shrub
12	Buddleja polystacha	Buchema	Loganiaceae	Tree
13	Carica papaya	Papaya	Caricaceae	Tree
14	Carissa spinarum	agamsa	Apocynaceae	Shrub
15	Casimiroa edulis	Hambadeda	Rutaceae	Tree
16	Casuarina equisetifolia	Shewshewe	Casuarinaceae	Tree
17	Celtis africana	Metekom	Ulmaceae	Shrub
18	Citrus aurantifolia	tuto	Rutaceae	Tree
19	Citrus sinensis	Ambalta	Rutaceae	Tree
20	Coffea arabica	buna	Rubiaceae	Shrub
21	Combretum molle	Dandamsa	Combretaceae	Tree
22	Cordia africana	Wodesa	Boraginaceae	Tree
23	Croton macrostachyus	Burtukana	Rutaceae	Tree
24	Cupressus lusitanica	Getira-ferenji	Cupressaceae	Tree
25	Dodonaea viscosa	Etacha	Sapindaceae	Shrub
26	Dodonea angustifolia	Itancha	Sapindaceae	Shrub
27	Dombeya torrid	Danissa	Sterculiaceae	Tree
28	Dovyalis abyssinica	Koshim/Ankekute	Flacourtiaceae	Tree
29	Ehretia cymosa	Ulaga	Boraginaceae	Tree
30	Entada abyssinica	Ambalta	Fabaceae	Tree
31	Erythrina abyssinica	Wolensu	Fabaceae	Tree
32	Eucalyptus camaldulensis	Bargamo dima	Myrtaceae	Tree
33	Eucalyptus globulus	Bargamo adi	Myrtaceae	Shrub

34	Eucalyptus saligna	Bargamo saligna	Myrtaceae	Tree
35	Faidherbia albida	Gerbi	Fabaceae	Shrub
36	Ficus sur	Harbu	Moraceae	Tree
37	ficus vasta	Qilxu	Moraceae	Tree
38	Grevillea robusta	Giravilia	Proteaceae	Shrub
39	Grewia bicolor	haroresa	tiliaceae	Shrub
40	Jacaranda mimosifolia	muka kewe	Biginoniaceae	Tree
41	Jatropha curcas	Jatrova	Euphorbiaceae	Shrub
42	Juniperus procera	hindessa	Cupressaceae	Tree
43	Justicia schimperiana	Dumuga	Acanthaceae	Shrub
44	Lawsonia inermis	Hina	Lythraceae	Tree
45	Lucean lucocephala	Lucina	Fabaceae	Tree
46	Mangifera indica	Mango	Anacardiaceae	Tree
47	Melia azedarach	Muka kinin	Meliaceae	Tree
48	Millettia ferruginea	Birbira	Fabaceae	Tree
49	Moringa oleifera	Shifera	Moringaceae	Tree
50	Olea africana	Ejerssa	Oleaceae	Tree
51	Persea Americana	Avocado	Lauraceae	Tree
52	Psidium guajava	Zeituna	Myrtaceae	Shrub
53	Rhus glutinosa	Tatesa	Anacardiaceae	Tree
54	Senna didymobotrya	Ceka	Fabaceae	Shrub
55	Sesbania sesban	Enchini	Fabaceae	Tree
56	Vernonia amygdalina	Aebicha	Asteraceae	Shrub
57	Ziziphus mauritiana	Qurqura	Rhamnaceae	Tree

Appendix 2: List of woody species and their IVI under Coffee based AF, Habro District, Ethiopia

No.	Species Name	Frq	Rel. Frq	Den	Rel. Den	Dom	Rel. Dom	IVI	Den/Ha
1	Coffea Arabica	16	13.2	1280	89.07	5.378	54.43	156.7	2000
2	Erythrina abyssinica	11	9.09	16	1.11	0.544	5.50	15.71	25.00
3	Casimiroa edulis	11	9.09	18	1.25	0.315	3.19	13.54	28.13
4	Cordia africana	8	6.61	13	0.90	0.484	4.90	12.42	20.31
5	Faidherbia albida	5	4.13	6	0.42	0.424	4.29	8.84	9.38
6	Mangifera indica	6	4.96	6	0.42	0.247	2.50	7.88	9.38
7	Lawsonia inermis	7	5.79	9	0.63	0.009	0.10	6.51	14.06
8	Cupressus lusitanica	3	2.48	4	0.28	0.295	2.99	5.74	6.25
9	Citrus sinensis	4	3.31	6	0.42	0.140	1.42	5.14	9.38
10	Albizia gummifera	3	2.48	5	0.35	0.218	2.20	5.03	7.81
11	Millettia ferruginea	3	2.48	4	0.28	0.201	2.04	4.80	6.25
12	Eucalyptus camaldulensis	3	2.48	7	0.49	0.159	1.61	4.57	10.94
13	Croton macrostachyus	3	2.48	5	0.35	0.161	1.63	4.45	7.81
14	Casuarina equisetifolia	2	1.65	3	0.21	0.253	2.56	4.42	4.69
15	Annona muricata	3	2.48	4	0.28	0.111	1.13	3.89	6.25
16	Entada abyssinica	4	3.31	4	0.28	0.009	0.09	3.68	6.25
17	Olea africana	2	1.65	2	0.14	0.174	1.76	3.55	3.13
18	Eucalyptus globulus	2	1.65	3	0.21	0.129	1.31	3.17	4.69
19	Sesbania sesban	3	2.48	7	0.49	0.007	0.07	3.03	10.94
20	Melia azedarach	2	1.65	3	0.21	0.115	1.17	3.03	4.69
21	Albizia scimperiana	2	1.65	3	0.21	0.102	1.03	2.89	4.69
22	Acacia seyal	3	2.48	4	0.28	0.008	0.08	2.84	6.25
23	Annona senegalensis	2	1.65	5	0.35	0.043	0.43	2.43	7.81
24	Grevillea robusta	1	0.83	2	0.14	0.128	1.29	2.26	3.13
25	Carica papaya	2	1.65	4	0.28	0.028	0.28	2.21	6.25
26	Lucean lucocephala	2	1.65	4	0.28	0.006	0.06	1.99	6.25
27	Juniperus procera	1	0.83	2	0.14	0.095	0.96	1.93	3.13
28	Vernonia amygdalina	2	1.65	2	0.14	0.004	0.04	1.84	3.13
29	Acacia brevispica	1	0.83	1	0.07	0.045	0.46	1.35	1.56
30	Ehretia cymosa	1	0.83	1	0.07	0.025	0.25	1.15	1.56
31	Grewia bicolor	1	0.83	2	0.14	0.010	0.10	1.07	3.13
32	Dombeya torrid	1	0.83	1	0.07	0.006	0.06	0.96	1.56
33	Justicia schimperiana	1	0.83	1	0.07	0.005	0.05	0.95	1.56
	Total	121	100	157	100	4.50	100	300	2245.3

Appendix 3: List of woody species and their IVI under parkland AF, Habro District, Ethiopia

No.	Species name	Frq	Rel. Frq	Den	Rel. Den	Dom	Rel. Dom	IVI	Den/ha
1	Cordia Africana	15	13.9	59	20.70	1.16	14.55	49.15	23.05
2	Eucalyptus camaldulensis	8	7.41	26	9.12	0.8	10.04	26.57	10.16
3	Faidherbia albida	7	6.48	18	6.32	0.86	10.79	23.59	7.03
4	Croton macrostachyus	8	7.41	20	7.02	0.6	7.53	21.95	7.81
5	Milletia ferruginea	5	4.63	13	4.56	0.66	8.28	17.47	5.08
6	Erythrina abyssinica	5	4.63	11	3.86	0.41	5.14	13.63	4.30
7	Olea Africana	5	4.63	8	2.81	0.45	5.65	13.08	3.13
8	Ziziphus mauritiana	4	3.70	9	3.16	0.47	5.90	12.76	3.52
9	Entada abyssinica	6	5.56	16	5.61	0.12	1.51	12.68	6.25
10	Jatropha curcas	6	5.56	15	5.26	0.1	1.25	12.07	5.86
11	Casimiroa edulis	5	4.63	11	3.86	0.2	2.51	11.00	4.30
12	acacia seyal	5	4.63	16	5.61	0.06	0.75	11.00	6.25
13	Ficus sur	3	2.78	3	1.05	0.57	7.15	10.98	1.17
14	Acacia abyssinica	3	2.78	6	2.11	0.22	2.76	7.64	2.34
15	Senna didymobotrya	4	3.70	9	3.16	0.01	0.13	6.99	3.52
16	Carica papaya	4	3.70	7	2.46	0.05	0.63	6.79	2.73
17	Melia azedarach	2	1.85	5	1.75	0.2	2.51	6.12	1.95
18	Cupressus lusitanica	2	1.85	4	1.40	0.22	2.76	6.02	1.56
19	Mangifera indica	2	1.85	4	1.40	0.22	2.76	6.02	1.56
20	Grevillea robusta	1	0.93	4	1.40	0.2	2.51	4.84	1.56
21	grawia bicolor	2	1.85	6	2.11	0.05	0.63	4.58	2.34
22	Rhus glutinosa	2	1.85	5	1.75	0.07	0.88	4.48	1.95
23	Ehretia cymosa	1	0.93	4	1.40	0.08	1.00	3.33	1.56
24	ficus vasta	1	0.93	1	0.35	0.15	1.88	3.16	0.39
25	Justicia schimperiana	1	0.93	3	1.05	0.02	0.25	2.23	1.17
26	Dodonea angustifolia	1	0.93	2	0.70	0.02	0.25	1.88	0.78
	total	139	100	285	100	7.97	100.0	300.0	0.00