

Structure and Farmers' Woody Species Preference in Parkland Agroforestry in Womberima District, West Gojjam Zone, Amhara Region, Ethiopia

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Abstract: In this study, the structure and farmer preferences of woody species in parkland agroforestry systems in the Amhara Region of Ethiopia's Womberima district, West Gojjam Zone, are examined. A traditional land-use system that is important for preserving biodiversity, improving soil fertility, and sustaining rural livelihoods is parkland agroforestry. For this study, 129 households and 60 parkland agroforestry plots, with 30 plots in the lowland and 30 plots in the midland were taken for the data collection. Within each agro-ecological zone, plots were randomly located in farmers' fields, ensuring a minimum distance of 100 m between plots to avoid spatial autocorrelation. Woody species inventory was conducted using square plots measuring 50 m × 50 m. A total of 47 woody species identified which is belonging to 28 families with the most abundant being *Fabaceae*, *Moraceae*, and *Myrtaceae*. The lowland parkland agroforestry had a substantially higher species density than the midland, which had a somewhat larger basal area. In terms of frequency, density, and the Importance Value Index (IVI), *Croton macrostachyus*, *Acacia abyssinica*, *Cordia africana*, and *Ficus vasta* were some of the most ecologically and socially significant species. Farmers' preferences for woody species were assessed using a preference ranking and scoring method. Soil fertility improvement, Crop compatibility, Provision of fuelwood and timber, Fodder value, Shade provision and Cultural and economic importance were the criteria for preference ranking. According to farmer preference rankings, *Acacia abyssinica*, *Croton macrostachyus*, *Acacia nilotica*, and *Cordia africana* were the most preferred species because of their multiple uses. The ecological drawbacks of species like *Grevillea robusta* and *Eucalyptus*, on the other hand, made them less popular. The study emphasizes that in order to improve sustainability and conservation outcomes, agroforestry development should be in line with farmers' preferences and local ecological conditions.

Keywords: Woody species, Preference, Womberima, Structure, Basal area

Introduction

Agroforestry has long been practiced around the world as a sustainable land use strategy that integrates trees and crops to enhance agricultural productivity and environmental health

(Bogale and Bekele 2023). However, the type, character, and breadth of agroforestry practices vary widely due to regional topography, biophysical conditions, and socioeconomic contexts (Getahun, Mamo et al. 2024). The development of various traditional agroforestry practices in Ethiopia has been impacted by the country's diverse landscapes and cultural heritage (Girmay, Teshome et al. 2023). These include typical practices across the nation, such as hedgerow intercropping, parkland agroforestry, multi-strata home gardens, and riparian vegetation (Dagar and Tewari, 2017).

Parkland agroforestry is particularly significant in Ethiopia since it contributes to the overall diversity of the system and aids in the preservation of native woody plants (Degefa and Markos 2022). Woody species structure is closely linked to landscape resilience and quality in parkland agroforestry systems, and it directly affects soil fertility, biodiversity, and productivity (Yirga, Asfaw et al. 2024). In these systems, the selection of tree species is determined by several factors, including the trees' utility, drought resilience, crop compatibility, and ability to increase soil fertility (Mulugeta, 2023). Through increasing the number of rare or indigenous species, it is also possible to increase species variety and richness, which would ensure long-term sustainability (Debie 2024).

Trees are vital to agricultural systems in Ethiopia, where parkland agroforestry has been practiced for millennia. They provide shade, enhance soil quality, and yield resources like fuel wood and lumber (Girma, 2024). In agricultural landscapes, parkland agroforestry systems are defined by the species composition, tree density, and spatial arrangement of trees (Wondimenh, 2023). Knowing which tree species farmers prefer is essential to increasing the sustainability and productivity of these systems (Sjögren, 2015).

In the Womberima district of the West Gojjam Zone of Ethiopia, farmers possess a wealth of indigenous knowledge regarding the management of parkland agroforestry systems, particularly with the diversity and structure of woody and non-woody species (WDOARD 2022). Nevertheless, little is understood about how farmers manage woody species' structure and preferences in parkland agroforestry systems. In order to bridge this gap, this study aims to compare the woody species structure of parkland agroforestry systems across different agro-ecological zones, identify and rank farmers' preferred woody species based on their perceived functions and benefits; and assess the conservation priority of woody species through integrating structural attributes with farmers' preference criteria in Womberima district, West Gojjam Zone, Amhara region, Ethiopia.

Materials and Methods

Description of the Study Area

The study was conducted in Womberima district West Gojjam Zone of Amhara regional state of Ethiopia. Womberima district is located about 165 km southwest of Bahir Dar and 426 km from Addis Ababa with an altitude that ranges from 800 to 2212m.a.s.l. Geographically, it is located between 36° 49'to 37° 00' E longitude and 10° 41'to 10° 58' N Latitude (Figure 1). Womberima district is bordered in the North by Awi Zone and Burie District, in the South Oromiya National Regional State, in the east by Burie district, and in the west by Awi Zone. The district has 18 rural Kebeles and 2 urban Kebeles. The administrative center of the district is Shindy WDOBOARD (2022).

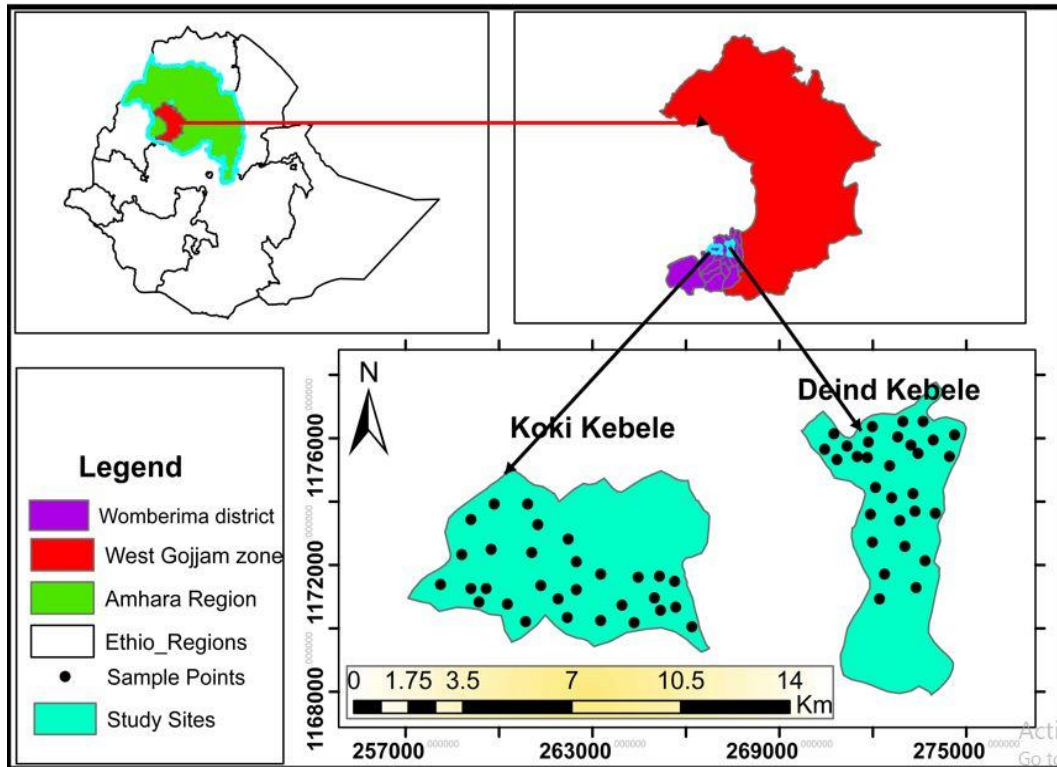


Figure 1: Map of the study area (a) Ethio Regions, (b) West Gojjam Zone, and (c) Study sites.

Womberima district has two agro-ecological Zones, namely *lowland* (warm) from 800 to 1500 meter above sea level and *mid land* (moderate) from 1500 to 2212 meter above sea level which covers 48% and 52%, respectively. These agro-ecological zones differ in altitude and rainfall distribution. The rainfall distribution is uni-modal. *Summer* is the main rainy season that occurs from the beginning of June to August. The mean minimum and maximum annual precipitation is 1441 and 1745mm, respectively. The mean minimum and maximum temperatures are 16 and 28°C, respectively WDOARD (2022).

Formerly, the district was covered by dense natural forests, but the distribution of natural forests is declining from time to time, due to human interference. Currently, the forest coverage of the district is only 13.6% of the total land area (WDOARD, 2022). The common trees in the study area include *Cordia africana Lam.*, *Croton macrostachyus Del.*, *Ficus sur Forssk*, *Dodonia viscosa (L.) Jacq.*, *Acacia nilotica L.*, *Acacia abysinica Hochst.ex Benth.*, *Albizia gummifera J.F.Gmel.* and *Eucalyptus* species are found scattered in most farmland.

The soil is pale in color, generally coarse-textured and freely drained. Most of the soils have low bulk density and weak structure, which renders them vulnerable to erosion. Generally, the common soil types in the district are Vertisol and Rigosol. Vertisol is the dominant soil type in the study area (WDOARD, 2022).

The demographic characteristics of the study area can be described as follows: Womberima district has 20 Kebeles with a total population of 92,052 with 45,861 males and 46,191 females (WDOARD 2022). The population density of Womberima district is 0.678 persons per hectare (WDOARD 2022).

The livelihood of the people in the district depends mainly on mixed agriculture (crop-livestock tree production). It is characterized by mixed farming of rain-fed crops and livestock production associated with tree species on farmland. The most commonly cultivated crops in the district are teff (*Eragrostis tef* Zucc.), wheat (*Triticum aestivum* L.) maize (*Zea mays* L.), pepper (*Piper nigrum* L.) and coffee (*Coffea arabica* L.). Maize is the staple food crop for the majority of the community, while wheat and pepper are the dominant cash crops. Fruit trees such as avocado (*Persea americana* Mill.), banana (*Musa paradisiaca* L.), mango (*Mangifera indica* L.), and papaya (*Carica papaya* L.) are also cultivated for household consumption and to some extent income generation (WDOARD, 2022).

Sampling techniques and sample size determination

In order to represent the structure of observed woody species and their farmer's preference in parkland agroforestry, Womberima District was purposefully chosen from among 16 districts in the west Gojjam Zone based on the existence of substantial parkland agroforestry. Based on their altitudinal range, the study district was divided into two agro-ecological zones: lowland and midland. Administrative units were employed to choose representative study locations within each agro-ecological zone. For woody species structural analysis, a total of 60 parkland agroforestry sample plots were established. To ensure proportional representation, the plots were equally distributed between the two agro-ecologies, with 30 plots in the lowland and 30 plots in the midland. Within each agro-ecological zone, plots were randomly located in farmers' parkland fields, ensuring a minimum distance of 100 m between plots to avoid spatial autocorrelation.

Woody species inventory was conducted using square plots measuring 50 m × 50 m, which is appropriate for capturing scattered trees typical of parkland agroforestry systems. All woody individuals falling within the plot boundaries were recorded. Woody species were identified in the field using local names with the assistance of knowledgeable farmers and later verified using standard botanical references. Woody plants were categorized into trees (woody plants with a stem height ≥5 m) and shrubs (woody plants with multiple stems height <5 m) based on growth form:

Diameter at breast height (DBH) was measured for all woody individuals with DBH ≥5 cm. DBH was measured at 1.3 m above the ground using a diameter tape. For multi-stemmed individuals, each stem meeting the DBH threshold was measured separately. Tree height was measured using clinometer.

To assess farmers' preferences for woody species, household sample size was determined using Cochran (1965) formula at a 95% confidence level with a 5% margin of error and an assumed population proportion of 10%. With a total of 2010 households, the finite population correction resulted in a final sample size of 129 households. The sampled households were proportionally allocated to the selected Kebeles.

The formula is as follow:

$$n = \frac{Z^2 P(1-P)}{d^2}, n' = \frac{NZ^2 P(1-P)}{d^2(1-p) + Z^2 P(1-P)} \quad \text{Equation (1)}$$

$$n' = \frac{2010 * (1.96)^2 0.1(1 - 0.1)}{0.05^2(1 - 0.1) + 1.96^2 0.1(1 - 0.1)}$$

$$n' = 129$$

Where n is the sample size required, P is the expected prevalence or proportion of the population to be included in the sample, as a decimal (0.1 for 10 %), d is a Precision error, expressed as a decimal (0.05 for 5 %), n' is sample size with finite population correction, N is the total number of households, Z is the value of the statistics based on the confidence level (1.96 for 95 % confidence).

A preference ranking and scoring approach was used to determine farmers' preferences for woody species. In semi-structured interviews, participants were asked to rank woody species that are frequently kept in parkland agroforestry according to a variety of factors, such as improving soil fertility, crop compatibility, fuel wood and timber provision, fodder value, shade provision, and cultural and economic significance. A five-point Likert scale (1 being least preferred, 2 being somewhat preferred, 3 being moderately preferred, 4 being highly preferred, and 5 being most preferred) was used to score each species. Each species' preference index was computed by adding together the weighted scores for all respondents and criterion, then dividing the result by the total number of respondents.

Data Analysis

The data was presented and analyzed using descriptive and inferential statistics. The woody species density, relative abundance, frequency and importance value index data were organized using Microsoft Office Excel. Prior to inferential statistical analysis, all continuous variables were checked for conformity with the assumptions of parametric tests. Normality of data distributions was assessed using the Shapiro–Wilk test, while homogeneity of variances between agro-ecological zones was determined using Levene's test. Variables that met both assumptions were analyzed using independent sample t-test to compare woody species structural attributes between the lowland and midland agro-ecological zones. For variables that violated normality and/or homoscedasticity assumptions, the non-parametric Mann–Whitney U test was applied. Regarding tree species preference, farmers in the study area cultivate trees for a variety of reasons, so no single tree species can be thought of as being ideal for meeting every household need. Farmers' preference scores were ranked to identify the most preferred species and linked with structural attributes to assess conservation priority within parkland agroforestry systems. The benefits of maintaining trees on farmlands determine which tree species are chosen (Chauhan and Chauhan, 2011). Note: To get the relative score, multiply the number of responses in each rank by the percentage, for example, $50 \times (50/129)$.

Results

Woody Species Composition

From all the total sample plots, a total of 47 woody species were recorded from the two agro ecological zones of parkland agroforestry practices (Table 1). Out of this, 28 species were collected from midland agro ecology while 33 were collected from the lowland. Fourteen woody species were common in both agro ecological zones. The woody species are belonging to 28 families, of these Fabaceae, Moraceae and Myrtaceae were the most dominating families having 7, 4, and 4 species respectively.

Table 1. List of Woody species recorded in parkland agroforestry of Womberima district

	SCIENTIFIC NAME	COMMON NAME	FAMILY	LOCATION	GROWTH HABIT	ORIGIN
1.	<i>Acacia abyssinica</i> Hochst. ex Benth.	Yehabesha girar	Fabaceae	midland	Tree	Indigenous
2.	<i>Acacia nilotica</i> L.	Cheba	Fabaceae	lowland	Shrub	Indigenous
3.	<i>Acacia sieberiana</i> Var. woodi.	nech girar	Fabaceae	lowland	Tree	Indigenous
4.	<i>Acanthus polystachius</i> Delile	Kosheshile	Acanthaceae	lowland	Shrub	Indigenous
5.	<i>Albizia gummifera</i> J.F.Gmel.	Sesa	Fabaceae	midland	Tree	Indigenous
6.	<i>Azadirachta indica</i> L.	Nim	Meliaceae	both	Tree	Exotic
7.	<i>Boswellia papyrifera</i> (Del.) Hochst.	ye tigre etan zaf	Burseraceae	lowland	Tree	Indigenous
8.	<i>Calpurnia subdecandra</i> (L`Hérit.) Schweick.	Ligita	Fabaceae	lowland	Tree	Indigenous
9.	<i>Carica papaya</i> L.	Papaya	Caricaceae	midland	Tree	Exotic
10.	<i>Carissa spinarum</i> (C. edulis)	Agam	Apocynaceae	midland	Shrub	Indigenous
11.	<i>Citrus aurantifolia</i> (Christm.) Swingle	Lomi	Rutaceae	both	Tree	Exotic
12.	<i>Citrus sinensis</i> (L.) Osb.	Birtukan	Rutaceae	both	Tree	Exotic
13.	<i>Clausena anisata</i> (Willd.) Benth	Limich	Rutaceae	lowland	Shrub	Indigenous
14.	<i>Coffea arabica</i> L.	Buna	Rubiaceae	both	Shrub	Indigenous
15.	<i>Combretum collinum</i> Fresen.	Tunjit	Combretaceae	lowland	Tree	Indigenous
16.	<i>Combretum molle</i> R. Br. ex G. Don.	Avalo	Combretaceae	lowland	Tree	Indigenous
17.	<i>Cordia africana</i> Lam.	Wanza	Boraginaceae	midland	Tree	Indigenous
18.	<i>Croton macrostachyus</i> Del.	Bisana	Euphorbiaceae	both	Tree	Indigenous
19.	<i>Cupressus lusitanica</i> Mill.	Yeferenji tid	Cupressaceae	midland	Tree	Exotic
20.	<i>Dodonaea viscosa</i> (L.) Jacq.	Kitkita	Sapindaceae	lowland	Shrub	Indigenous
21.	<i>Dovyalis abyssinica</i> (A. Rich.) Warb.	Koshim	Flacourtiaceae	midland	Shrub	Indigenous
22.	<i>Eucalyptus camaldulensis</i> Dehnh.	Key bahirzaf	Myrtaceae	both	Tree	Exotic
23.	<i>Entada abyssinica</i> Steud. ex A. Rich.	Kentefa	Fabaceae	lowland	Tree	Indigenous
24.	<i>Eucalyptus citriodora</i> Hook.	Shito bahirzaf	Myrtaceae	both	Tree	Exotic
25.	<i>Eucalyptus globulus</i> Labill.	Nech bahirzaf	Myrtaceae	midland	Tree	Exotic
26.	<i>Euclea racemosa</i> subsp. Schimper	Dedeho	Ebenaceae	lowland	Tree	Indigenous
27.	<i>Euphorbia tirucalli</i> L.	Kinchib	Euphorbiaceae	lowland	Tree	Indigenous
28.	<i>Ficus carica</i> L.	Beles	Moraceae	lowland	Tree	Exotic
29.	<i>Ficus elastic</i> Roxb. ex. Hornem.	yegoma zaf	Moraceae	lowland	Tree	Exotic

30.	<i>Ficus sur</i> Forssk.	Shola	Moraceae	midland	Tree	Indigenous
31.	<i>Ficus vasta</i> Forssk	Warka	Moraceae	both	Tree	Indigenous
32.	<i>Gardenia volkensii</i> K. Schum.	Gambilo	Rubiaceae	lowland	Tree	Indigenous
33.	<i>Grevillea robusta</i> R. Br.	Gravilea	Proteaceae	midland	Tree	Exotic
34.	<i>Grewia bicolor</i> Juss.	Somaya	Tiliaceae	lowland	Shrub	Indigenous
35.	<i>Jacaranda mimosifolia</i> D. Don	Yetemnja zaf	Bignoniaceae	both	Tree	Exotic
36.	<i>Justicia schimperiana</i> (Hochst. Ex Nees)	Simiza	Acanthaceae	midland	Shrub	Indigenous
37.	<i>Mangifera indica</i> L.	Mango	Anacardiaceae	lowland	Tree	Exotic
38.	<i>Maytenus arbutifolia</i> Hochst.ex.A.Rich	Atat	Celastraceae	lowland	Shrub	Indigenous
39.	<i>Olea europaea</i> subsp. <i>cuspidate</i>	Woyira	Oleaceae	midland	Tree	Indigenous
40.	<i>Persea americana</i> Mill	Avocado	Lauraceae	both	Tree	Exotic
41.	<i>Psidium guajava</i> L.	Zeituna	Myrtaceae	both	Tree	Exotic
42.	<i>Rhamnus prinooides</i> L'Hérit.	Gesho	Rhamnaceae	both	Shrub	Indigenous
43.	<i>Ricinus communis</i> L.	Gulo	Euphorbiaceae	both	Shrub	Indigenous
44.	<i>Rosa abyssinica</i> R.Br.	Kega	Rosaceae	midland	Tree	Indigenous
45.	<i>Schinus molle</i> L.	Qundo berbere	Anacardiaceae	both	Tree	Exotic
46.	<i>Sesbania sesban</i> (L.) Merr.	Sasibaniya	Fabaceae	lowland	Shrub	Indigenous
47.	<i>Vernonia amygdalina</i> Del.	Girawa	Asteraceae	midland	Shrub	Indigenous

Basal area

For the purpose of managing woody species, the distribution of their basal areas is crucial. The results of the calculation of the total basal area of woody species were 12.19 m^2 per hectare in midland and 11.19 m^2 per hectare in lowland. The study found that the total basal area of woody species in the midland agro-ecology was greater than that of the lowland agro-ecology. This is because midland agroecology's contains large tree species. The relatively low basal area values observed in this study are attributed to the scattered nature of parkland agroforestry systems, which are intentionally managed at low tree densities to minimize competition with crops. This structural characteristic has been widely reported for Ethiopian parkland systems and reflects management objectives rather than measurement error. Nevertheless, DBH measurements and unit conversions were rechecked to ensure accuracy.

Table 2. Mean \pm SD of Structures of woody species in the study area.

PARAMETERS	AGRO ECOLOGY	MEAN \pm STANDARD DEVIATION	P VALUE
DBH(cm)	Lowland	15.4 \pm 2.27	0.562
	Midland	15.87 \pm 2.89	
Height (m)	Lowland	9.31 \pm 1.91	0.078
	Midland	8.53 \pm 1.41	
Density (ha)	Lowland	55.73 \pm 7.64	0.027
	Midland	51.33 \pm 7.36	
Basal area (m^2)	Lowland	0.37 \pm 0.24	0.655
	Midland	40 0.31	

Density and frequency of woody species

In this study, 756 individual woody species were collected from 15 ha from the two agro-ecological zones of parkland agroforestry in Womberima district. The mean density per plot of woody species in the midland parkland agroforestry (12.83 ± 1.84) was significantly lower than lowland parkland agroforestry (13.93 ± 1.91) at ($P = 0.027$) (Table 2).

Table 3. Top five woody species with a high frequency of occurrence in the sample plot of the two agro-ecological zones.

AGRO ECOLOGY	SPECIES NAME	FREQUENCY (%)
Lowland	<i>Acacia sieberiana</i> Var.woodi.	60
	<i>Croton macrostachyus</i> Del.	53
	<i>Acacia nilotica</i> L.	53
	<i>Rhamnus prinoides</i> L`Hérit.	50
	<i>Acanthus polystachius</i> Delile	43
Midland	<i>Croton macrostachyus</i> Del.	67
	<i>Acacia abyssinica</i> Hochst. ex Benth.	53
	<i>Albizia gummifera</i> J.F.Gmel.	53
	<i>Cordia africana</i> Lam.	50
	<i>Justicia schimperiana</i> (Hochst. Ex Nees)	40

The current study revealed variations in density and frequency of woody species between agro-ecologies. This is due to the farmer's species preference, compatibility of the species to farmlands and opportunity to afford the farmer to maintain woody species on their farm. In this study, the frequency of woody species was recorded at both study sites. This finding has shown that woody species including *Acacia sieberiana* Var.wooddi. (60 %), *Croton macrostachyus* Del. (53 %), *Acacia nilotica*.L (53 %), *Rhamnus prinoides* L`Hérit.(50 %) and *Acanthus polystachius* Delile (43 %) were the dominantly observed woody species in the lowland parkland of the study area whereas *Croton macrostachyus* Del. (67 %), *Acacia abyssinica* Hochst. ex Benth. (53 %), *Albizia gummifera* J.F.Gmel. (53 %), *Cordia africana* Lam. (50 %) and *Justicia schimperiana* (Hochst. Ex Nees) (40 %) were the most frequent woody species found in midland agro ecology (Table 3). The current finding is in agreement with Motuma Tolera, Zebene Asfaw et al. (2008) who reported that *Croton macrostachyus* is the most frequent woody species encountered in the plot of crop field at Beseku, in Arsi Negele. A similar result also reported that *Cordia africana* Lam. is the most frequent tree species in sampled farms in Bahirdar Zuria District (Mulugeta and Admassu, 2014)

Eucalyptus citriodora Hook., *Psidium guajava* L., *Jacaranda mimosifolia* D. Don, *Ficus elastic* Roxb. ex. Hornem., and *Ricinus communis* L. were the less frequent woody species with all 7 % frequency of occurrence in lowland agroecology (Figure 2). This happened due to less preference for these species by farmers. In the midland parkland agro ecology, the less frequent woody species were *Eucalyptus citriodora* Hook., *Citrus sinensis* (L.) Osb. , *Jacaranda mimosifolia* D. Don, *Psidium guajava* L., and *Azadirachta indica* L. with all 3 % frequency of occurrence (Figure 2). This means out of 30 sample plots these species were recorded in only one plot. This indicated that these particular species are rare relative to the others species and may become non-available from farmlands of the study sites in the future. The reason behind this is due to the unwillingness of the local communities to retain or plant these woody species on farmland, instead, they cut trees for agricultural expansion.

An indicator of a species' ecological success in a given location, the importance value index (IVI) calculates the overall significance of woody species (Kent 2011). Prioritizing species for conservation can also be done using the IVI value; species with high IVI values require less conservation work, while species with low IVI values require more (Rana, Kapoor et al. 2020). *Ficus vasta* Forssk, *Croton macrostachyus* Del., *Acacia sieberiana* Var.woodi, *Acacia nilotica* L. and *Rhamnus prinoides* L`Hérit. were the top five important woody species in the lowland parkland agroforestry whereas *Ficus vasta* Forssk, *Croton macrostachyus* Del., *Acacia abyssinica* Hochst. ex Benth, *Cordia africana* Lam., and *Albizia gummifera* J.F. Gmel. were in the midland (Table 4).

Table 4. Top five woody species with the highest IVI in parkland agroforestry of the study area

AGROECOLOGY	SCIENTIFIC NAME	RF (%)	RD (%)	RDO (%)	IVI (%)
Lowland	<i>Ficus vasta</i> Forssk	0.96	0.51	25.73	27.2
	<i>Croton macrostachyus</i> Del.	7.66	9.52	9.47	26.65
	<i>Acacia sieberiana</i> Var.woodi	8.61	9.25	6.29	24.16
	<i>Acacia nilotica</i> L.	7.66	10.01	2.47	20.14
	<i>Rhamnus prinoides</i> L`Hérit.	7.18	9.25	0.48	16.92
Midland	<i>Croton macrostachyus</i> Del.	12.12	15.49	6.91	34.52
	<i>Acacia abyssinica</i> Hochst. ex Benth.	9.7	11.55	4.95	26.19
	<i>Cordia africana</i> Lam.	9.09	9.86	5.41	24.36
	<i>Ficus vasta</i> Forssk	0.61	0.28	22.58	23.47
	<i>Albizia gummifera</i> J.F. Gmel.	9.7	9.3	4.09	23.08

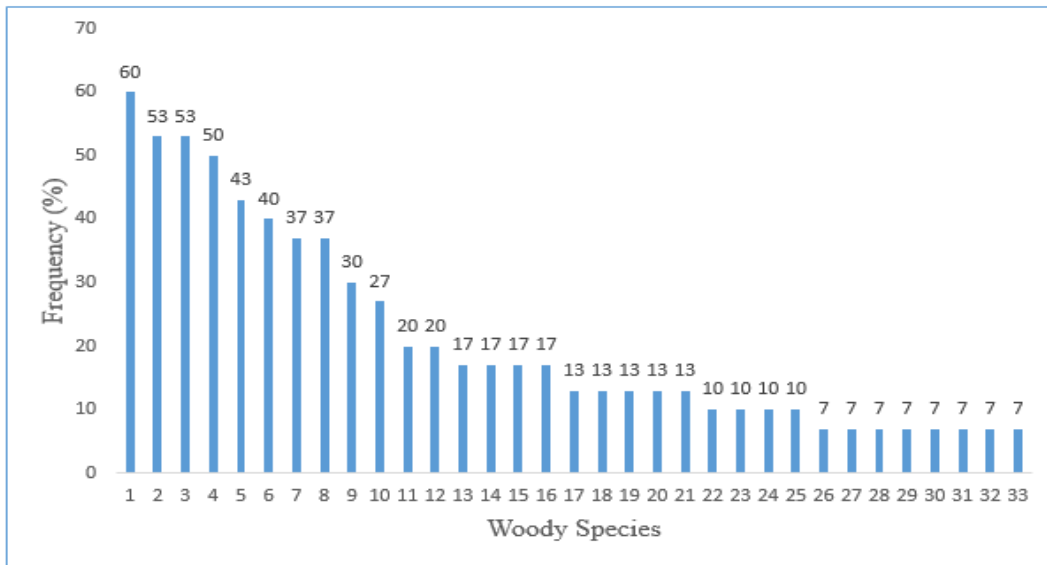


Figure 1. Frequency occurrence of woody species in the sample plots of lowland agroecology zone.

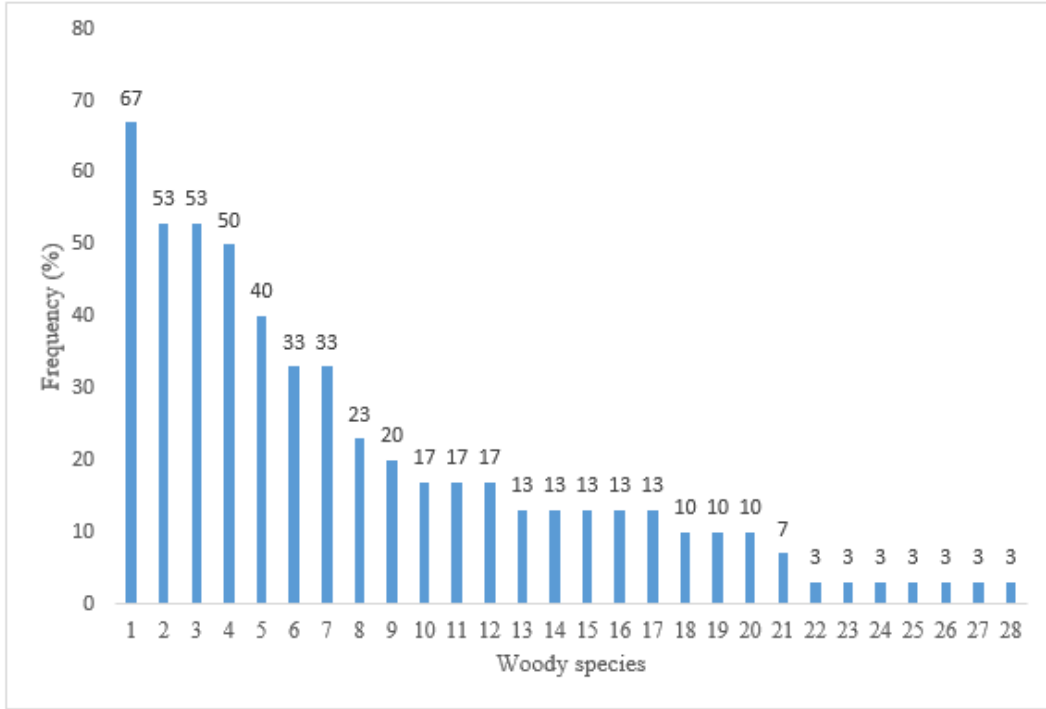


Figure 2. Frequency occurrence of woody species in the sample plots of midland agro ecology.

Farmer’s woody species preference

Nearly 95% of respondents kept a variety of woody species in their crop fields following the conversion of the original forest. The variety and quantity of species that farmers keep varies depending on their goals. The top five woody species that farmers preferred were ranked in order to scale their preferences. The most preferred species were *Acacia abyssinica*, *Croton macrostachyus*, *Acacia nilotica*, *Cordia africana*, and *Acacia sieberiana* var. *woodii* (Table 5). The preference ranking tool is commonly used in participatory rural appraisal (PRA) activities (Ronald, 2011) and helps capture local knowledge about species selection.

The relative score was calculated as follow:

$$\text{Relative Score } ij = \frac{n_{ij} * w_j}{N}$$

Where n_{ij} = number of respondent assigning species i to rank j

w_j =weight of rank ($1^{st}=5, \dots, 5^{th}=1$)

N = Total number of respondents

Then the total score for each species is the sum of relative scores across all ranks.

Farmers plant and preserve trees for a variety of reasons, and no one species can satisfy all of their requirements. Whether the trees are meant for fuel wood, fodder, lumber, or soil fertility enhancement influences the species selection. Farmers who prioritize improving soil fertility, for example, might not give priority to species that are needed for fuel wood or

fodder. Farmers frequently choose or preserve trees that serve several purposes at once, though (Schroth and Sinclair, 2003).

When choosing species for agroforestry systems, the "right species for the right place" principle emphasizes how crucial it is to take into account both farmer preferences and local ecological knowledge. To make sure that the selected species satisfy ecological and social objectives, it is essential to comprehend farmers' requirements and priorities in tree management (Derero, Coe et al. 2021).

Table 5. Woody species preference ranking of parkland agroforestry practice in Womberima district (N=129).

SPECIES NAME	RESPONDENTS					RELATIVE SCORE					TOTAL SCORE	RANK
	1 st	2 nd	3 rd	4 th	5 th	1 st	2 nd	3 rd	4 th	5 th		
<i>Acacia abyssinica</i> Hochst. ex Benth.	50	45	20	9	3	19.38	15.70	3.10	0.63	0.07	38.88	1
<i>Acacia nilotica</i> L.	22	14	45	18	31	3.75	1.52	15.7	2.51	7.45	30.93	3
<i>Acacia sieberiana</i> Var. woodi.	19	22	28	31	25	2.80	3.75	6.08	7.45	4.84	24.92	5
<i>Albizia gummifera</i> J.F.Gmel.	11	16	14	27	19	0.94	1.98	1.52	5.65	2.80	12.89	9
<i>Boswellia papyrifera</i> (Del.) Hochst.	4	4	0	0	6	0.12	0.12	0.00	0.00	0.28	0.53	17
<i>Coffea arabica</i> L.	12	22	18	14	23	1.12	3.75	2.51	1.52	4.10	13.00	8
<i>Combretum collinum</i> Fresen.	5	6	2	11	13	0.19	0.28	0.03	0.94	1.31	2.75	14
<i>Cordia africana</i> Lam.	30	33	37	14	7	6.98	8.44	10.6	1.52	0.38	27.93	4
<i>Croton macrostachyus</i> Del.	54	40	16	11	7	22.60	12.40	1.98	0.94	0.38	38.31	2
<i>Dodonaea viscosa</i> (L.) Jacq.	0	0	7	9	5	0.00	0.00	0.38	0.63	0.19	1.20	15
<i>Dovyalis abyssinica</i> (A. Rich.) Warb.	9	4	0	0	0	0.63	0.12	0.00	0.00	0.00	0.75	16
<i>Eucalyptus camaldulensis</i> Dehnh.	22	18	9	4	7	3.75	2.51	0.63	0.12	0.38	7.40	12
<i>Eucalyptus globulus</i> Labill.	25	12	16	14	19	4.84	1.12	1.98	1.52	2.80	12.26	10
<i>Grevillea robusta</i> R. Br.	0	3	7	0	0	0.00	0.07	0.38	0.00	0.00	0.45	19
<i>Mangifera indica</i> L.	17	12	19	10	15	2.24	1.12	2.80	0.78	1.74	8.67	11
<i>Olea europaea</i> subsp. cuspidate	11	7	0	14	8	0.94	0.38	0.00	1.52	0.50	3.33	13
<i>Rhamnus prinoides</i> L'Hérit.	21	17	11	19	22	3.42	2.24	0.94	2.80	3.75	13.15	7
<i>Rosa abyssinica</i> R.Br.	4	0	6	1	3	0.12	0.00	0.28	0.01	0.07	0.48	18
<i>Sesbania sesban</i> (L.) Merr.	16	18	25	24	21	1.98	2.51	4.84	4.47	3.42	17.22	6
Total	332	293	280	230	234							

Discussion

Woody species compositions

According to the current study, there was a significant difference ($p < 0.05$) between the two agro-ecological zones, with 355 and 401 individual species from midland and lowland agro-ecological parkland agroforestry, respectively. Studies in Ethiopia have shown that variation in rainfall, temperature, soil fertility, and land-use intensity across agro-ecological zones significantly affects woody species density and composition in farmlands (Kindu et al., 2016; Assefa et al., 2020). Lowland areas often support higher numbers of drought-tolerant and multipurpose woody species due to farmers' deliberate retention of trees that provide shade, fodder, and soil fertility improvement under harsher climatic conditions. In terms of habit classification, 70.21% were trees and 29.79 % were shrubs. The dominance of trees over shrubs in the present study is in line with the study by Abebe et al. (2019) and Tadesse et al. (2017) reported that trees constitute more than 60% of woody species in parkland agroforestry, mainly because farmers preferentially retain tree species that provide long-term benefits such as timber, fuelwood, fruits, and soil fertility enhancement. Shrubs are often selectively removed during cultivation to reduce competition with crops, which explains their relatively lower proportion in managed farmlands. From the total species, 65.96 % were indigenous and 34.04 % were exotic. The higher proportion of native species recorded in this study agrees with earlier reports from Ethiopian agroforestry systems, which highlight farmers' preference for native woody species due to their better adaptation to local environmental conditions and cultural importance (Azene Bekele, 2007; Tesfaye et al., 2015). Indigenous species are often favored for their roles in soil fertility maintenance, fodder provision, traditional medicine, and ecosystem resilience. However, the notable presence of exotic species also reflects increasing farmer awareness of fast-growing and economically valuable species such as *Eucalyptus* spp., which are widely, integrated into farmlands for income generation and construction purposes (Girma et al., 2021). In terms of family, Fabaceae was the dominant family from the total 28 families recorded in the present study comprised of six species. This result is in agreement with the study done by Muche et al. (2022) who reported that Fabaceae was the dominant family representing 18.9 % of the species in the North Eastern part of Ethiopia. This result agrees with also the study done by Aklilu Bajigo and Mikrewongel Tadesse (2015) who reported that Fabaceae was the one with a higher number of woody species in Gununo Watershed in Wolaita Zone, Ethiopia. The dominance of Fabaceae in the present study is well documented in agroforestry research across Ethiopia and other tropical regions. This is due to their nitrogen-fixing ability, which improves soil fertility and enhances crop productivity (Sileshi et al., 2014). Similar dominance of Fabaceae has been reported in parkland agroforestry systems in different parts of Ethiopia, including the Central Rift Valley (Tolera et al., 2008), northern Ethiopia (Gebru et al., 2019), and southwestern highlands (Asfaw & Agren, 2007). The ecological adaptability and multifunctional roles of Fabaceae species make them particularly suitable for integration into crop-based farming systems.

A comparison of the woody species richness in this study with others shows that it is generally higher. In total, 47 woody species were recorded from the two study sites. For example, Motuma Tolera (2006) reported 32 in Arsi Negelle, while Nikiema (2005) reported 41 in Burkina Faso. Similarly, 11 were reported in the Wolaita district's Gununo watershed

by Aklilu Bajigo and Mikrewongel Tadesse (2015). Agro-ecological variation, socioeconomic factors, cultural differences, and farmer management practices are the causes of these differences in farmlands. The relatively higher woody species richness recorded in this study compared to earlier reports may be attributed to differences in sampling intensity, agro-ecological heterogeneity, and farmer management practices. Studies have shown that areas with diversified livelihood strategies and strong traditional knowledge systems tend to maintain higher woody species diversity in parkland agroforestry systems (Mekonnen et al., 2018; Endale et al., 2020). Furthermore, farmers in ecologically diverse landscapes often conserve multiple species to reduce risk and ensure year-round access to ecosystem services, which contributes to increased species richness.

Structure of woody species

Basal Area: The midland (0.40 ± 0.31 m²/ha) had a slightly larger total basal area per hectare than the lowland (0.37 ± 0.24 m²/ha), but the difference was not statistically significant ($p = 0.655$). According to this finding, the midland area may have a few large, mature trees that contribute more significantly to the overall basal area, even though the lowland has a higher tree density. This finding is consistent with the finding that larger tree species are more prevalent in the midland agro-ecology (Teshome et al. in 2023).

The slightly higher basal area observed in the midland agro-ecological zone, despite the absence of a statistically significant difference, is consistent with findings from several agroforestry and parkland studies in Ethiopia and other parts of sub-Saharan Africa. Previous studies have shown that basal area is more strongly influenced by the presence of a few large-diameter trees rather than by overall tree density (Asfaw & Ågren, 2007; Kindu et al., 2016). In parkland agroforestry systems, farmers often selectively retain mature trees in midland areas due to more favorable moisture and soil conditions, allowing trees to attain larger diameters and contribute disproportionately to total basal area.

Similar patterns were reported by Tolera et al. (2008) in the Central Rift Valley of Ethiopia, where mid-altitude agro-ecological zones exhibited higher basal area values despite lower tree densities compared to lowland sites. Likewise, Mekonnen et al. (2018) observed that farmlands with fewer but larger trees had greater basal area than sites dominated by numerous small-sized individuals. These findings suggest that basal area reflects stand structure and management history more than simple stem counts.

Moreover, studies in northern and southwestern Ethiopia have demonstrated that agro-ecological zones with moderate climatic conditions tend to support slower-growing but longer-lived tree species, resulting in larger diameters and higher basal area accumulation over time (Gebru et al., 2019; Endale et al., 2020). In contrast, lowland agro-ecological zones are often characterized by higher tree density dominated by small- to medium-sized, fast-growing species, which contribute less to total basal area despite their numerical abundance.

The lack of a statistically significant difference in basal area between the two agro-ecological zones in the present study is also supported by Abebe et al. (2019), who reported comparable basal area values across different agro-ecologies due to similar farmer management practices, such as selective pruning, pollarding, and removal of large trees to reduce crop competition. Such practices can homogenize basal area values across landscapes even when species composition and density differ.

Diameter at Breast Height (DBH): The midland (15.87 ± 2.89 cm) had slightly higher tree DBH than the lowland (15.4 ± 2.27 cm), but the difference was not statistically significant (p

= 0.562). The two regions' tree growth in terms of diameter appears to be comparable, as indicated by the relatively similar DBH. This could be due to similar species composition or growing conditions (Bastin et al. 2021). The existence of older or more mature tree species in the midland may be the cause of the larger tree diameters.

Tree Height: Trees in the lowland were taller on average (9.31 ± 1.91 m) than those in the midland (8.53 ± 1.41 m), although this difference was not statistically significant ($p = 0.078$). Because of more favorable environmental conditions like soil fertility and moisture availability, tree species in the lowland agro-ecology may be better suited to grow taller (Kassie et al. 2022).

Tree Density: The lowland had a significantly higher tree density per hectare (55.73 ± 7.64 trees/ha) than the midland (51.33 ± 7.36 trees/ha), with a p-value of 0.027. This suggests a greater tree concentration in the lowland region, which could be brought about by a number of variables, such as species regeneration rates, land use practices, or environmental conditions that encourage denser planting (Abebe et al. in 2020). The results are consistent with studies by Mulugeta et al. (2022) and Fenta et al. (2021) found that differences in tree structure between highland and lowland agro-ecologies often reflect variations in tree species composition, environmental factors, and land management practices.

Different agro-ecologies had different woody species densities and frequencies, according to the current study. This is because the species is compatible with farmlands, the farmer prefers it, and the farmer can afford to keep woody species on their property. At both study locations, the frequency of woody species was noted. According to this discovery, woody species include. *Acacia sieberiana* Var. wooddi. (60 %), *Croton macrostachyus* Del. (53 %), *Acacia nilotica*.L (53 %), *Rhamnus prinoides* L'Hérit.(50 %) and *Acanthus polystachius* Delile (43 %) were the dominantly observed woody species in the lowland parkland of the study area whereas *Croton macrostachyus* Del. (67 %), *Acacia abyssinica* Hochst. ex Benth. (53 %), *Albizia gummifera* J.F.Gmel. (53 %), *Cordia africana* Lam. (50 %) and *Justicia schimperiana* (Hochst. Ex Nees) (40 %) were the most frequent woody species found in midland agro ecology (Figure 3). The current finding is in agreement with Motuma Tolera, Zebene Asfaw et al. (2008) who reported that *Croton macrostachyus* is the most frequent woody species encountered in the plot of crop field at Beseku, in Arsi Negele. A similar result also reported that *Cordia africana* Lam. is the most frequent tree species in sampled farms in Bahirdar Zuria District (Getachew Mulugeta and Mesfin Admassu, 2014).

Eucalyptus citriodora Hook., *Psidium guajava* L., *Jacaranda mimosifolia* D. Don, *Ficus elastic* Roxb. ex. Hornem., and *Ricinus communis* L. were the less frequent woody species with all 7 % frequency of occurrence in lowland agroecology (Figure 2). This occurred because farmers no longer preferred these species. In the midland parkland agro ecology, the less frequent woody species were *Eucalyptus citriodora* Hook., *Citrus sinensis* (L.) Osb. , *Jacaranda mimosifolia* D. Don, *Psidium guajava* L., and *Azadirachta indica* L. with all 3 % frequency of occurrence (Figure 3). This indicates that these species were found in just one plot out of the thirty sample plots. This suggested that these specific species are uncommon in comparison to the others and might eventually disappear from the study sites' farmlands. This is because local communities are unwilling to plant or preserve these woody species on farmland; instead, they cut down trees to make room for more agriculture.

Woody species' overall significance is determined by the importance value index (IVI), which also shows how well a species is doing ecologically in a given location (Kent 2012). Prioritizing species for conservation can also be done using the IVI value; species with a high

IVI value require less conservation work than species with a low IVI value (Neill, Dawson et al. 2001). *Ficus vasta* Forssk, *Croton macrostachyus* Del., *Acacia sieberiana* Var.woodi, *Acacia nilotica* L. and *Rhamnus prinoides* L'Hérit. were the top five important woody species in the lowland parkland agroforestry whereas *Ficus vasta* Forssk, *Croton macrostachyus* Del., *Acacia abyssinica* Hochst. ex Benth, *Cordia africana* Lam., and *Albizia gummifera* J.F. Gmel. were in the midland (Table 4). These species may be most important for their ecological and socioeconomic roles, which include improving soil fertility, providing shade, and increasing environmental adaptability, as well as for building construction, firewood production, and income. Accordingly, the more farmers like them and the more the species is cultivated, conserved, and dispersed, the more beneficial they are.

This finding is supported by Ewuketu Linger (2014) who reported that Multiple-use species have high IVI. The findings of a related study revealed that *Cordia africana* Lam, *Croton macrostachyus* Del., and *Albizia gummifera* J.F.Gmel. are among the top six important woody species found in Ethiopia's Tembaro district at the Waro site (Belayneh Lemage and Abayneh Legesse 2018). The current study supported by Getachew Mulugeta and Mesfin Admassu (2014) who reported that *Croton macrostachyus* Del. and *Cordia africana* Lam. were the most important woody species to the farmers in Bahirdar zuria district, Ethiopia.

The importance value index (IVI) in agroecology is a composite measure that reflects the ecological importance of plant species in a given area. It contains three components: relative frequency (RF), relative density (RD) and relative dominance (RDO), which provides a more holistic view of the plant's role in the ecosystem. The IVI allows us to assess the competitive strength, abundance and ecological role of species.

Ficus vasta has a notable IVI of 27.2 percent in the lowland agroecological zone, mainly due to its high Relative Dominance (25.73 percent). This implies that a significant amount of the ecosystem's resources, especially biomass, are occupied by *Ficus vasta*. Similarly, with IVIs of 26.65% and 24.16%, respectively, *Croton macrostachyus* and *Acacia sieberiana* exhibit significant ecological roles. These species are crucial for preserving the stability of ecosystems because they have a significant impact on both frequency and density (Abate et al. 2020). On the other hand, *Rhamnus prinoides* has a lower IVI of 16.92 percent, suggesting that it is less prevalent in the lowland region. Its low relative dominance indicates that it does not dominate in terms of total biomass production or resource use, despite its moderate frequency and density.

Croton macrostachyus is once again a prominent species in the midland agroecological zone, where it has the highest IVI (34.52 percent). Its greater RD and RDO values show how important it is to the composition and operation of the midland ecosystem. Notable IVIs are also displayed by the species *Acacia abyssinica* and *Cordia africana* (26.19 percent and 24.36 percent, respectively), indicating their ecological significance in midland systems where they add to the overall species diversity and structural complexity (Mulugeta et al. 2019). *Albizia gummifera* has a moderate IVI (23.08 percent) in the midland, suggesting that it plays a significant but marginally less dominant ecological role than other species. Between zones, there are minor differences in the species composition. This shift in species dominance between the lowland and midland regions could be due to changes in climatic conditions such as temperature, elevation, and soil moisture, all of which have an impact on plant growth patterns and distribution.

Croton Macrostachyus had a high IVI in this study, both on the midland area (34.52%) and the lowlands (26.65%). This species' durability and adaptability in arid environments are

frequently praised. According to research by Mengistu et al. (2017), *Croton Macrostachyus* is also emphasized as a dominant in agroforestry systems in northern Ethiopia, particularly due to its capacity to enhance soil fertility and withstand dryness. Their IVI levels, however, were somewhat lower (around 22.28 percent), suggesting that *Croton Macrostachyus* is important, while its relative dominance may be influenced by other local factors including soil type or management techniques.

The species composition shift between the midland and lowland zones is noted in this study. For instance, *Croton Macrostachyus* and *Acacia abyssinica* are more prevalent in the midlands (IVI of 34.52% and 26.19%, respectively), but *Ficus vasta* and *Rhamnus prinoides* are more prevalent in the lowlands (IVI of 27.2% and 16.92%, respectively). This finding is in line with Kassa et al. (2020) note that species like *Acacia abyssinica* flourish in midland regions with more moderate rainfall and colder temperatures, while species like *Ficus vasta* are more prevalent in lowland regions because of their water needs and temperature tolerance.

Farmer's woody species preference

With the highest overall score of 38.88, *Acacia abyssinica* was the most favored species, *Croton macrostachyus* came in second with 38.31, and *Acacia nilotica* came in third with 30.93 (Table 5). These preferences align with research demonstrating the benefits of *Acacia* species in agroforestry systems, which are recognized for improving soil fertility and fixing nitrogen, both of which increase crop yields (Tessema et al. 2023). According to a number of authors, farmers purposefully keep *Acacia* species in parkland systems because of their many uses, such as improving soil fertility through biological nitrogen fixation, providing fuelwood and fodder, and increasing crop productivity beneath tree canopies (Sileshi et al., 2014; Tolera et al., 2008). Due to its beneficial impacts on soil organic matter and crop yield performance, *Acacia abyssinica* has been identified as one of the most popular parkland species in central and northern Ethiopia (Kindu et al., 2016). Similarly, studies by Abebe et al. (2019) and Mekonnen et al. (2018) reported that *Acacia nilotica* is highly valued species in lowland and midland agro-ecologies due to its ability to respond to moisture stress and its contribution to enhancing the physical and chemical characteristics of soil, which promotes consistent crop production. These findings reinforce the high preference scores recorded for *Acacia* species in the present study. The high ranking of *Croton macrostachyus* in this study aligns with previous research identifying the species as one of the most commonly retained and preferred trees in Ethiopian agroforestry systems. According to Assefa et al. (2020) and Endale et al. (2020), farmers favor *Croton macrostachyus* for its fast growth, ease of management, and its ability to improve soil fertility through rapid litter decomposition. *Cordia africana*, a species that is important in agroforestry due to its ecological benefits and wood value, placed in fourth place in the study with a total score of 27.93, suggesting that farmers in many places are aware of it (Alemu et al. 2022).

Boswellia papyrifera and *Dovyalis abyssinica*, on the other hand, were ranked lowest, suggesting little preference or use. Slower development rates or decreased usefulness in the systems could be the reason of this (Fenta et al. 2021). Their relatively low ranking, which includes *Eucalyptus camaldulensis* (ranked 12th) and *Eucalyptus globulus* (ranked 10th), this could be water consumption and soil quality impacts of *Eucalyptus* species in agroforestry systems (Kahinda et al. 2020). The preference for *Coffea arabica* (ranked 8th)

further supports the increased interest in integrating cash crops within agroforestry systems, as supported by research demonstrating the significance of coffee trees in enhancing soil conditions and biodiversity (Bais et al. 2023).

Acacia abyssinica is commonly preferred for its many advantages, such as soil improvement and its use as fodder, which have been repeatedly mentioned in other studies like those by Tessema et al. (2023). Likewise, it has been noted that *Croton macrostachyus* and *Acacia nilotica* are preferred species in parkland systems because of their climate resilience and suitability for regional farming methods (Alemu et al. 2022).

Nevertheless, species that were placed lower in this study, such as *Eucalyptus camaldulensis* and *Grevillea robusta*, have also shown mixed preferences in earlier agroforestry studies, with some farmers expressing worries about their invasiveness or negative effects on soil health (Kahinda et al. 2020).

Farmers choose species with low crown density, few branches, fast growth, multipurpose usage, fruit species, and timber species because they are easy to decompose and yield a quick return on investment (Chakra borty et al., 2015). Tesfaye (2017) and Motuma (2006) claim that farmers kept a range of woody species on their properties for various uses. Aladi and John's (2014) analysis also revealed the similar tendency. However, according to Hasanuzaman et al. (2014), choosing the appropriate tree species depends on satisfying local market demands and attaining environmental sustainability.

Conclusions

This study examined the woody species structure of parkland agroforestry systems across different agro-ecological zones in Womberima District, identified farmers' preferred woody species, and assessed conservation priorities by integrating ecological attributes with farmers' preferences. The results showed that parkland agroforestry systems support considerable woody species diversity, with a total of 47 species recorded, dominated by the Fabaceae family. Structural variations observed between midland and lowland agro-ecological zones indicate that both environmental conditions and local farming practices shape species composition and distribution. The assessment of farmers' preferences revealed that multipurpose tree species such as *Acacia abyssinica*, *Croton macrostachyus*, *Cordia africana*, and *Acacia nilotica* are highly valued for their contributions to improved soil, fuelwood supply, fodder provision, and other livelihood benefits. On the other hand, farmers were less interested of species like *Eucalyptus* that were thought to be less beneficial or ecologically unfavorable. Integrating structural analysis with farmers' preference highlighted the need to prioritize certain species for conservation and management, particularly those that are ecologically important but relatively less abundant.

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