STATUS OF NATIVE TREE DIVERSITY IN RELATION TO LAND-USE IN THE MERHABETE DISTRICT, ETHIOPIA

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ABSTRACT

Most studies undertaken on native fodder and fruit species have focused on planting preferences and socioeconomic importance. The focus has been less on diversity aspects. This study aimed to make a comparative investigation on the status of native fodder and fruit tree /shrub diversity and their management in three land types in Merhabete district, North Shewa Zone, Ethiopia. A total of 127 households were randomly selected for interviews on management practices and threats to the targeted species. Furthermore, 90 sampling plots representing three land use types were used for vegetation data collection. Altogether, a total of 34 tree /shrub species were recorded from three land use types in the study area. Out of the 34 tree/shrub species identified, 31 (91.2 %) species were native fodder and fruit tree/shrub species, and the remaining 3 (8.8 %) were exotic tree/shrub species. The mean tree/shrubdiversity, species richness, and species density were significantly higher in the remnant natural forest than in homegarden and parkland ($p \leq 0.05$). Likewise, the highest tree basal area was recorded in remnant natural forest, followed by homegarden and parklands. The common management practices for native fodder and fruit species were pollarding, thinning, pruning, lopping, and fencing. Based on the findings, it is concluded that species diversities and stem numbers were lower in parkland than in other land-use types. Therefore, it is recommended that planting native fodder and fruit tree/shrub species on parkland is essential to enhance the conservation and domestication process of the targeted species.

Keywords; Conservation**,** Land use types, Merhabete district, Native species, Species diversity

INTRODUCTION

Ethiopia is one of the 25 countries with the highest biodiversity in the world and is home to two biodiversity hotspots in the world, namely, the Eastern Afromontan and the Horn of Africa hotspots (Liu *et al*., 2016; Girma & Worku, 2020). It is also one of the countries in the Horn of Africa, considered the most important center of diversity and endemism for several plant species. The country is a center of origin for native cultivated plants such as *Ensete ventricosum* Welw. *Cheesman*, *Coccinia abyssinica* (Lam.) *Cogn*. and *Coffea arabica* L. (EBI, 2014). This species diversity is due to diverse climatic with topographic, and edaphic conditions, and diverse ecosystems (Mucheye & Yemata, 2020; Legesse & Negash, 2021).

Native plant species are adapted to the local environment and are ecologically more valuable than exotic species for the conservation of biodiversity, water, and land (Mucheye & Yemata, 2020; Gemechu *et al*., 2021). In addition, these species are less susceptible to serious damage from disease or pests and they are an integral part of the ecological niche (Gemechu *et al*., 2021). Despite all these facts, due to the conversion or degradation of natural forests, native flora diversity is declining, and its persistence in human-modified ecosystems is threatened by anthropogenic and environmental factors (Newbold *et al*., 2015). Consequently, *Cordia africana* Lam. and *Afrocarpus falcatus* (Thunb.) C.N. Page are considered locally threatened native species of Ethiopia (Negash *et al*., 2012).

There are different land use types that help to conserve native species in different parts of Ethiopia. Cultivated land, trees on grazing land, agroforestry, and natural forest have the potential to conserve native species (Endale *et al*., 2017; Gebre *et al*., 2019; Eyasu *et al*., 2020; Legesse & Negash, 2021). Agroforestry can serve as in-situ conservation for native species and wild species diversity (Negash *et al*., 2012). For instance, Eyasu *et al*. (2020) who reported 21 native woody species from two land-use types in Raya Alamata, Northern Ethiopia. Retaining native species in agricultural landscapes improves biodiversity conservation at the species, genetic and landscape levels (Negash *et al*., 2012). Moreover, agroforestry can also play an important role in the conservation of biodiversity through the provision of corridors for species between land use types and homes for pollinators to enhance the persistence and conservation of the native flora (Negash *et al.*, 2012; Molla & Kewessa, 2015).

Farmers know the habitat of native tree species, their uses, management, seasonal yields, and compatibility with other species, mainly in traditional agro-forestry practices (Legesse & Negash, 2021). For instance, in the Somali region, livestock raisers use the branches of *Acacia tortilis* (Forssk.) Hayne, and *Ziziphus spina-christi* (L.) *Willd*. for fencing, and feeding their livestock, cutting branches rather than cutting the whole tree, because they know the ability of these species to grow back (Derero & Kitaw, 2018). Likewise, farmers in the Gedeo zone practice a cut-and-carry system of fodder production to prevent damage to naturally regenerated seedlings of important native species (Negash, 2007). However, information on local use and management of landscape diversity must be studied and documented. This helps to identify endangered species and develop a conservation plan and sustainable utilization guidelines (Tefera *et al*., 2015).

In Ethiopia, studies on native fodder and fruit species have been focused on the productive role and service function (Lelamo, 2021); nutritive value (Derero & Kitaw, 2018); planting preferences (Mekoya *et al*., 2008); ecological and socioeconomic importance of native fodder species (Geta *et al.*, 2014). Less emphasis has been given to the composition, diversity, structure of the ecosystems in which they thrive, and the management of native fodder and fruit species.

Farmers in the Merhabete district have been practicing different traditional agroforestry practices for many years. They have well-founded indigenous knowledge of managing the farming system, particularly native species diversity of land use types. According to the district office of agriculture and key informants, most of the reports are studies in the study area focused on plant species diversity of agroforestry practices. However, there is limited empirical scientific information on comparing the agroforestry practices and adjacent remnant natural forests in native species diversity conservation in the Merhabete district.

Understanding the status of native fodder and fruit tree/shrub diversity and their management under different land-use types is crucial for developing effective strategies for conservation and sustainable use. This information can be used to identify areas of high conservation value, promote the use of sustainable land-use practices, and support the development of policies and programs that promote the conservation and sustainable use of native tree and shrub species.

Therefore, further research on the diversity of native fruit trees and shrubs and how they are managed under various land-use types is necessary to address the following questions: (1) How are the composition, diversity, and structure of native fodder and fruit tree species and do they vary among land use types? (2) How and why do local farmers manage the native fodder and fruit tree/shrub species in the study area? and (3) What are the major threats to native fodder and fruit tree/shrub species? To address these research questions, the following specific objectives were developed. Therefore, the objectives of this study were: (1) to assess the species composition, diversity, and structure of native fodder and fruit tree/ shrub species within homegarden, parkland, and remnant natural forest; (2) to describe the management practices of native fodder and fruit tree/shrub species; and (3) to identify the existing threats to native fodder and fruit tree /shrub species in the study area.

MATERIALS AND METHODS

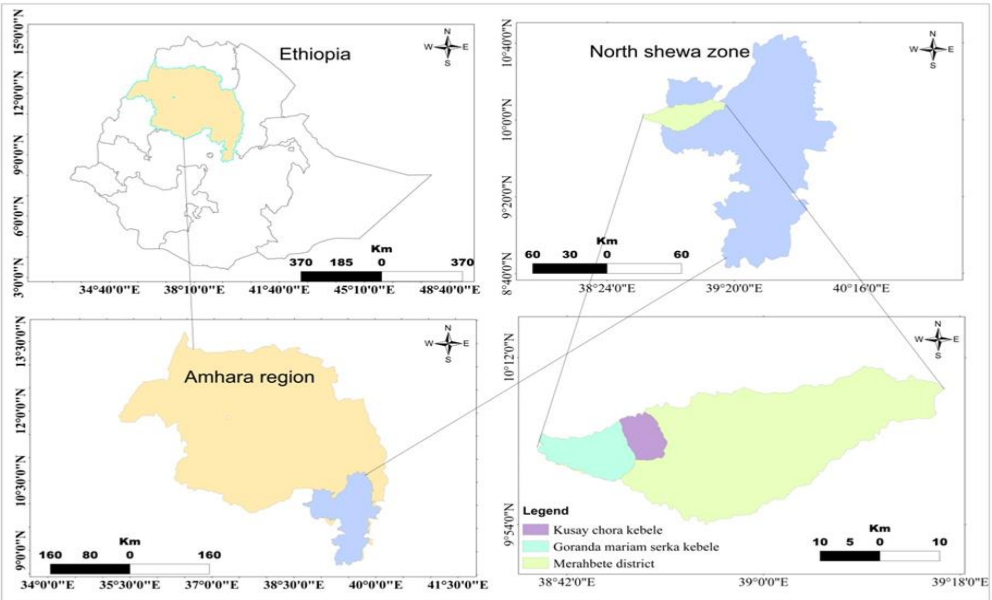
Description of the study area

The study was conducted in Merhabete district, North Shewa Zone, Amhara Regional State, Ethiopia. Merhabete district has 25 kebeles. More specifically, out of 25 kebeles within the district, two kebeles Kusay Chora, and Goranda Mariam Serka, are the sampled kebeles for the study. Kusay Chora kebele is located around 10°1'17.231"-10°6'14.63"N and 38°48'17.292"- 38°49'7.733"E (Fig. 1) and with altitude ranging from 1117 to 1350 m a.s.l (Kefelegn, 2020). Goranda Mariam Serka kebele is found around 9°59'0.035"- 10°5'19.82 N and 38°39'24.005"- 38°48'20.729" E (Fig. 1) and with altitude ranging from 1108 to 1381 m a.s.l (Kefelegn, 2020).

The topography features of the two kebeles are characterized by rugged topography. The annual rainfall in the studied kebeles follows a unimodal regime which is characterized by one distinct rainfall peak (July-September) and the driest season observed between November and May (Kefelegn, 2020). The mean annual temperature ranges from 20°C to 29°C, and the mean annual rainfall ranges from 299 to 940 mm in Kusay Chora kebele (Kefelegn, 2020). Whereas the mean annual temperature ranges from 20°C to 31°C, and the mean annual rainfall ranges from 200 to 921 mm in Goranda Mariam Serka kebele (Kefelegn, 2020). Nitisol, cambisols, and vertisols are soils found in both kebeles. (MDARDO, 2019). Natural forests, homegarden, parkland, cultivated, and grazing lands are the land uses found in the study areas. *Acacia tortilis*, *Z. spina- christi* , and *Balanites aegyptiaca* (L.) *Delile* are native tree species found in both kebeles (MDARDO, 2019).

Rainfed agriculture with a mixed farming system (annual crop production and livestock rearing) are the primary livelihood source of the inhabitants in study areas (Belayneh *et al.*, 2019). Teff (*Eragrostis tef (Zucc.) Trotter)* Sorghum (*Sorghum bicolor (L.) Moench*), and Sesame (*Sesamum indicum L.)* are the most dominant crops in study areas (Belayneh *et al.*, 2019). The total population is 5773 in Kusay Chora and 6770 in Goranda Mariam Serak Kebele.

Fig. 1: Map of the study area



Research site selection and sampling techniques

A multi multi-stage sampling procedure was used to collect the data. Firstly, preliminary information was collected at the district level through discussions with agricultural experts and local elders who have knowledge of native fodder and fruit species. Then, a reconnaissance survey was conducted to identify the study sites and verify land use types having native fodder and fruit species. Secondly, out of 25 kebeles within the district, Kusay Chora and Goranda Mariam Serka kebele were selected purposively based on the high abundance and large distribution of targeted species in the adjacent remnant natural forest and agroforestry practices (Fig. 1). The reason to have two kebeles samples was for replication purposes. Thirdly, we identified all households having native fodder and fruit tree/shrub species in their homegardens and parklands (87 from Kusay Chora and 103 households from Goranda Mariam Serka) by asking key informants, but in the remnant natural forest, data were collected following a transect line. Finally, a total of 127 households, 58 from the Kusay Chora and 69 from Goranda Mariam Serka, were randomly selected from the list of identified households in those two kebeles for interview. The proportional sample size formula, which was adapted from the Kothari (2004) method, was used to determine the needed number of household respondents from the two kebeles with a 5 % level of precision.

$$\mathbf{n} = \frac{\mathbf{Z^2 pqN}}{\mathbf{e^2(N-1)+Z^2pq}} \qquad \text{Eq.(1)}$$

Where n = the required sample size; p = sample proportion which is 50 % (this would provide the maximum sample size and the sample would yield at least the desired precision [1] =0.5 and q = 1-p (1-0.5) =0.5; N = A total number of households having study species in the selected kebeles; Z = Confidence level at 95 % which is 1.96 from Z-table, and; e= the margin of error considered as 5 % for this study which is 0.05.

$$\mathrm{n} = \frac{1.96^2(0.5)(0.5)(190)}{0.09^2(189) + 1.96^2(0.5)(0.5)} = 127$$

The number of households for each kebele was calculated as shown below:

$$n = \frac{n*N1}{N} \qquad \text{Eq.(2)}$$

Where n is the sample size in the respective kebeles, N1 is the total number of households included in the study (127), and N is the total number of households having study species in both kebeles (190).

$$\mathrm{n(Kusay\ Chora)} = \frac{87*127}{190} = 58$$

$$\mathrm{n(Goranda\ Marima\ Serka)} = \frac{103*127}{190} = 69$$

Methods of data collection

Household questionnaire survey

The household questionnaire survey consisted of both closed-ended and open-ended questions. The closed-ended questions provided quantitative data that can be analyzed using statistical methods, while the open-ended questions provided qualitative data that can be analyzed thematically. The questions were prepared in English and then translated into Amharic, the language used in the study sites. The questionnaires were designed to generate data on the background information of the respondents, the type of native fodder and fruit trees that they grow, major management practices, local use value, and threats to the studied species in the study areas. Enumerators who were experts and knowledgeable about the area were involved in data collection. Before performing the household respondent interview, the study objectives were explained to the enumerators, and they were trained in data collection and interviewing methods.

In addition, face-to-face semi-structured interviews were conducted with key informants. Twelve key informants were interviewed for the study. Key informants were selected through the snowball sampling methodology (Bernard, 2011). Moreover, focus group discussions were conducted with model farmers, local elders, youths, and women households selected from each kebele. The focus group discussions were guided by a semi-structured interview guide and involved groups of 8-12 participants. The focus group discussions were conducted separately with men and women and with different wealth ranks. The purposes of the focus group discussions were to validate the information given by different groups on: the type of native fodder and fruit trees that they grow, major management practices, local use value, and threats to the targeted species in the study areas.

Fodder and fruit woody species inventory

In this study, parkland is described as an area reserved with dispersed multipurpose trees in cultivated land with the selection, deliberate planting, and management of farmers, and there is no grass covering in the cultivated land of the parklands (Kim *et al.*, 2016: Manaye *et al.*, 2021) (Fig. 2). Moreover, it refers to a type of agroforestry system where trees are planted in a specific arrangement within agricultural fields to provide shade, improve soil fertility, and diversify production. Homegarden is defined as an area with multipurpose trees that are deliberately integrated with crops and/or animals around their homestead (Manaye *et al*., 2021), the remnant natural forest is a small fragmented portion of forest containing native flora and fauna that is still left (Hobbs & Wallace, 1991).

Fig. 2: Native tree/ shrub species in remnant natural forest (A), parkland agroforestry (B), and homegarden (C) (Photo: Goremsu Getachew, 2021)

Therefore, an inventory of native fodder and fruit tree/shrub species was conducted in homegarden, parkland agroforestry, and remnant natural forest. Inventory of homegarden and parkland was done from randomly selected 30 households of the total households (N=127) that had native fodder and fruit species. The plot size was 20 m×20 m for homegarden and 50 m × 100 m for parkland to conduct tree/shrub inventory (Gebre *et al*., 2019; Manaye *et al*., 2021). This represents 15 households from each of the two main land use types (homegarden and parkland) in each kebele, for a total of 30 households per kebele and 60 households in total.

In the remnant natural forests, a systematic sampling technique was carried out to collect the vegetation data. Two remnant natural forests (Chebera Guba from Kusay Chora and Mehalu Kersa from Goranda Mariam Serka kebele) closest to selected agroforestry practices were purposively identified in each kebele. A total of five transect lines (160 m) were laid down in each selected remnant natural forest. Along the transect lines, sample quadrat measuring 20 m x 20 m were laid down followed by adapting the approach of Mucheye & Yemata (2020). The distance between the sample plots and transect lines was 50 m and 100 m, respectively. GPS waypoints have been used to permit transects to be parallel. In general, a total of 90 sample plots, representing homegarden (30), parkland (30), and remnant natural forest (30) were used to collect the vegetation data.

To compare the species diversity of various land uses in our sample technique, we took into account the differences in plot size. We used Shannon's diversity index, which is sensitive to plot size, to calculate the species diversity of each land use. Firstly, the objective of the study was intended to see the contribution of traditional agroforestry practices and adjacent remnant natural forests for maintaining native fodder and fruit species. Secondly, we used a statistical approach to account for the differences in plot sizes when comparing species diversity across different land uses. Finally, we used rarefaction curves and calculated species richness and diversity indices per unit area to standardize the data. This allowed us to compare the species diversity of different land uses on an equal footing, despite the differences in plot sizes.

All tree and shrub species within the sampled plots were counted and recorded in each land-use type to assess diversity, richness, and density. Tree/shrub in the study area was defined as woody plants (DBH) ≥ 2.5 cm and height ≥ 1.5 m. Specifically, a tree is defined as woody perennials with a single main trunk, or coppice with multiple trunks and a more or less distinct crown (FRA, 2015). Whereas a shrub is defined as a woody perennial plant, generally more than 0.5 meters and less than 5 meters in height at maturity and without a definite crown (FRA, 2015). Therefore, all tree and shrub species with Diameter at Breast Height (DBH) ≥ 2.5 cm and height ≥ 1.5 m were measured. At the end of vegetation data inventories, samples of treeand shrub species with their local names were collected across land use types, they were pressed, and dried for identification. Specimens' local names, codes, GPS locations, site names, and life forms were recorded for each collected sample. Some of the tree species' scientific names were identified and verified based on Bekele (2007) and Ermias (2011). Species that could not be identified at the sites were taken to a National Herbarium at Addis Abeba University.

Data analysis

The quantitative data collected from household surveys were analyzed using SPSS 25 Package Software program, mainly for descriptive statistics such as frequency, percentage, and means. The Shannon diversity index, species richness, evenness index, and Simpson diversity (Sagar *et al*., 2003) and plot frequency, relative abundance, mean DBH, basal area, and stem number were calculated for each species, and land use type (Gebre *et al.*, 2019). Therefore, species diversity and structural features were estimated using following formula:

$$S = \sum n \qquad \text{Eq.(3)}$$

Where: n= is the number of species recorded from the study area; S = Species richness; Σ=Standards for summation.

$$H' = -\sum_{i=1}^{S} (pi)(\ln pi) \qquad \text{Eq.(4)}$$

Where: H'=Shannon–Wiener's diversity index
Pi =n/N proportion of individuals found in the ith species; ln = natural logarithm

$$\text{(Evenness) } J = \frac{H'}{Hmax} = \frac{H'}{\ln s} \qquad \text{Eq.(5)}$$

Where: E= evenness; H, = Calculated Shannon diversity index; H_{max} = ln (s) [species diversity under maximum equitability conditions]; S = the number of species

$$D = 1 - \sum_{i=1}^{S} Pi^2 \qquad \text{Eq.(6)}$$

Where, D= Simpson's diversity index; S= Number of species; Pi = proportion of total sample belongs to i^{th} species.

The density and basal area for each tree/shrub species in the three land use types were calculated as follows:

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total sample area in hectare}} * 100 \qquad \text{Eq.(7)}$$

$$\text{BA} = \frac{\pi * (\text{DBH})^2}{4} \qquad \text{Eq.(8)}$$

BA= basal area in m^2; π=3.14: DBH= Diameter at breast height in meter.

Prior to performing the data analysis, a check was carried out for normal distribution and homogeneity of residuals from plots for species diversity index variable, stem number, and basal area. In regards to the normality assumption, we have examined the distribution of each variable using normal probability plots and the Shapiro-Wilk test. In cases where the data were not meet the assumption of normality, the data were transformed into log valuesto ensure that the analyses were valid and reliable. When the data did not meet the assumption of normality even after transformation, the Kruskal-Wallis test was employed for all comparisons. Comparisons because, this test is usually resistant to diverse data.

Finally, the diversity indices, stem numbers, and basal area data were compared using one-way ANOVA when the results were normal. When ANOVA showed a significant difference, we used the Tukey Test (HSD) results for multiple comparisons of the mean. The data obtained in this study were analyzed using SPSS version 25 with $p \leq 0.05$ as the probability level.

RESULTS

Fodder and fruit tree/shrub species composition

A total of 34 tree and shrub species belonging to 16 families were recorded in the three land-use types (Table 1). Of 34 tree/shrub species, 31 (91.2 %) species were native fodder and fruit tree/shrub species and the remaining 3 (8.8 %) were exotics tree/shrub species (Table 1). Among the species, trees constituted 55 % (19 species), shrubs 32 % (11 species), and tree/shrub 11 % (4 species) (Table 1).

When classifying plants into the categories of tree, shrub, and tree/shrub, the classification is typically based on their growth habit and characteristics. Trees are generally taller, with a single main trunk and a well-defined canopy. Shrubs, on the other hand, are shorter and have multiple stems arising from the base. The tree/shrub category refers to plants that can exhibit characteristics of both trees and shrubs, such as having a single trunk but also multiple stems branching out from the base.

The highest proportion of native species was recorded in remnant natural forest (100 %,18 of 18 species) and parkland agroforestry (100 %, 14 of 14 species), followed by homegarden 86 % (18 of 21 species).

The variations were also observed in terms of the relative frequency of native fodder and fruit species in the plots (Table 1). A. tortilis, *Acacia senegal* (L.) Willd and *Z. spina-christi* were the three most frequently found native fodder and fruit species in the homegarden (n=30). *B. aegyptiaca* A. *tortilis,* and *Stereospermum kunthianum* cham. were the most abundant species, after *A. senegal* and *Z. spina-christi* in parkland agroforestry (n=30). While in remnant natural forests, *Dichrostachys cinerea* (L.) *Wight* & Arn. (100 %), *A. senegal* (80 %), and *A. tortilis* (76.6 %) were the three most frequent native species (n=30).

Table 1: Tree/shrub species composition, frequency, relative abundance, habit, and origin in each land use type in Merhabete district, Ethiopia (N=90)

Local name	Scientific name	Family	Life form	Plot (%)	RA (%)	Plot (%)	RA (%)	Plot (%)	RA (%)	Origin	uses
				HG	HG	PL	PL	RF	RF		
Lemba	*Acacia nilotica (L.) Delile*	Fabaceae	T	-	-	3.3	1.07	10	1.3	I	1
Kentafa	*Acacia polyacantha Willd.*	Fabaceae	T	-	-	3.3	2.15	10	`1.3	I	1
Dera	*Acacia senegal (L.) Willd.*	Fabaceae	T	53.3	24	60	30.1	80	17.4	I	1
Nech girar	*Acacia seyal Delile*	Fabaceae	T	-	-	3.3	1.07	56.6	9.21	I	1
Wacha	*Acacia tortilis (Forssk.) Hayne*	Fabaceae	T	70	28	36.6	12.9	76.6	14.2	I	1
Shefera	*Paraserianthes lophantha (Willd.) I.C.Nielsen*	Fabaceae	T	3.3	0.7		-		-	E	1
Nim	*Azadirachta indica A.Juss.*	Meliacea	T	3.3	0.7		-		-	E	1
Bedeno	*Balanites aegyptiaca (L.) Delilel*	Zygophyllaceae	T	-	-	30	10.8	16.6	3.68	I	3
Yezinjero Geba	*Bridelia micrantha (Hochst.) Baill*	Phyllanthaceae	T	-	-	3.3	2.15	20	2.37	I	3
Agam	*Carissa spinarum L.*	Apocynaceae	S	3.3	0.7		-	-	-	I	3
Gumero	*Capparis tomentosa Lam.*	Capparidaceae	S	10	1.9		-	-	-	I	3
Wanza	*Cordia africana Lam.*	Boraginaceae	T	6.6	3.3	3.3	1.07	-	-	I	3
Chewanza	*Cordia monoica Roxb*	Boraginaceae	T	3.3	1.3		-	30	3.16	I	3
Bisana	*Croton macrostachyus Hochst. ex Delile*	Euphorbiaceae	T	3.3	0.7	3.3	1.07	-	-	I	1
Ader	*Dichrostachys cinerea (L.) Wight & Arn.*	Fabaceae	T/S	-	-		-	100	19.5	I	1
Tahses	*Dodonaea viscosa subsp. angustifolia (L.f.) J.G.West*	Sapindaceae	S	3.3	0.7		-	-	-	I	1
Wilaga	*Ehretia cymosa Thonn.*	Boraginaceae	S	10	2.6		-	3.3	0.8	I	2
Kinchib	*Euphorbia tirucalli L.*	Euphorbiaceae	S	13.3	5		-		-	I	1

Girar	*Faidherbia albida (Delile) A. Chev.*	Fabaceae	T	-	-	6.6	2.15	16.6	1.84	I	1
Shola	*Ficus sur Forssk.*	Moraceae	T	3.3	1.3		-	-	-	I	2
Banba	*Ficus sycomorus L.*	Moraceae	T	10	1.9		-	-	-	I	2
Warka	*Ficus vasta Forssk.*	Moraceae	T	6.6	1.3		-	-	-	I	2
Sefa	*Grewia damine Gaertn.*	Malvaceae	S	-	-		-	13.3	1.3	I	3
Lenkuata	*Grewia ferruginea Hochst ex A. Rich.*	Malvaceae	S	-	-		-	30	3.42	I	3
Chirnchir	*Grewia villosa Willd.*	Malvaceae	S	-	-		-	13.3	1.3	I	3
Lucinia	*Leucaena leucocephala (Lam.) de Wit*	Fabaceae	T/S	3.3	1.3		-	-	-	E	1
Atat	*Maytenus arbutifolia (Hochst. ex A.Rich.) R.Wilczek*	Celastraceae	S	20	3.9		-	-	-	I	1
Shiferaw	*Moringa stenopetala (Baker f.) Cufod.*	Moringaceae	T	6.6	1.3		-	-	-	I	1
Takma	*Rhus natalensis Bernh. ex C.Krauss*	Anacardiaceae	S	-	-		-	53.3	8.95	I	1
Girangire	*Sesbania sesban (L.) Merr.*	Fabaceae	S	3.3	0.7		-	-	-	I	1
Washint	*Stereospermum kunthianum cham.*	Bignoniaceae	T	-	-	33.3	10.8	26.6	3.95	I	1
Enkoy	*Ximenia americana L.*	Olacaceae	T	-	-	3.3	1.07	-	-	I	3
Foch	*Ziziphus mucronata Willd.*	Rhamnaceae	T/S	3.3	0.7	10	3.2	23.3	3.16	I	3
Geba	*Ziziphus spina-christi (L.) Willd.*	Rhamnaceae	T/S	43.3	18	36.6	20.4	16.6	3.16	I	3

Where, Local names: Amharic name; Land uses: HG- Homegarden, PL -Parkland, and RF-- Remnant natural forest; Life form: T- Tree, S- Shrub, T/S-Tree or shrub; Origin of species: E- Exotic, I -Indigenous: RA - Relative abundance and -: Absent; Uses --1-Used for fodder, 2- Used for fruit, and 3- Used for both fodder and fruit.

Fodder and fruit tree/shrub species diversity

The diversity indices of tree/shrub species were 1.64, 0.85, and 0.82 in remnant natural forest, homegarden, and parkland, respectively (Table 2). The results indicated that there were significant differences between land use types in terms of richness, abundance, and diversity indices of tree/shrub species. The mean species richness of native species was higher in the remnant natural forest than in the homegarden and parkland (Table 2). The Simpson diversity index was highest for remnant natural forest ($p<0.05$) and lowest for parkland agroforestry. Moreover, the evenness was highest for the remnant natural forest followed by homegarden and parkland (Table 2).

Table 2: Means (±SD) tree/shrub species richness, abundance, Shannon diversity, Simpson, and evenness of homegarden, parkland, and remnant natural forest in Merhabete District, Ethiopia

Land-use	N	Richness	Abundance	Shannon diversity(H)	Simpson Diversity	Evenness
Homegarden	30	2.8(±1.24) ^{a}	5.06(±2.69) ^{a}	0.85(±0.479) ^{a}	0.48(±0.24) ^{a}	0.76(±0.35) ^{a}
Parkland	30	2.4(±0.72) ^{b}	3.1(±1.24) ^{b}	0.82(±0.33) ^{b}	0.49(±0.16) ^{b}	0.89(±0.24) ^{b}
Remnant natural forest	30	3.72(±1.96) ^{c}	12.66(±2.17) ^{c}	1.64(±0.23) ^{c}	0.77(±0.05) ^{c}	0.77(±0.02) ^{c}
P-value		<0.05	<0.05	<0.05	<0.05	0.036

The different letters indicate a significant difference between land use types at $p<0.05$

Structure of native fodder and fruit tree/shrub species

The analysis of variance indicated that there were strongly significant differences between land use types in terms of mean basal area and stem number (Table 3). The mean basal area was the highest in the remnant natural forest (8.85±2.91m^2 ha^{-1}) followed by the homegarden agroforesty system (5.01±4.31m^2 ha^{-1}) and parkland (0.69±0.35m^2 ha^{-1}) (Table 3). The mean number of stems in the remnant natural forest was 98 and 60 % higher than that in parkland and homegarden (Table 3). A. senegal (was the most abundant native species in the remnant natural forest (66 individuals), followed by homegarden (36 individuals) and parkland (28 individuals).

Table 3: Mean (±SD) tree/shrub species, DBH, basal area, and density for each land use type in Merhabete District, Ethiopia

Land-use	N	DBH (cm)	Basal area (m^2 ha^{-1})	Density (stems ha^{-1})
Homegarden	30	18.39(±6.47) ^{a}	5.01±4.31) ^{a}	126.66 (±67.3) ^{a}
Parkland	30	36.97(±5.95) ^{b}	0.69(±0.35) ^{b}	6.2(±2.5) ^{b}
Remnant natural forest	30	15.92(±2.70) ^{c}	8.85(±2.91) ^{c}	316.67(±54.3) ^{c}
P-value		<0.05	<0.05	<0.05

The different letters indicate a significant difference between land use types at $p<0.05$

Management of native fodder and fruit tree /shrub species

According to the respondents, 92.1 % (N=127) stated that natural regeneration was the dominant propagation method rather than planting in the study area. Pollarding, thinning, pruning, lopping, and fencings were the common management practices used for native fodder and fruit species in the study areas (Table 4). In remnant natural forest, some respondents did practice fencing for the sapling of *B. aegyptiaca*, *Ximenia americana* L. and *Z. spina-christi* to enhance the growth and to protect damage by animals. Moreover, according to key informants, cutting valuable fodder and fruit species such *Balanites aegyptiaca* (L.) Del, *X. americana* and *Z. spina-christi*, particularly for charcoal, was strongly prohibited by community rules.

Table 4: The percentage of respondents practicing management activities on native fodder and fruit tree/shrub species in land-use types in Merhabetedistrict, Ethiopia (N=127)

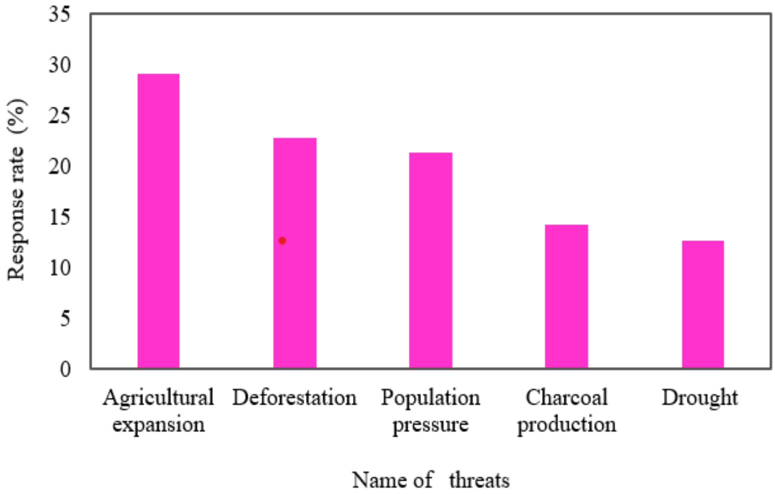
Species name	Percentage of repondents and management practices						
	Pruning	Thinning	Pollarding	Lopping	Fencing	Reason	Land-use type
Acacia nilotica Lam.	-	-	10.2	-	-	1,2,3,4,8	2
Acacia senegal (L.) Willd	23.6	-	15.7	-	-	1,2,3,4,8	1,2
Acacia seyal Del.	24.4		-	7.9	-	1,4,8	2
Acacia tortilis Forssk.) Hayne	-	27.6	-	-	-	3,4,6,8	2
Balanites aegyptiaca (L.) Del	11	-	20.5	47.2	4.7	1,2,3,4,5,9	1,2,3
Cordia africana Lam.	12.6	-	50.4	15.7	-	2,3,4,6,9	1,2
Ficus vasta Forssk	-	-		14.2	-	1,4,9	1,2
Stereospermum kunthianum cham.	-	-	8.7	55.1	-	1,3,4	2
Ximenia americana L.	-	-	-	-	18.1	2,5,9	1,2,3
Ziziphus mucronata Willd	-	-	-	31.5	-	1,4,9	2
Ziziphus spina-christi (L.) Willd.	22	-	19.7	27.6	13.4	1,2,3,5,6,7,9	1,2,3

Keys for reasons: 1: for fodder, 2: for growth, 3: for firewood, 4:to reduce shade, 5:to prevent disturbance, 6:to reduce competition, 7: to get more poles for construction; 8: soil fertility improvement; 9: for fruit; Keys for land use type: 1: homegarden, 2: parkland, 3: remnant natural forest.

Threats to native fodder and fruit tree/shrub species

The common threats that affected the survival and development of native fodder and fruit species were agricultural expansion, deforestation, population pressure, and charcoal production, as mentioned by the respondents (Fig. 2). Each of the threat factors contributed differently to the decline in abundance and diversity of native fodder and fruit species in the study area (Fig. 3).

Fig. 3: The major threats to native fodder and fruit species in the study area (N=127)



DISCUSSION

The the findings of study were important for conserving and managing of native fodder and fruit tree/shrub in Merhabete district, Ethiopia as they are crucial for the sustainable development of the livestock and forestry sectors of the country. The study can serve as a reference point for future research on the ecological and economic benefits of native fodder and fruit tree/shrub management in Ethiopia. The study also provides an important information on the distribution and abundance of native fodder and fruit tree/shrub under different land-use types in the study area. This information can be used to guide land-use planning and management efforts that aim to promote the conservation and sustainable use of these species. Moreover, the study only focused on the Merhabete district, which may not be representative of other regions in Ethiopia. It would be beneficial to expand the study to other areas to determine if the findings are consistent across different regions. Besides, the study did not consider the socioeconomic factors that influence the management of native fodder and fruit trees in the study area.

Fodder and fruit tree/shrub species composition

Our findings indicated that the three land use types maintained a higher proportion of native fodder and fruit tree/shrub species (91.2 %) in the study area (Table 1). The highest number of tree/shrub was recorded in home garden (21) followed by remnant natural forest (18) and parkland (14) (Table 1).

A. tortilis is the most preferred native species in the study area, and it is retained in homegarden agroforesty systems for its contribution to soil fertility improvement, bee forage, fodder (leaves), firewood, shade, house construction, and fencing materials (dry branches). *A. senegal* is the second preferred native fodder species, and it is grown in homegarden agroforesty systems for its firewood, charcoal, bee forage, shade, fencing material, house construction, and nitrogen fixation purpose. *Z. spina-christi* is also a multipurpose native plant, used for food (fruit), firewood, charcoal, poles for construction, timber, live fences, shade, fodder (leaves, young shoots), and fencing material (dry branches).

Some variations were observed between land use types in terms of native tree/shrub species composition. The variation in species composition was probably due to environmental variability in terms of topographic differences, soil characteristics, species adaptability, management practices, altitudinal gradients, and the amount of suitable environmental conditions in respective areas (Negash *et al.,* 2012; Demie, 2019; Muche *et al*., 2022). Moreover, the differences may also be due to socioeconomic features, cultural-related issues, and land-holding size. Native fodder and fruit species were also higher in remnant natural forests and parkland. This implies that farmers often prefer naturally occurring native tree seedlings over planting them from seeds or seedlings in remnant natural forests and parklands. Similar practices were used by farmers in other parts of Ethiopia for the establishment of native tree species (Negash, 2007; Endale *et al*., 2017; Eyasu *et al*., 2020). Fabaceae was the most diverse family with six species (42.8 %) in parkland followed by six species (33.3 %) in remnant natural forest and five species (23.8 %) in homegarden (Table 1). Overall, Fabaceae was the most dominant family with ten species (29.4 %) of the total tree/shrub species recorded in study areas (Table 1). The dominance of Fabaceae could be attributed to the farmers' preferance to retain leguminous plant species on their farmlands and due to the suitability of the ecological conditions and adaptation of the environment. This study was supported by the finding of Alemayehu *et al.* (2015) who reported that Fabaceae was the most dominant family in the Berehet district, North Shewa Zone of Amhara region, Ethiopia.

Furthermore, our results also showed that *A. senegal* in particular was the most abundant and frequently found native species across all land use types. This is mainly due to the species being highly preferred by farmers in the study sites for bee forage, fodder (leaves), firewood, shade, house construction, and fencing material (dry branches).

Fodder and fruit tree/shrub species diversity

The finding indicated that mean species richness, Shannon diversity index, and evenness were significantly different between land use types (Table 2). Therefore, based on the results, the species richness was highest for homegardens and lowest for parkland (Table 1). The higher number of tree/shrub species in homegarden agroforestry system was due to the farmers' preferred exotic tree species planting and retention of native tree species in the homegarden. This demonstrates that homegardens can serve as in-situ conservation for native and exotic species, reducing deforestation pressure on remnant natural forests and enabling farmers to cope with limited farming land and resources. Other scholars in different parts of Ethiopia also reported similar results of a higher number of woody species in homegarden than other traditional agroforestry practices, for instance, Tefera *et al*. (2014) at Debark district, northern Ethiopia, and Eyasu *et al*. (2020) in Raya Alamata, northern Ethiopia.

Low species richness in parkland agroforestry was due to those farmers applying thinning management practices in parkland agroforestry to ensure compatibility with different crops and improve crop productivity (Negash *et al*., 2012). The continuous reduction of tree/shrub species in parklands may result in the loss of biodiversity, products, and other ecological services in the study area. Therefore, an appropriate intervention either through research or extension is needed to enhance the diversity and domestication process of targeted species in the study area.

The results showed that the diversity indices were significantly higher in remnant natural forests than in homegarden or parkland, which is confirmed also in the works of Guyassa & Raj (2013) and Mengistu & Asfaw (2016). Parkland had the lowest Shannon diversity index due to the low density of tree/shrub. In general, the variation of species diversity among different areas could be associated with the differences in the distribution of individuals, management activities, species adaptability in different areas, and environmental conditions (Negash *et al*., 2012; Eyasu *et al*., 2020).

Stand structure of native fodder and fruit tree/shrub species

The mean basal area and stem number show a decreasing trend from the remnant natural forest to homegarden and parkland (Table 3). This is possibly due to favorable environmental conditions, socioeconomic features, farmers' tree species preference, and cultural-related issues. Other studies have also shown that stand structure was influenced by farm size, proximity to the highway, household wealth status, population pressure, tree species attributes, adoption of agricultural technologies, access to credit, and the presence of a nursery (Tolera *et al*., 2008; Abebe *et al*., 2013; Legesse & Negash, 2021). The study of Abebe *et al*. (2013) found out that the number of stems per farm decreases as one moves away from the main road, implying that proximity to the highway provides better market access for the exploitation of tree products.

The highest density tree/shrub was recorded in remnant natural forests, while the lowest was in parkland. Therefore, this fact could be due to a relatively high regeneration rate in remnant natural forest in comparison to homegarden and parkland. the Moreovere, the regeneration of young trees in cultivated land was almost nonexistent (Tolera *et al*., 2008) and farmers preferred highly economic and ecological important species in the agricultural landscape (Mengistu & Asfaw, 2016; Endale *et al*., 2017). On the other hand, the low stem per ha in parkland might be caused by dispersed trees/shrubs in parkland to minimize competition with crops. The homegarden tree/shrub density in this study was lower compared to the homegarden agroforestry system in the East Shewa zone, Ethiopia (132 tree ha^{-1}) (Endale *et al*., 2017). The variation in density among land-use types was due to the difference in composition, farmers’ intensive tree selection, and environmental conditions (Negash *et al*., 2012).

Management of native fodder and fruit tree/shrub species

The results indicated that local farmers highly preferred natural regeneration to planting seeds or seedlings to establish new plants. This study was supported by the finding of Endale *et al*. (2017) who reported that farmers in semi-arid East Shewa Zone, Ethiopia, use farmer-managed natural regeneration for the establishment of native tree species. Farmers applied management practices to maximize and harmonize survival with crops and animals. Moreover, they applied different management practices for various products and services such as construction materials, fodder, shade, soil fertility improvement, and firewood. Likewise, such management practices in traditional agroforestry practices are important for soil fertility improvement through mulching, livestock feed as fodder, timber, firewood, house construction, fencing, and also for markets (Negash, 2007; Negash *et al*., 2012; Lameso & Bekele, 2020; Legesse & Negash, 2021; Lelamo, 2021). Farmers have well-founded indigenous knowledge to manage native fodder/fruit species and integrated them with scientific research to sustain the targeted species. Therefore, assessing and documenting native tree management practices in specific areas is critical in developing conservation plans and guidelines for sustainable utilization (Tefera *et al*., 2015).

Threats to native fodder and fruit tree/shrub species

Farmers have strong bonds with their natural surroundings, and they are aware of the threats to native fodder/fruit species in the study area. Agriculture expansion was one of the most serious problems for native fodder/fruit species in the study area (Fig. 3). This conforms to the results reported by Tamiru *et al*. (2021), that agricultural expansion and intensification are the causes of the decline of woody species. The threat of agricultural expansion was followed by deforestation for various purposes such as firewood, poles for construction, farm tools, and fencing materials. The degradation of native species resulted in the loss of wild species. Therefore, well-coordinated ex-situ conservation activity should be needed to sustain multipurpose native fodder and fruit species.

Some of the threats reported by a small proportion of respondents in this study are regarded as the main threats to the diversity of woody species in other parts of Ethiopia. For instance, charcoal production and drought were the major threats to fodder/forage species in the Afar region, Ethiopia (Bahiru *et al*., 2014; Birhane *et al*., 2014). Overall, the threat factors erode associated indigenous knowledge with native fodder and fruit species ine study area.

CONCLUSIONS

The present study confirms that remnant natural forests had higher mean species richness, stem numbers, and diversity of native tree/shrub species than homegarden and parkland agroforestry systems, even several decades after deforestation. Therefore, many fruit and fodder species are moderately distributed in remnant natural forests than in non–forest habits. This suggests that there is a potential for the domestication of native fodder and fruit species in the study area.

Farmers in the study area accumulated a wealth of knowledge on native fodder and fruit tree/shrub species management. Hence, this knowledge should be encouraged by the government through improved research, and extension services, to maximize its use value to farmers and sustain the targeted species. Agriculture expansion, deforestation, demographic pressure, charcoal production, and drought are the main threats to the native fodder and fruit species in the study area. Therefore, design and implement well-coordinated complementary in situ and ex-situ conservation activities to save native fodder and fruit species. In this study, stem number and species diversity were lower in parkland compared to other land-use types.

Based on the current finding of the study, the following recommendations are given, which can be helpful for the sustainability of targeted species:

- Awareness creation should be given on planting native fodder and fruit tree/shrub species in the parkland to enhance species diversity as well as for nutritional security and improved animal production.
- Development agents, governmental organizations, non-governmental organizations, and other responsible bodies are advised to prepare training on sustainable utilization of native fodder and fruit tree/shrub species to enhance their conservation of native fodder and fruit tree/shrub species.
- Further research is needed on nutritional value, the interaction of fruit and fodder species with annual crops, and qualitative economic analysis of the study species in the study area, it is crucial for any researchers who are interested in the topic. Moreover, the outcome of this research serves as an input for scientific studies,

researchers, governmental and non-governmental organizations, policy and decision-makers, and forestry projects in the area, and at the national level.

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COMPETING INTEREST

The authors declare no conflict of interest.

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