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Review Article

Woody species diversity among different agroforestry niches at Dollo watershed Kamba Zuria Woreda, Gamo zone Southern Ethiopia

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ABSTRACT

Woody species are the chief components of agroforestry practices. These species composition and diversity vary across the different types of agroforestry practices in Dollo watershed, kamba zuria woreda, Southwestern Ethiopia. This study was conducted to assess woody species diversity across different land uses (agroforestry practices) in Dollo watershed, Kamba Zuria Woreda, Southwestern Ethiopia. In each agroforestry niche, a plots of 20 m × 20 m size was drown by using systematic sampling method following the transect line. A total of 20 sample plots were sampled along the transect line laid down inside each agroforestry niches. In each plot, woody species were counted, the diameter and height of trees and shrubs were measured. Shannon, richness, evenness, multiple-site similarity diversity index was used to analysis species diversity of agroforestry practiced. One-way ANOVA was used to compare species diversity significance between agroforestry practiced. A total of 47 woody species belonging to 27 families and 44 genera were identified in the agroforestry practices. Among identified woody species, 20 species were found from home-gardens, 14 from farmland, and 23 from grazing land and 13 from woodlots agroforestry practices. Combretaceae, Euphorbiaceae and Myrtaceae family had the highest number of woody species (4 each), Rubiaceae family had the second highest number of woody species (3 species). The dominantly observed species were *Eucalyptus grandis* (27.25%) followed and by *Coffee arabica* (21.38%). Grazing land verified highest species diversity than other agroforestry practices. The multiple-site similarity index shows that 57% species were overlapping between the home-garden, parkland, grazing land and woodlots. The current woody plant species should be well-maintained and should be more diversified than the present status by maintaining these species and planting seedling which can be the farmer preferences and agroforestry species.

Keywords: Agroforestry niches, Density, Diversity, Woody species

INTRODUCTION

The rapid expansion of agriculture is one of the greatest threats for the losses and degradation of both forest and agricultural land biodiversity. This uncontrolled expansion of agriculture has led to deforestation and forest degradation, which in turn led to food insecurity and poverty in many parts of the world particularly developing country including Ethiopia.

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Agroforestry are important reservoirs of human culture, technical experiences, biodiversity, and ecosystems (Casas A, Camou A, Otero Arnaiz A, Rangel Landa S, Cruse-Sanders J, Solis L, 2014). Agroforestry systems deliberately integrate the conservation of forest species with crops and a high diversity of semi-domesticated organisms for the purpose of obtaining ecological, economic, and social benefits (Moreno-Calles AI, Galicia-Luna V, Casas A, Toledo VM, Vallejo-Ramos M, Santos-Fita D, 2014). These systems have a high capacity for biodiversity conservation (Bhagwat SA, Willis KJ, Birks HJB, Whittaker RJ, 2008; Vallejo-Ramos M, Moreno-Calles AI, Casas A, 2016).

Agroforestry systems may favor maintenance of local and regional biodiversity. At regional level, the mosaic of agricultural and forest patches allows maintaining habitats, connectivity and gene flow among populations of flora and fauna species of conserved and fragmented areas (Parra F, Blancas J, Casas A, 2012). At local scale, AFS may increase the floristic composition of both useful and not useful plants species, wild, weedy and domesticated plants, species from primary and secondary forests, and even plant species from several forest types of a region (Vallejo M, Casas A, Blancas J, Moreno-Calles AI, Solís L, Rangel-Landa S, Dávila P, 2014).

There are several types of agroforestry practice in different part of our country (Tadesse E, Abdulkedir A, Khamzina A, Son Y, Noulèkoun F, 2019). Among the agroforestry practices used by farmers, home gardens, parklands, woodlots and live fences are the most dominant practices in Ethiopia (Worku M, Bantihun A, 2017). Floristic species vary across different types of agroforestry practices in different parts of Ethiopia. Agroforestry has the transformative potential to biodiversity conservation (Minang P, van Noordwijk M, Freeman O, Duguma L, Mbow C, Leeuw J de, Catacutan D, 2018). The maintenance of species-rich, multi-strata agroforestry is important because of their material, nonmaterial, and regulating contributions to biodiversity and sustainability (Brondizio Eduardo S, Josef Settele, Sandra Díaz, Hien T Ngo, 2019; Rendón-Sandoval FJ 2020). Agroforestry contribute to biodiversity conservation by providing supplementary habitat for species tolerating a certain level of disturbance (Jose S, 2019). Agroforestry systems reflect the wisdom of the traditional culture and ecological knowledge of the local community (Kebebew Z, Garedew W, Debela A, 2011). In Ethiopia agroforestry is the most common practices which are familiar to small holder farmers (Yakob G, 2011).

The woody species are threatened at an alarming rate on both natural and agricultural land due to expansion of agricultural practices as a solution to both agricultural land shortage and yield reduction and increasing demand for forest products especially rural people who depend their livelihoods on forests in Ethiopia. Finding alternative options to conserve biodiversity and increasing stable supply of forest products from outside of natural forest have become a fundamental concern. Agroforestry practices were discovered and adopted as a conservation tool to biodiversity. The studies undertaken in agroforestry practices in Ethiopia focused on system design, soil fertility management, system interactions, and judgments with each other within different site. However, less emphasis has been placed on agroforestry niche comparisons with each other within single watershed (Negash M, Yirdaw E, Luukkanen O, 2012). Therefore, this study aims to assess the contribution of each agroforestry niches in conserving floristic composition, diversity and structure in Dollo micro-watershed kamba woreda, southern Ethiopia.

MATERIALS AND METHODS

The study area

The southern Ethiopian region of Kamba woreda Gamo zone is home to the Dollo watershed. Geographically, it is located between longitudes of 37° 9'30.29" E and latitudes of 6° 4'41.09" N (Figure 1). The area is roughly 282 hectares, and the elevation spans from 1646 to 2708 meters above sea level. As the predominant soil types in the area, cambisols, vertisols, and andosols make up the majority of the watershed's soil type. The region's climate is bimodal, with the main rainy season taking place from March to June and a brief period of rain from late September to November. The average annual temperature is 19.7˚C, and there is 1470 mm of rainfall on average.

The rolling hills with valley bottoms that are quite steep are the area's defining feature. There are numerous means of subsistence and revenue available to the local communities residing inside the woreda. These include of cereals, cattle production, coffee arabica, lumber, and other non-timber forest products. These goods can be used for cash revenue, home consumption, or both. Livestock and field crops, for instance, are mostly for domestic use.

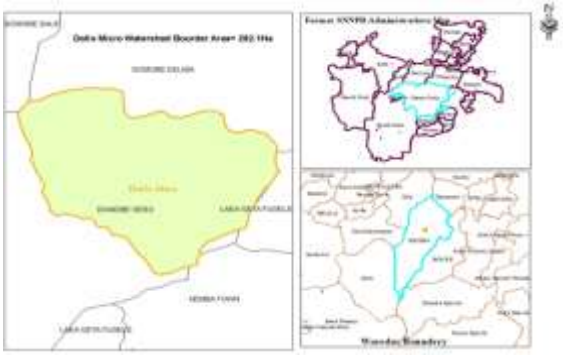

Figure 1. Map of the study sites in Kamba Woreda, southeastern Ethiopia: Yohannes dikola, 2022.

Methods of data collection

Between October and December 2021, the researchers conducted a number of in-depth reconnaissance field surveys to determine the study site, confirm the type of agroforestry, and establish the sampling strategy. Based on which approaches were most prevalent and which the community preferred, four agroforestry niches were chosen. Each transect and plot in each agroforestry niche were spaced roughly 500 meters apart, respectively. Sample plots of 20 x 20 meters were utilised to measure the DBH and tree height in side plots on dominant agroforestry niches.

Sampling design

The sample plots have been identified using a "nested" sampling technique in order to evaluate the richness and composition of woody species. The transect line was followed in the data collection process for all agroforestry niches. The first plot and transect line in the data gathering process were specifically chosen to fall inside the land uses. Every surviving tree and shrub in the sample plot with a Diameter at Breast Height (DBH) of at least 5 cm was measured. Tree callipers and diameter measuring tapes have been used to determine the DBH of the trees and plants.

Sampling techniques

All woody species have been identified for the purpose of evaluating the diversity of woody species in agroforestry techniques. Diameters at breast height for all woody species ≥ 5 cm were measured using diameter tape, with the exception of coffee (MacDicken KG, 1999). The coffee shrub's diameter was measured at 15 cm above the ground (Segura M, Kanninen M, Suarez D, 2006). A 400 m^2 quadrat was utilised to evaluate woody species with a diameter of at least 5 cm (Hernandez RP, Koohafkan P, Antoine J, 2004). Five 25-meter-square subplots were placed for sapling shrubs with a diameter class of 1 to 5 cm in the centre of the plot and at each of the four corners. Once more, a tiny four-meter-square five-plot was placed in each subplot's centre and corner for the purpose of collecting and sampling seedlings.

Data analysis

Vegetation identification: Utilising the published volumes of Flora of Ethiopia and Eritrea (Edwards S, Tadesse M, Hedberg I, 2004) and beneficial trees and shrubs for Ethiopia (Azene Bekele, T, Birnie A, Tengbna B, 1993), plant identification was carried out in the field.

Woody species diversity indices: The diversity of woody species was analysed using the Shannon diversity index (H), evenness index (E), species richness (S), Simpson diversity index (D), and multiple site similarity indexes (Ss).

Shannon-wiener diversity index (H'): The Shannon-Wiener diversity measure is frequently used to calculate species diversity and evenness (Kent M, P Coker, 1992). The Shannon diversity index combines two aspects of diversity:

$$H' \quad \sum$$

Where,
H'=Shannon diversity index, Pi=The proportion of individuals or the abundance of the i^{th} species expressed as a proportion of a total cover K=The number of species, ln=log basen

Evenness was calculated using most common and widely used methods of (Kent M, 2011) as follows:

$$\frac{H'}{H}$$

Where,
J= Evenness, H'=Shannon-Wiener diversity index and H 'max=lnS where S is the number of species

The Sorensen coefficient of similarity (Ss) is given by the following formula:

$$Ss \quad \text{———}$$

Where,
Ss is Sorensen similarity coefficient, is number of species common to both samples, is number of species distinctive in sample 1, and c is number of species distinctive in sample 2.

The similarity of woody species diversity among the four types of Agroforestry niches were analyzed by using a multiple-site similarity index (Ss) using a multiple-site similarity measure (Magurran AE, 1988; Diserud OH, Odegaard F, 2006).

$$MSSI \quad \text{———————————}$$

MSSI=Multiple Site Similarity Index a=number of species site 1, b=number of species found in site 2, c=number of species found in site 3, d=number of species found in site 4 ab = number of species common to site 1 and 2 system, ac=number of species common to site 1 and 3system, bc=number of species common to site 2 and 3system, cd=number of species common to site 3 and 4 system abcd=the number of species found in the four sites systems.

Forest structure and composition analysis: Tree density, diameter at breast height, height, frequency, and basal area was used for description of vegetation structure. Basal area is expressed in square meter ha^{-1}.

Basal area per tree $\frac{(D)2}{}$

Basal area ha^{-1} = $\frac{\sum_i^n}{}$ ×10000

Relative dominance ———————

$$\text{Density} = \frac{}{\text{e (m2)}}$$

$$\text{Relative density} = \frac{}{}$$

$$\text{Frequency} = \frac{}{}$$

$$\text{Relative frequency} = \frac{}{}$$

Statistical analysis

Shannon, richness, evenness, multiple-site similarity diversity index was used to analysis species diversity of each agroforestry niches. One-way ANOVA was used to compare species diversity significance between agroforestry practiced. SPSS version 20.0 software was used for readily quantifiable data and the output was discussed using tabulation and graphs with percentage values in descriptive statistics.

RESULTS AND DISCUSSION

Floristic composition

A total of 47 woody species belonging to 27 families and 44 genera were gathered, identified, and recorded in the agroforestry niches of the Dollo watershed Kamba woreda Gamo zone southern Ethiopia. Plant species composing the tree and crop component in four agroforestry niches were represented by a mixture of fruit trees and shrubs, timber trees, firewood and root crops.

Among identified woody species, 20 species were found in home-gardens, 14 in farmland, and 23 in the grazing land and 13, in the woodlots.

The woody species richness of the study area was comparable with another study in Ethiopia (Amare ADINA, 2018) 44 woody species, (Tesfaye MA, Gardi O, Anbessa TB, Blaser J, 2020) 41 woody species and lower than a study in Ethiopia (Tolera M, 2008) 83 tree species, in Kenya (Oginosako Z, P Simitu, C Orwa, S Mathenge 2006) 459 tree and shrub species.

However, it was higher than that of (Bajigo A, Tadesse M, 2015) who recorded 32 woody species in the three agroforestry practices at Gununo in wolayitta zone Southern Ethiopia.

From the plant families, Combretaceae, Euphorbiaceae and Myrtaceae family had the highest number of woody species (4 each), Rubiaceae family had the second highest number of woody species (3 species), Anacardiaceae, Celasteraceae, Cupressaceae, Fabaceae, Meliaceae and Rubiaceae family had the third highest number of woody species (2 each), while resting family had the lowest number of woody species (1 each).

From the 28 plant families assessed in studied agroforestry, Combretaceae, Euphorbiaceae and Myrtaceae family had the highest number of woody species, was the most dominant one and the most likely reason for this might be that the households' preference is tending towards growing of income generating woody, soil fertility improvement, construction material and fire wood plant species in their farm land. The plant family's result of the study area was similar with another study in Ethiopia (Tefera Y, Abebe W, Teferi B, 2016) the most species rich families were Myrtaceae and others. Out of the total 46 woody species found in the area, the dominantly observed species were *Eucalyptus grandis* (27.25%) followed by *Coffee arabica* (21.38%) followed by *Cordia africana* (9.94%) while 8 species had the lowest frequency (1.2%) (See Appendix 1)

Wood species diversity

The results shown that across agroforestry practices, tree density was high in woodlots, followed by grazing area, then parkland and home-garden. More tree seedlings were planted with crops in woodlots by the farmers at earlier stages of woodlot introduction in the study area. The grazing land recorded highest species diversity than other land use system in overall study sites. The highest woody species richness in the range land agroforestry could be due to its relatively well rehabilitated activities with zero grazing and management strategy compared with the other agroforestry.

This result in lined with study result of (Faye, 2011) the variation in woody species richness could be due to site characteristics, socioeconomic factors, farmers' preferences for tree species and functions in different localities. A total of 13 woody species were identified in woodlots of the study sites.

The woody species richness of the woodlots was in lined with another study in Ethiopia (Buchura, 2019) 13 woody species in the woodlots. The number of species identified in this study was much lower than the result of Shiferaw and Pavlis [33] in South Western Ethiopia. This might be associated with the high relative density of Eucalyptus grandis, Cordia africana *Lam* and *terminalia brownii* plantation by dominant certain species composition (Figure 2).

Figure 2. Features of the four studied agroforestry practices: parkland (A), Woodlots (B), Home garden (C) and Range land (D).

Diversity index

The wood species diversity of various agroforestry practices in the study area was analysed using the Shannon diversity index. Range land agroforestry had a higher diversity index than the other three forms of agroforestry, according to Shannon-Wiener's diversity index. There were notable differences in tree diversity between the study area's agroforestry niches. When comparing the diversity of the Dollo watershed vegetation diversity among its several agroforestry niches, the Shannon diversity index reveals that the range land niche is the most diverse, followed by the woodlot and home-garden niches, and parks (Table 1).

In terms of the main agroforestry niche, our study was consistent with that of Abreha and Gebrekidan, who found that grazing land is more diverse than crop land and (Buchura NW, 2019). In contrast, the highest diversity was recorded in the grazing land followed by home gardens.

An analogous pattern was seen with Simpson's diversity index. Among the three agroforestry types, range land agroforestry had the highest homogeneity of woody species, according to Shannon evenness (91%) analysis. The results showed that species evenness varied between 0.32 and 0.56 in the home-garden and range land agroforestry, and that species diversity was greatest in range land (H'=2.74), followed by home gardens (H'=1.89) and woodlots (H'=1.89). It was higher than home gardens in the Tigray region of northern Ethiopia Guyassa and Raj and lower in both species Shannon diversity and evenness than traditional agroforestry practice in Dellomenna District, Southeastern Ethiopia Abiot and Gonfa, 2015.

Species diversity of grazing land, home-garden, park land and woodlots land were 2.74, 1.89, 1.73 and 1.89, respectively. The Species diversity of the study area was similar with another study in Ethiopia Buchura et al. species diversity of grazing land, home-garden, crop field, woodlots and coffee farm were 3.1, 2.87, 2.555, 0.667 and 0.643, respectively.

Table 1. Woody species diversity indices in different agroforestry practiced in Dollo watershed.

Diversity indices			
Agroforestry	**Shannon**	**Evenness**	**Simpson's**
Home garden	1.89	0.32	0.77
Parkland	1.73	0.33	0.71
Range land	2.74	0.56	0.91
Woodlots	1.89	0.39	0.78

Similarity indices

Agroforestry practices (land use categories) were evaluated based on similarities in the composition of woody species. Using a multiple-site similarity measure, the similarity of woody species diversity among the four land use types was examined. based on the kinds of land uses (agroforestry practices) that were practiced in the sampled plots and the presence or absence of woody species. The home-garden showed the largest resemblance in woody species compositions (48.5%), followed by range land and parkland (43.2%), and range land and woodlot (27.8%), which showed the lowest similarity. Agroforestry methods in woodlots, parklands, rangelands, and home gardens were shown to have a multiple-site similarity index of 57%. That is, roughly 57% of the species found in woodlots, parklands, grazing areas, and residential gardens overlapped. This suggests that the four there is

a lot of species overlap between land uses. Woody species are planted on four different types of agroforestry practices: plantations, remnants of once-covered natural vegetation, and certain woody species that farmers favored and were native to the area.

Croton macrostachyus, Persea Americana, terminalia brownie, Mangifera indica L., *Cordia africana* Lam*., causaria equistfolia, Carica papaya* L. *and Coffee arabica* L. were common to home-garden and parkland. Whereas, *Croton macrostachyus, Persea americana Mill., Eucalyptus grandis, Ficus vasta, terminalia brownie, Mangifera indica* L., *causaria equistfolia,* and *Coffee arabica* L. were common for home-garden and grazing land. *Croton macrostachyus, terminalia brownie, Cordia africana Lam, Juniperus procera (Hochst. ex. Endl.)* and *Syzygium guineense*, are species commonly grown both in the home-garden and woodlots. *Croton macrostachyus, terminalia brownie, Cordia africana Lam, Syzygium guineense*, and *combret*um molle are species commonly grown both in the range land and woodlots. *Croton macrostachyus, Persea americana Mill, Mangifera indica* L., *Cordia africana Lam, Coffee arabica* L. and *Olea Africana* are species commonly grown both in the range land and parkland. *Croton macrostachyus, terminalia brownie, Cordia africana* Lam and *Eucalyptus grandis* are species commonly grown both in the woodlots and parkland (Table 2).

Table 2. Similarity indexes of wood species among the agroforestry practices.

S. No	Types of agroforestry practices	Similarity	(%)
1	Home-garden *vs.* Parkland	0.48485	48.5
2	Home-garden *vs.* Range land	0.42857	42.8
3	Home-garden *vs.* Woodlots	0.3125	31.2
4	Range land *vs.* Parkland	0.43243	43.2
5	Range land *vs.* Woodlot	0.27778	27.8
6	Parkland *vs.* Woodlots	0.2963	29.6
7	Home-garden *vs.* Parkland *vs.* Range land *vs.* Woodlots	0.57143	57

Appendix 2 contains a list of each woody species' Important Value Index (IVI) in the study watershed. Table 3 lists the five woody species in each agroforestry niche that have the highest IVIs in descending order. An aggregate index that condenses a species' density, abundance, and dispersion is called the IVI. It assesses the total significance of a wood species and provides a measure of the species' ecological success in a specific location. *Coffee arabica* from the home garden, *Terminalia brownie* from range land, *Eucalyptus grandis* and *Cordia africana* from woodlots, and *Eucalyptus grandis* and *Cordia africana* from parkland agroforestry were the species with the greatest IVI in Table 3. Prioritizing species can also be done using the IVI values preservation, and species with high IVI values require less work in the way of conservation, whereas species with low IVI values require more.

Table 3. Woody species with the highest IVIs in each agroforestry niches at Dollo watershed.

Agroforestry type	Scientific name	Local name	Relative dominance	Relative density	Relative frequencies	IVI %
Home garden	*Coffee arabica L.*	Tuke	1.211	40.278	46.296	87.785
	Persea americana	Avocado	23.671	8.333	37.037	69.042
	Cordia africana	Mokotha	29.589	8.333	27.778	65.699
	Eucalyptus grandis	Keybahirzaf	0	22.222	18.518	40.741
	Citrus sinensis (L.)	Burte	8.257	3.703	18.519	30.479
Parkland	*Eucalyptus grandis*	Keybahirzafe	12.6	48.295	22.727	83.623
	Cordia africana	Mokotha	25.625	9.6591	34.091	69.375
	Mangifera indica	Mango	19.915	2.841	22.727	45.483
	Coffee arabica L.	Tuke	0	19.886	22.727	42.613
	Persea Americana	Avocado	9.061	3.977	22.727	35.765

Range land	*Terminalia brownie*	Galalio	5.177	8.029	75.472	88.678
	Viburnum tinus	Dhankara	12.127	10.219	56.604	78.951
	Eucalyptus globulus	Nechbahir zaf	11.825	8.029	56.604	76.458
	Securinega durissima	Unko	5.003	4.379	56.604	65.986
	Ccombretum molle	Sobo	2.274	4.379	56.604	63.257
Woodlots	*Eucalyptus grandis*	Keyibahirzafe	38.854	37.398	65.041	141.293
	Cordia africana	Mokotha	24.647	22.764	48.78	96.192
	Syzygium guineense	Ocha	10.321	9.756	32.52	52.597
	Juniperus procera	Habesha tida	6.118	6.504	32.52	45.143
	combretum molle	Sobo	4.752	6.504	32.52	43.776

CONCLUSION

The results of this study have shown that home gardens, parkland, range land and woodlots are the common agroforestry practices in the study area. Woody species composition on each agroforestry niches was identified. In between the agroforestry niches of the study area significant difference of overall woody diversity was found. Highest woody species diversity was recorded in the rangeland niches, followed by both home gardens and woodlot and park land niches was the least one. Based on the results obtained from the study, the following recommendations were offered: This study focused mainly on the assessment of the woody species diversity in agroforestry niches.

RECOMMENDATION

The study recommend that the existing woody plant species should be well-maintained and should be more diversified than the present status by planting seedling which can be the farmer preferences and agroforestry species. The governmental and nongovernmental organizations should promote different agroforestry practices to conserve woody species conservation.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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