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Potential of Agroforestry Practices on Woody Species Diversity and Composition: Implication for Conservation of Indigenous Trees in Selected Districts of Tigray, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Author GE designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author YG managed the analyses of the study. Authors GE and YG managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Human activities such as expanding farmland, producing charcoal, and harvesting construction materials and fuel wood are major contributors to forest degradation and biodiversity loss in Northern Ethiopia. This study aimed to assess woody species' diversity, composition, and threat

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levels in different agroforestry practices to prioritize their conservation. As the result three potential Agroforestry practices were purposively identified and selected for the study. A total of 45 sample plots, 15 plots from each agroforestry practices such as Woodlot agroforestry (WLAF) (10m x 10m), Homegarden Agroforestry (HGAF) (20m x 10m), and Parkland agroforestry (PLAF) (50m x 100m). Data on woody species were analyzed using Past version 2.17c and SPSS version 20. The results identified 36, 26, and 21 woody plant species from 31, 23, and 19 genera, as well aswell as 22, 16, and 15 families in HGAF, PLAF, and WLAF, respectively. Significant differences ($p < 0.001$) were found among the agroforestry practices in terms of tree density, species richness, species abundance, and Shannon diversity, though species evenness did not vary. The Importance Value Index (IVI) highlighted the top species in HGAF as *A. etbaica* (75.2), *F. albida* (33.1), and *A. seyal* (30.6). Species with low IVI values, such as *B. polystachya* (1.56), *R. vulgaris* (1.57), *G. ferruginea* (1.62), and *C. aurantiifolia* (0.90), require significant conservation efforts. In PLAF, the key species were *F. albida* (131.03), *A. seyal* (59.33), and *C. africana* (26.21). In WLAF, *E. globulus* (61.8), *A. seyal* (8.83), and *C. edulis* (31.4) were the most abundant, frequent, and dominant. Trees and shrubs in HGAF and WLAF had smaller stem diameters compared to those in PLAF. However, WLAF had greater tree height and basal area (BA, m^2) than both HGAF and PLAF, with HGAF also showing a higher BA than PLAF ($p \leq 0.05$). The study concluded that HGAF and PLAF are vital for sustaining local livelihoods, providing food, and conserving biodiversity. These agroforestry systems enhance natural forests and help prevent the extinction of woody species. Therefore, developing and enhancing HGAF, and PLAF in densely populated landscapes should be integral to biodiversity conservation strategies.

Keywords: Biodiversity; native species; agroforestry; dryland.

1. INTRODUCTION

Deforestation which is mainly associated with human pressure has been a major problem for quite a long time with serious consequences for northern Ethiopia, in particular, [1]. Some drivers of deforestation and associated biodiversity loss include agricultural expansion, charcoal making, fuel-wood collection, illegal logging, fire, and the need for wood construction. These consequences include decline or loss of biodiversity, degradation of land and water bodies, possible negative effects on the local, regional, and global climatic conditions as well as negative impacts on the welfare of human beings [2,3]. Thus, small remnant forests, woodlands, or shrublands have become restricted to inaccessible areas such as hillsides, mountaintops, and around churches, monasteries, mosques, or graveyards, particularly in the northern parts of the country.

Tigray is one region that has fallen victim to the land degradation problem in the northern parts of the country. In Tigray, the severely degraded lands can be typically characterized by heavily eroded or nutrient-deficient soils, hydrological instability, reduced primary productivity, and loss of biological diversity [4,2,3]. The floral, faunal, and microbial diversity of these areas could be reduced, to the extent that they might be changed into wastelands. Past reforestation/afforestation programs in such areas have been unsuccessful due to either total failure or low survival rate of planted species [5]. Several major factors such as unavailability or low availability of propagules, low soil nutrient availability, absence of fungal/bacterial root symbionts or unsuitability of the microhabitats for plant establishment in general and seasonal drought may be attributed to such failures [6].

To circumvent these problems, Agroforestry practices, which integrate trees into agricultural systems, offer significant potential for climate change mitigation and biodiversity enhancement in arid environments [7]. Different agroforestry practices have different potentials to conserve woody species diversity and climate change mitigation depending on site characteristics, geographical location, and management practice. Agroforestry has been acknowledged as one of the most promising land use types for the conservation of biodiversity and climate change mitigation besides its several benefits through supporting people's livelihoods via offering energy, food and fiber [8,9].

Despite the emerging and promising socio-economic and ecological importance of agroforestry practices in Northern Ethiopia, very little or virtually no systematic and scientific studies have been made. Woody species are disappearing at an alarming rate; thus, agroforestry systems' role as a conservation tool and climate change mitigation needs to be further explored [8]. As a result, documented information on agroforestry practices is scanty or completely lacking. Therefore, this study aims to explore the extent of diversity, and composition, and identify threatened tree species for the conservation priority of woody species in the agroforestry practices and manner of population structure, as well as the regeneration status of woody species.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The research was carried out in three different areas in the eastern zone of the Tigray region, northern Ethiopia: Ganta-Afeshum (Simret), Hawzen (Freweyni), and Kilte-Awlaelo (Abreha Weatsbeha). These areas are situated between 13° 30′–14° 15′ N latitude and 39° 15′–39° 45′ E longitude Fig. 1. The characteristics of the three traditional agroforestry systems in the Tigray Region, Northern Ethiopia are outlined in the study Table 1.

2.2 Agroforestry Practices Selection and Layout

Three specific land uses - homegarden agroforestry (HGAF), parkland agroforestry (PLAF), and woodlot (WLAF) - with similar biophysical conditions (Soil type and climatic conditions) were intentionally chosen from each study site to prevent differences in species composition that could arise from variations in altitude. WLAF, HGAF, and PLAF are common agroforestry practices in these three districts.

WLAF: A woodlot is a small area of woodland, typically privately owned, that is managed to produce timber, fuelwood, or other forest products [10].

HGAF: integrating trees, shrubs, and crops within a small-scale farming system around people's homes. It is a traditional practice in many cultures worldwide, where edible and non-edible plants are grown together for subsistence or commercial purposes. Home gardens provide diverse products, improve nutritional security, enhance microclimate, and contribute to soil fertility and biodiversity conservation [11].

PLAF: refers to an agricultural system combining scattered trees or tree clusters with annual or perennial crops in open spaces. This approach is commonly observed in semi-arid regions where trees provide shade, shelter, and other benefits to the crops. The trees' deep root systems help access groundwater, prevent erosion, and enrich the soil. Parkland agroforestry can improve crop yields, diversify income sources, and increase resilience to climate variability [12].

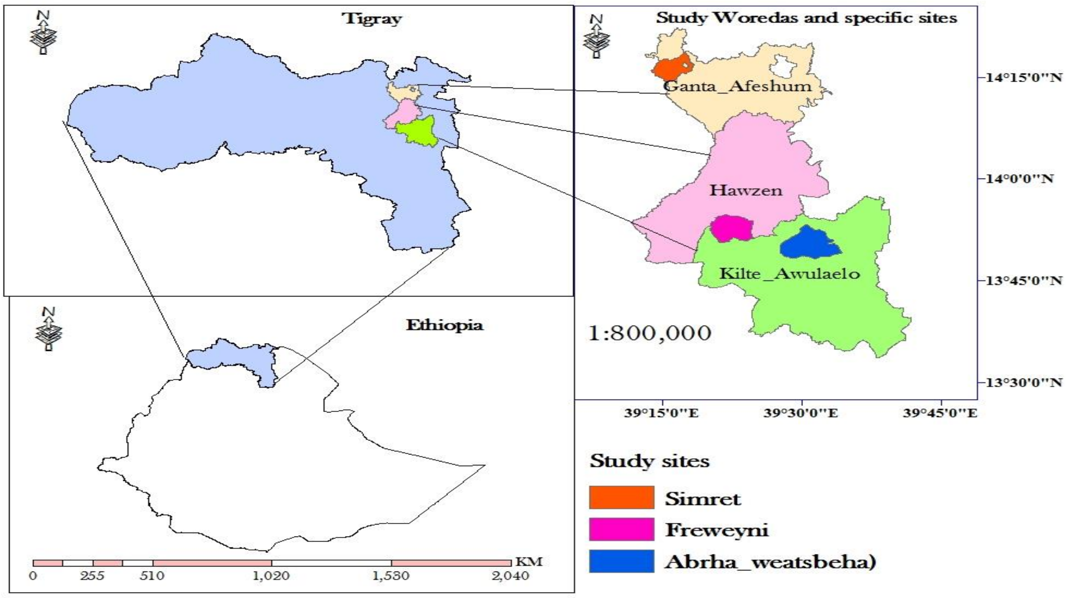

Fig. 1. Map of the study area

Table 1. Characteristics of the three indigenous agroforestry systems in the Tigray Region, Northern Ethiopia

Characteristics	Ganta-Afeshum	Hawzen	Kilte Awlaelo
Altitude (m a.s.l)	1840-3216	1800-2500	2000-2500
Mean annual rain falls (mm)	600-800	600-900	700
Average minimum and maximum To (oC)	10 to 25	10 to 25	12.6 to 31.1
Dominant soil type	Arensol and Regosol	Andosol	Rigosol and Cambisol
Textural Class	clay to clay loam	clay to clay loam	clay to loamy
Major trees	Juniperus procera; Olea europaea; Cordia africana and Acacia species	Acacia species, Euphorbia,Juniperus procera, Ficus species,Cordia africana,	Cordia africana, Acacia etbaica, Faidherbia albida, and Ziziphus spina-christi
Major food and cash crops	Teff, barley, wheat, Maize and pulses	Teff, barley, wheat, Maize and pulses	Teff, Barley, Wheat, Sorghum, Maize, Potato, Tomato, Onion, Cabbage

2.3 Sampling Design and Layout

Three sites were purposely chosen on each district based on the presence of HGAF, WLAF, and PLAF. A survey of tree species was conducted in sample plots of 10m x 10m for WLAF [13] 20m x 10m for HGAF [8] and 50m x 100m for PLAF [12]. The inventory of tree species was carried out in 15 plots for each agroforestry practice, totaling 45 sample plots.

2.4 Data Collection

To assess the diversity and dominance of woody species in different agroforestry practices, biometric parameters such as diameter at breast height (DBH) and height were measured on all the trees within each plot. For multi-stemmed woody species each stem was measured separately and the equivalent diameter of the plant was calculated as the square root of the sum of diameters of all stems per plant [14]. According to Negash & Kanninen [7] tree/shrub in the study area was defined as woody plants with DBH 2.5 cm and height 1.5m. Specifically, trees were defined as a woody perennial plant with a single main stem or in case of coppice several stems and has a more or less definite crown. While shrubs were woody perennial plants, often without a definite crown, several stems growing from the same root. The saplings and seedlings were counted within sub-plots in the main plot, from the corners, and in the middle [15,16].

2.5 Data Analysis

The diversity of species in different agroforestry (AF) practices was evaluated using measures such as species richness, the Shannon diversity index (H'), and the Shannon equitability or evenness index (E). All woody species taller than 20 cm were included in the diversity analysis [8]. The Shannon-Wiener index and evenness were employed to assess species diversity and the even distribution of species [17]. The Shannon index was calculated by multiplying the abundance of a species (pi) by the natural logarithm of this number.: $H' = -\sum_{i=1}^{s} \mathrm{Pi} \ln(\mathrm{Pi})$.

Where: H'= Shannon diversity indices
Pi =proportion of individuals found in the i^{th} species.

Evenness is calculated using the observed Shannon index (H') ratio to the maximum diversity (Hmax). The formula used to calculate evenness is as follows: $\text{Equitability (evenness)} J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{S} \mathrm{Pi} \ln pi}{\ln s}$

Where S = the number of species
H'=, Shannon diversity indices and
P_i = proportion of individuals found in the i^{th} species.

The important value index (IVI) for each species with a diameter at breast height (DBH) of at least 2.5 cm was calculated by summing its relative abundance, relative dominance, and relative frequency.

Dominance is the total basal area of a given species per unit area within the community; hence relative dominance is the dominance of one species as a percentage of total dominance calculated as follows: $\text{Relative dominance} = \frac{\text{total basal area for a species}}{\text{total basal area of all species}} * 100$

Where, the basal area of each woody species having DBH ≥2.5cm are calculated using the formula: $\text{Basal Area(BA)} = \left(\frac{\pi D^2}{4}\right)$

Where; D is a diameter in M

Woody species density is the number of individuals within a chosen area (*e.g.*, m^2/ hectare) so, relative density, the density of one species as a percentage of total density calculated as follows; $\text{Relative density} = \frac{\text{number of individuals of a species}}{\text{total number of individuals}} * 100$

Frequency is the percentage of total plots that contain at least one individual of a given species; relative frequency is the frequency of one species as a percentage of total frequency and is calculated as follows; $\text{Relative frequency} = \frac{\text{frequency of a species}}{\text{sum of all frequencies}} * 100$

Important value index combines data for three parameters (Relative frequency, Relative density, and Relative dominance). The importance value index (IVI) for each woody plant in the agroforestry practices was calculated as follows: Important Value Index (IVI) = Relative dominance + Relative density + Relative frequency.

2.6 Statistical Analysis

The independent variables in the study were HGAFs, PLAF, and WLAF, while the dependent variables included vegetation data. Differences between means were analyzed using a one-factor ANOVA at a significance level of $p \leq 0.05$. Diversity analysis was conducting using Past version 2.17c and Statistical analyses were conducted using SPSS version 20. The normality of the data distribution was assessed with the Shapiro-Wilk test.

3. RESULTS AND DISCUSSION

3.1 Woody Species Composition, Diversity, and Evenness

A combined total of 36, 26, and 21 woody plant species from 31, 23, and 19 different genera and 22, 16, and 15 families were identified in the HGAF, PLAF, and WLAF respectively, as presented in Table 2. The predominant plant families in all agroforestry practices belonged to the Fabaceae family, constituting 41% (9 out of 22) in HGAF, 56% (9 out of 16) in PLAF, and 40% (6 out of 15) in WLAF. In HGAF, each of the families comprised 9% of the total, namely Anacardiaceae, Euphorbiaceae, Lamiaceae, Myrtaceae, Oleaceae, and Rhamnaceae. Conversely, in PLAF, Celastraceae and Euphorbiaceae accounted for 12.5% of the total. Euphorbiaceae represented 13.3% in WLAF. Within HGAF, the percentages for tree, shrub, shrub/tree, climber/shrub, and herb/shrub species were 31, 39, 22, 3, and 5 respectively Table 4. Meanwhile, in PLAF, these percentages were 35, 42, 12, 4, and 7 for the corresponding species Table 5. For WLAF, the percentages were 29, 43, 10, 5, and 13 for the same species Table 6.

The percentage of Indigenous woody species in HGAF, PLAF, and WLAF was 78% (28 out of 36 species), 92% (24 out of 26 species), and 86% (18 out of 21 species) respectively, with the remaining species being non-native. The largest number of indigenous woody species was found in PLAF, followed by WLAF and HGAF.

The frequency of indigenous trees in plots varied, with *A. etbaica*, *F. albida*, and *A. seyal* being the three most common indigenous tree species in HGAFs (n=15) Table 4. These indigenous species are highly favored by farmers in the study areas for purposes such as fuelwood, fodder, soil fertility, bee forage, medicine, shade, timber/poles, ornamental use, and soil conservation. In PLAF, the three most frequently found indigenous tree species were *F. albida*, *A. seyal*, and *C. Africana* (n=15) Table 5, and these species are also highly preferred by farmers in the study areas for soil fertility, fodder, food/fruit, fuelwood, soil conservation, bee forage, shade, and timber/poles. Similarly, in WLAF, *E. globulus*, *A. seyal*, and *C. edulis* were among the frequently found indigenous species (n=15) Table 6, and these indigenous woody species were also planted or retained by farmers for purposes such as fuelwood, timber/poles, food/fruit, soil fertility, soil conservation, bee forage, and shade.

The analysis of variance revealed highly significant differences ($p < 0.001$) among various agroforestry practices regarding mean values for tree density, species richness, species abundance, and Shannon diversity, as indicated in Table 3. However, species evenness did not vary across the different agroforestry practices.

Specifically, woodlot agroforestry (WLAF) exhibited significantly lower species richness and Shannon diversity compared to both homegarden agroforestry (HGAF) and parkland agroforestry (PLAF). This trend may be attributed to farmers in the study area favoring specific species, such as Eucalyptus spp., for targeted purposes within woodlot agroforestry.

In contrast, tree density per hectare and species abundance were notably greater in WLAF than in HGAF and PLAF. This can be explained by the closer spacing of trees in woodlot agroforestry, which is primarily designed for producing fuelwood and construction materials. Conversely, in homegarden and parkland systems, trees are interplanted with crops and livestock feed, resulting in wider spacing compared to woodlot agroforestry.

3.2 Importance Value Index (IVI)

The IVI showed that *A. etbaica* (75.2), *F. albida* (33.1) and *A. seyal* (30.6) were the top three important species in HGAFs (Table 5). Whereas, *B. polystachya* (1.56), *R. vulgaris* (1.57), *G. ferruginea* (1.62) and *C. aurantiifolia* (0.90) and other with low IVI value need high conservation effort. While in PLAF, the most important three woody species were F. albida (131.03), *A. seyal* (59.33) and *C. africana* (26.21) respectively Table 5. In WLAF *E. globulus* (61.8), *A. seyal* (8.83) and *C. edulis* (31.4) were relatively recorded as abundant, frequent, and dominant species.

Woody species with a highly important value index (IVI) is considered more important than those with low IVI. This is likely due to their wider economic role [18] and the ecological requirement of the life strategy of the species [19]. IVI is also an important parameter that reveals the prioritizing of species for conservation [20-23]. Species with high IVI value need low priority for conservation effort whereas those with low IVI value need high conservation effort.

Therefore, the indigenous woody species in HGAFs, PLAF, and WLAF that had low IVI (<10) values need conservation priority.

3.3 Stand Characteristics DBH Distribution

The stand characteristics showed significant differences ($p < 0.05$) among various agroforestry practices, particularly in terms of height, diameter, and basal area, as detailed in Table **7**. Trees and shrubs in HGAF and WLAF exhibited significantly smaller stem diameters compared to those in PLAF. However, WLAF had notably greater tree height and basal area (BA, m^2) than both HGAF and PLAF, while HGAF also demonstrated a higher BA than PLAF ($p \leq 0.05$).

The reduced height of trees in HGAF and PLAF compared to WLAF may be attributed to the frequent management practices employed by farmers, including pruning and pollarding. Conversely, PLAF displayed significantly larger diameters at breast height (DBH), likely due to the natural retention of trees within that system.

The community structure of woody species in Homegarden Agroforestry (HGAF), Parkland Agroforestry (PLAF), and Woodlot Agroforestry (WLAF) was analyzed based on the densities of Diameter at Breast Height (DBH) (Fig. 2). The findings indicate that in both HGAF and WLAF, the number of individuals decreases as the DBH increases. This pattern in HGAF and WLAF is likely due to factors such as dense spacing, short harvest rotations, and pollarding practices.

Table 2. Woody species composition of the agroforestry practices in northern Ethiopia

Agroforestry Practice	Species	Genus	Family
HGAF	36	31	22
PLAF	26	23	16
WLAF	21	19	15

Table 3. Mean (SD) tree density, richness, abundance, woody species diversity index of shannon, and shannon evenness

Agroforestry practices	No obs.	Tree density ha-1	Diversity measurement			
			Species richness	Species abundance	Shannon diversity	Evenness
HGAF	15	735 (±117)[b]	5.53 (±0.54)[a]	29.40 (±4.69)[b]	1.30 (±0.09)[a]	0.73 (±0.04)
PLAF	15	49 (±6.71)[b]	5.13 (±0.74)[a]	24.67 (±3.36)[b]	1.12 (±0.14)[a]	0.70 (±0.03)
WLAF	15	6493 (±945)[a]	3.07 (±0.75)[b]	64.93 (±9.45)[a]	0.32 (±0.12)[b]	0.71 (±0.08)
P-value		***	***	***	***	0.92

Table 4. Woody species Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo) and Importance Value Index (IVI) in HGAF

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
1	Seraw	*Acacia etbaica* Schweinf.	Fabaceae	I	S	13.33	44.52	17.31	75.17
2	Momona	*Faidherbia albida* (Delile) A.Chev.	Fabaceae	I	T	6.67	4.47	21.95	33.09
3	Keyh/Tsaeda Chea	*Acacia seyal* Del.	Fabaceae	I	T	1.33	8.05	21.25	30.64
4	Keyh bahrzaf	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	E	T	6.67	8.5	6.03	21.19
5	Beles	*Opuntia ficus-indica* (L.) Miller.	Cactaceae	E	S	4	7.16	0	11.16
6	Awuhi	*Cordia africana* Lam.	Boraginaceae	I	T	4	0.67	4.55	9.22
7	Awulie	*Olea europaea* subsp. Cuspidata	Oleaceae	I	T	4	1.12	2.4	7.51
8	Ere	*Aloe vera* (L.) Burm.f.	Aloaceae	I	SH	2.67	3.8	0.89	7.36
9	Kincheb	*Euphorbia tirucalli* L.	Euphorbiaceae	I	ST	1.33	0.22	5.74	7.29
10	Kolkal	*Euphorbia candelabrum* Kotschy	Euphorbiaceae	I	T	2.67	1.34	3.22	7.23
11	Shibaka	*Ficus thonningii* Blume	Moraceae	I	ST	1.33	0.45	5.32	7.11
12	Tahases	*Dodonaoea angustifolia* L.f.	Sapindaceae	I	S	4	1.12	1.12	6.24
13	Hambo hambo	*Senna singueana* (Del.) Lock	Fabaceae	I	ST	4	1.79	0	5.79
14	Abatere	*Jasminum abyssinicum* Hochets. Ex DC.	Oleaceae	I	CS	2.67	0.45	2.31	5.43
15	Lihay	*Acacia lahai* Steud. & Hochst. ex Benth.	Fabaceae	I	ST	1.33	0.22	3.64	5.19
16	Tebeb	*Becium grandiforum* (Benth.) Pichiserm	Lamiaceae	I	SH	2.67	2.46	0	5.13
17	Nim	*Azadirachta indica* A. Juss.	Meliaceae	E	T	2.67	0.89	1.23	4.8
18	Gesho	*Rhamnus prinoides* L'Herit.	Rhamnaceae	I	S	2.67	2.01	0	4.68
19	Kebkeb	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	I	S	2.67	0.89	0.95	4.51
20	Gravella	*Grevillea robusta* R. Br.	Proteaceae	E	T	2.67	1.34	0.45	4.46
21	Gaba	*Ziziphus spina-christi* L.	Rhamnaceae	I	T	2.67	1.34	0	4.01
22	Gonek	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	I	ST	2.67	1.12	0.17	3.96

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
23	Egam	*Carissa edulis* (Forssk.) Vahl	Apocynaceae	I	S	2.67	1.12	0.17	3.96
24	Lusuniya	*Luceana leucocerphala* Lam.	Fabaceae	E	S	2.67	0.89	0.17	3.73
25	E'ka	*Agave sisalana* Perro ex Eng.	Agavaceae	I	S	1.33	0.67	0	2
26	Siwa kerni	*Leucas abyssinica* (Benth.) Briq.	Lamiaceae	I	S	1.33	0.67	0	2
27	Zeytuhun	*Psidium guajava* L.	Myrtaceae	E	TS	1.33	0.45	0.14	1.92
28	Kuliaw	*Euclea racemosa* Murr.	Ebenaceae	I	S	1.33	0.22	0.3	1.86
29	Mango	*Mangifera indica* L.	Anacardiaceae	E	S	1.33	0.22	0.24	1.79
30	Buna	*Coffea arabica* L.	Rubiaceae	I	S	1.33	0.45	0	1.78
31	Tseliem chea	*Acacia tortilis* (Frossk.) Hayne	Fabaceae	I	T	1.33	0.22	0.16	1.72
32	Akacha	*Acacia saligna* (Labill.) Wendl.	Fabaceae	E	T	1.33	0.22	0.1	1.66
33	bokri lomin	*Citrus aurantiifolia* (Christm.) Swingle	Rutaceae	I	S	1.33	0.22	0.1	1.66
34	Tsinkuya	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae	I	TS	1.33	0.22	0.07	1.62
35	Atami	*Rhus vulgaris* Meikle	Anacardiaceae	I	S	1.33	0.22	0.01	1.57
36	Metere	*Buddleja polystachya* Fresen.	Loganiaceae	I	ST	1.33	0.22	0	1.56

Table 5. Woody species Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo), and Importance Value Index (IVI) in PLAF

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
1	Momena	Faidherbia albida (Delile) A.Chev.	Fabaceae	I	T	1.61	65.99	63.43	131.03
2	Keyih/Tsaeda Chea	Acacia seyal Del.	Fabaceae	I	T	17.74	29.44	12.15	59.33
3	Awuhi	Cordia africana Lam.	Boraginaceae	I	T	11.29	6.09	8.83	26.21
4	Hohot	Rumex nervosus Vahl	Polygonaceae	I	S	6.45	16.75	0.00	23.20
5	Hambohabo	Senna singueana (Del.) Lock	Fabaceae	I	ST	8.06	14.72	0.00	22.79
6	Tselem chea	Acacia tortilis (Frossk.) Hayne	Fabaceae	I	T	6.45	4.06	5.48	15.99
7	Kinchib	*Euphorbia tirucalli* L.	Euphorbiaceae	I	ST	1.61	7.11	5.87	14.59
8	Kebkeb	Maytenus senegalensis (Lam.) Exell	Celastraceae	I	S	6.45	6.60	0.37	13.42
9	Seraw	Acacia etbaica Schweinf.	Fabaceae	I	S	4.84	2.03	0.87	7.74
10	Ere	*Aloe vera* (L.) Burm.f.	Aloaceae	I	SH	3.23	3.55	0.00	6.78
11	Gaba	*Ziziphus spina-christi* L.	Rhamnaceae	I	T	4.84	1.52	0.34	6.70
12	Alendia	Ormocarpum pubescens (Hochst.) Cuf. ex Gillet	Fabaceae	I	S	1.61	5.08	0.00	6.69
13	Gonek	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	I	ST	3.23	3.05	0.03	6.30

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
14	Kuliaw	Euclea racemosa Murr.	Ebenaceae	E	S	1.61	3.05	0.40	5.06
15	Beles	Opuntia ficus-indica (L.) Miller.	Cactaceae	E	S	3.23	1.02	0.00	4.24
16	Akacha	Acacia saligna (Labill.) Wendl.	Fabaceae	I	T	1.61	2.03	0.44	4.08
17	Atat	Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae	I	S	1.61	2.03	0.00	3.64
18	Keyh bahrzaf	Eucalyptus camaldulensis Dehnh.	Myrtaceae	I	T	1.61	1.02	0.88	3.51
19	Tambuk	Croton macrostachyus Del.	Euphorbiaceae	I	T	1.61	0.51	0.90	3.02
20	A'nka	Commiphora habessinica (Berg) Engl.	Burseraceae	I	S	1.61	1.02	0.00	2.63
21	Dander	Carduus nyassanus (S. Moore) R.E. Fries	Asteraceae	I	H	1.61	1.02	0.00	2.63
22	Shewit hagay	Parkinsonia aculeata L.	Fabaceae	I	S	1.61	0.51	0.02	2.14
23	Daero	Ficus vasta Forssk	Moraceae	I	T	1.61	0.51	0.00	2.12
24	A'ndel	Capparis tomentosa Lam.	Capparidaceae	I	CS	1.61	0.51	0.00	2.12
25	Egam	Carissa edulis (Forssk.) Vahl	Apocynaceae	I	S	1.61	0.51	0.00	2.12
26	Gindae	Calotropis procera (Ait.) Ait. f.	Asclepiadaceae	I	S	1.61	0.51	0.00	2.12

Table 6. Woody species Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo), and importance value index (IVI) in WLAF

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
1	Bahrzaf	*Eucalyptus globulus* Labill.	Myrtaceae	E	T	34.09	91.56	97.68	223.33
2	Keyh/Tsaeda chea	*Acacia seyal* Del.	Fabaceae	I	T	6.82	0.93	1.09	8.83
3	Egam	*Carissa edulis* (Forssk.) Vahl	Apocynaceae	I	S	6.82	1.03	0.00	7.85
4	Tahases	*Dodonaoea angustifolia* L.f.	Sapindaceae	I	S	4.55	0.51	0.10	5.16
5	Habi tseliem	*Jasminum floribundum*	Oleaceae	I	CS	4.55	0.41	0.00	4.96
6	Jatrofa	*Jatropha curcas* L.	Euphorbiaceae	E	S	4.55	0.41	0.00	4.96
7	Kebkeb	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	I	S	4.55	0.31	0.00	4.85
8	Seraw	*Acacia etbaica* Schweinf.	Fabaceae	I	S	4.55	0.31	0.00	4.85
9	Momona	*Faidherbia albida* (Delile) A.Chev.	Fabaceae	I	T	2.27	0.10	1.13	3.50
10	Tebeb	*Becium grandiforum* (Benth.) Pichiserm	Lamiaceae	I	SH	2.27	1.13	0.00	3.41
11	Hambo hambo	*Senna singueana* (Del.) Lock	Fabaceae	I	ST	2.27	1.03	0.00	3.30
12	Kuliaw	*Euclea racemosa* Murr.	Ebenaceae	I	S	2.27	0.82	0.00	3.10
13	Ere	*Aloe vera* (L.) Burm.f.	Aloaceae	I	SH	2.27	0.41	0.00	2.68
14	Dander	*Carduus nyassanus* (S. Moore) R.E. Fries	Asteraceae	I	SH	2.27	0.21	0.00	2.48
15	Hitsawuts	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	I	S	2.27	0.21	0.00	2.48

No.	Vencular name	Scientific name	Family	To Ethiopia	Life Form	RF	RD	Rdo	IVI
16	Chea	*Acacia abyssinica* Hochst.	Fabaceae	I	T	2.27	0.10	0.00	2.38
17	Gesho	*Rhamnus prinoides* L'Herit.	Rhamnaceae	I	S	2.27	0.10	0.00	2.38
18	Gulie	*Ricinus communis* L.	Euphorbiaceae	I	S	2.27	0.10	0.00	2.38
19	Tselim Berbere	*Schinus molle* L.	Anacardiaceae	E	T	2.27	0.10	0.00	2.38
20	Tsihdi	*Juniperus procera* Hochst. Ex Endl.	Cupressaceae	I	T	2.27	0.10	0.00	2.38
21	Tsinkuya	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae	I	TS	2.27	0.10	0.00	2.38

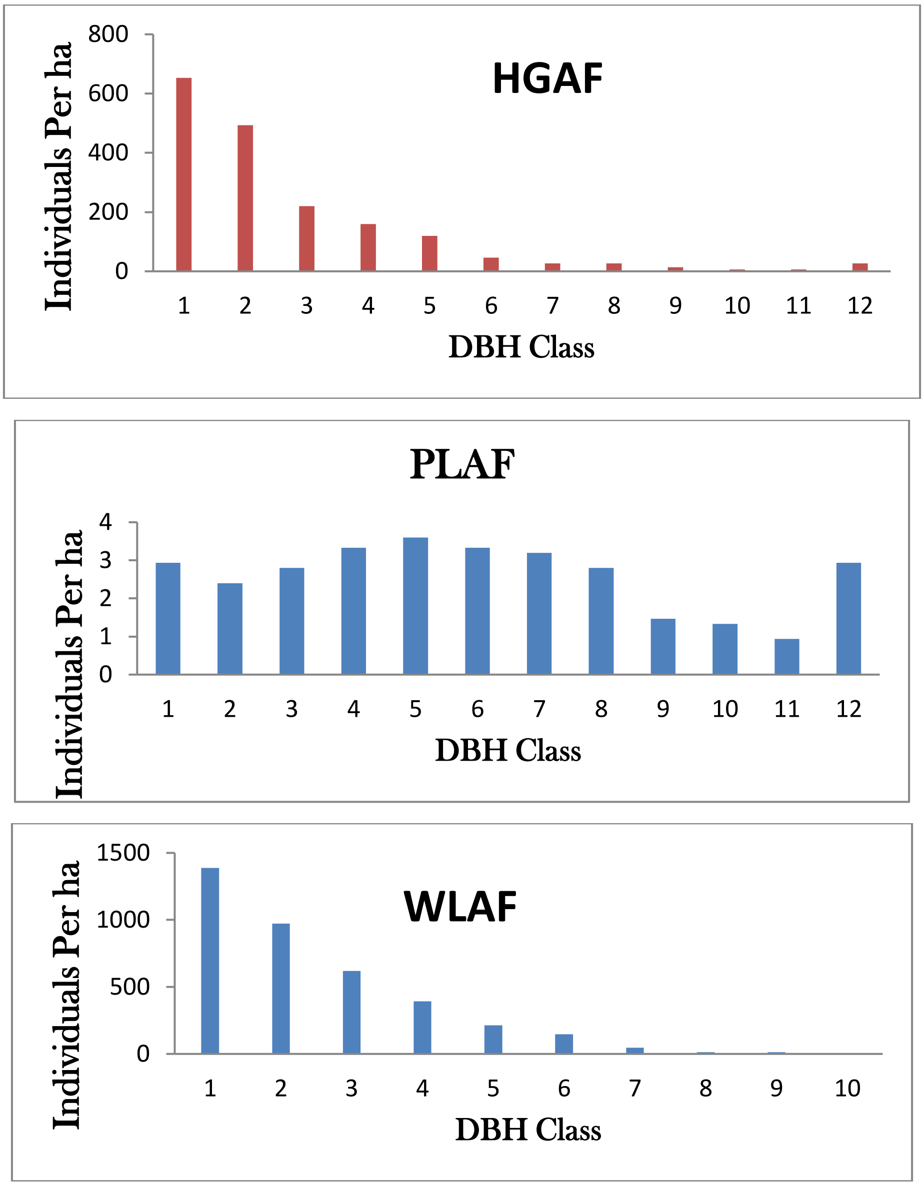

Fig. 2. Diameter class (cm) distribution of woody species per hectare encountered in agroforestry

practices1=2.50 - 7.49, 2=7.50 - 12.49, 3=12.50 - 17.49, 4=17.50 - 22.49, 5=22.50 - 27.49, 6=27.50 - 32.49, 7=32.50 - 37.49, 8=37.50 - 42.49, 9=42.50 - 47.49, 10=47.50 - 52.49, 11=52.50 - 57.49, 12=57.50+

Table 7. Stand structure of agroforestry practices in Eastern Tigray, Ethiopia

Agroforestry practices	Mean (SD) Stand characteristics		
	Height (m)	DBH (cm)$_{Av.}$	BA (m2)/ha
HGAF	6.31 (4.9)^{b}	14.8 (7.19)^{b}	31.29 (23.4)^{b}
PLAF	7.76 (4.2)^{b}	32.33 (8.72)^{a}	3.47 (2.32)^{c}
WLAF	12.75 (5.98)^{a}	12.73 (3.33)^{b}	77.41 (62.72)^{a}
P value	<0.001	<0.001	<0.001

In contrast, the DBH distribution in PLAF does not follow the same trend. This difference is attributed to the retention of large trees in farmers' fields for extended periods, which helps maintain soil fertility and provide shade. The overall stand characteristics of HGAF, PLAF, and WLAF offer insights into the regeneration status of these systems.

The DBH class distribution across all size classes shows an inverted J-shaped curve, particularly in HGAF and WLAF. This pattern suggests that most species have a higher number of individuals in the lower DBH classes, with a gradual decrease in numbers as DBH increases. This indicates a healthy recruitment process and dynamic population structure of woody species in the study area [8,24,12,25]. However, in PLAF, there is a declining trend in new regeneration, highlighting the need for attention to promote regeneration.

4. CONCLUSION AND RECOMMENDATION

The study concluded that species richness and diversity were significantly higher in Homegarden Agroforestry (HGAF) and Parkland Agroforestry (PLAF) compared to Woodlot Agroforestry (WLAF). However, WLAF exhibited greater abundance and tree density. HGAF and PLAF are crucial for preserving economically and ecologically valuable tree species such as *F. albida, C. africana, O. europaea, R. prinoides, Z. spina-christi, C. arabica,* and *C. macrostachyus*, which are now rare or scarcely found in the natural forests of the study area. Homegardens and PLAF, where farmers are motivated to maintain valuable tree species, serve as vital land uses for conserving many species due to active management by the farmers. However, species with low economic value to farmers are at risk of extinction.

The study recommends that Indigenous species with a low Importance Value Index (IVI) should be prioritized for conservation through community-based tree management practices. It is also important to conduct more detailed research involving a larger number of agroforestry practices across different soil and agro-climatic conditions to better understand the conservation status of native species.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Esser K, Vagen T, Haile M. Soil conservation in Tigray, Ethiopia; 2002. Available:http://www.nlh.no/noragric
2. Nyssen J, Poesen J, Deckers J. Land degradation and soil and water conservation in tropical highlands. Soil and Tillage Research. 2009;103(2):197–202. Available:https://doi.org/10.1016/j.still.2008.08.002
3. Temesgen G, Amare B, Hagos G. Land degradation in Ethiopia : Causes, impacts and rehabilitation techniques. Journal of Environment and Earth Science. 2014;4(9).
4. Gashaw T. Land degradation in Ethiopia : Causes, impacts and rehabilitation techniques land degradation in Ethiopia : Causes, Impacts and Rehabilitation Techniques. January; 2018.
5. Mehari A. Growth and suitability of some tree species selected for planting in adverse environments in Eritrea and Ethiopia Amanuel Mehari; 2005.
6. Yirdaw E, Tigabu M, Monge A. Rehabilitation of degraded dryland ecosystems – Review. In Silva Fennica. 2017;51(1). Available:https://doi.org/10.14214/sf.1673
7. Negash M, Kanninen M. The indigenous agroforestry systems of the south-eastern Rift Valley escarpment, Ethiopia: Their biodiversity, carbon stocks, and litterfall. Tropical Forestry Reports, 44(February). 2013;75. Available: https://doi.org/10.1007/s11104-015-2469-6
8. Eyasu G, Tolera M, Negash M. Woody species composition , structure , and diversity of homegarden agroforestry systems in southern Tigray , Northern Ethiopia. Heliyon, 6(September 2019). 2020;e05500. Available:https://doi.org/10.1016/j.heliyon.2020.e05500
9. Kumar BM, Nair PKR. The enigma of tropical homegardens. Agroforestry Systems, 61(Torquebiau 1992). 2004;135–152.
10. Nair PKR, Kumar BM, Nair VD, Nair PKR, Kumar BM, Nair VD. Agroforestry for

biodiversity conservation. An introduction to agroforestry: Four decades of scientific developments. 2021;539–562.

11. Nair PKR. An introduction to agroforestry. Springer Science & Business Media; 1993.
12. Gebrewahid Y, Gebre-Egziabhier TB, Teka K, Birhane E. Carbon stock potential of scattered trees on farmland along an altitudinal gradient in Tigray, Northern Ethiopia. Ecological Processes. 2018;7:1–8.
13. Wari BN, Feyssa DH, Kebebew Z. Assessment of woody species in agroforestry systems around Jimma Town, Southwestern Ethiopia. International Journal of Biodiversity and Conservation. 2019;11(1):18–30.
14. Snowdon P, Raison J, Keith H, Ritson P, Grierson P, Adams MA, Montagu K, Bi H, Burrows W, Eamus D. National carbon accounting system-protocol for sampling tree and stand biomass; 2002.
15. Linger E. Agro-ecosystem and socio-economic role of homegarden agroforestry in Jabithenan District, North-Western Ethiopia: implication for climate change adaptation. SpringerPlus. 2014;3 (1): 154.
Available:https://doi.org/10.1186/2193-1801-3-154
16. Mekonnen EL, Asfaw Z, Zewudie S. Plant species diversity of homegarden agroforestry in. International Journal of Biodiversity and Conservation. 2014;6(4):301–307.
Available:https://doi.org/10.5897/IJBC2014.0677
17. Kent M, Coker P. Vegetation description and analysis: A practical approach. Belhaven Press, London. 1992;263.
18. Talemos S, Sebsebe D, Zemede A. Home gardens of Wolayta , Southern Ethiopia : An ethnobotanical profile. Academia Journal of Medicinal Plants. 2013;1(1):14–30.
Available:https://doi.org/http://dx.doi.org/10.15413/ajmp.2012.0108
19. Neelo J, Teketay D, Kashe K, Masamba W. Stand structure , diversity and regeneration status of woody species in open and exclosed dry woodland sites around molapo farming areas of the Okavango Delta , Northeastern Botswana. Open J. For. 2015;5(4):313–328.
20. Berhanu A, Demissew S, Woldu Z, Didita M. Woody species composition and structure of Kuandisha afromontane forest fragment in northwestern Ethiopia. Journal of Forestry Research. 2017;28(2):343–355.
Available:https://doi.org/10.1007/s11676-016-0329-8
21. Regassa R, Bekele T, Megersa M. Ethnobotonical study of traditional medicinal plants used to treat human ailments by halaba people , southern Ethiopia. Journal of Medicinal Plants Studies 2017;5(4):36–47.
22. Sambaré O, Bognounou F, Wittig R, Thiombiano A. Woody species composition , diversity and structure of riparian forests of four watercourses types in Burkina Faso. 2011;22.
Available:https://doi.org/10.1007/s11676-011-0143-2
23. Zegeye H, Teketay D, Kelbessa E. Diversity and regeneration status of woody species in Tara Gedam and Abebaye forests, northwestern Ethiopia. In Journal of Forestry Research. 2011;22(3).
Available:https://doi.org/10.1007/s11676-011-0176-6
24. Forest A. The woody species composition and structure of Masha; 2003.
25. Gebrewahid Y, Abrehe S, Gebreab G. Woody species diversity under the different age of area closure and slope aspects of boswellia dominated woodland of Kafta Humera, Northern. 2019;2(1):1–13.

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