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Woody Species Diversity of Traditional Agroforestry Practices in Gununo Watershed in Wolayitta Zone, Ethiopia

Bajigo A[1]* and Tadesse M[2]

[1]Jigjiga University College of Dryland Agriculture (Natural Resource Management Department), Jigjiga, Ethiopia
[2]Mekelle University College of Dryland Agriculture and Natural Resources, Mekele, Ethiopia

Abstract

In Gununo watershed at Wolayitta zone, Ethiopia, to determine the variation of woody species structure and composition among agroforestry practices and along elevation gradients in the watershed, this study was conducted. The elevation gradient was stratified in to three transects (upper, middle and lower); and three dominant agroforestry practices (homegarden, parkland and woodlot) were used as treatments. Along each transect line, three agroforestry practices with three replications, a total of 27 sampling points, a complete enumeration of woody species in homegarden which has the average are of 900 m2. Whereas, 50 m × 100 m sampling quadrates in parklands, and 10 m × 10 m sample quadrates for woodlot were used. Number of individuals per plot, DBH, height, crown diameter, and plot area were measured and recorded. The structure and composition of woody species through important value index (IVI), basal area, canopy cover, and diversity indexes determine were determined. A total of 32 woody species belonging to 19 families were recorded in the three agroforestry practices. Fabaceae family 28%, (9 species) was the dominant family of the woody species recorded followed by Euphorbiaceae 13%, (4 species). From these species, 69% (22 species) were indigenous and 31% (10 species) were exotic. From the indigenous species, two were endemic to Ethiopia *(Erythrina brucei* and *Millettia ferruginea*). The largest indigenous species, and highest species diversity (20) were recorded in homegardens followed by parklands (11)). Middle elevation was exhibited higher indigenous species, and highest species richness (19): followed by upper (15) and lower elevation. The Shannon, Simpson and evenness diversity indexes were highest in homegardens. Comparing to parkland, homegarden diversity indexes were highest in upper, middle and lower elevations in decreasing order. Attention should be given to the existing agroforestry practices, and the practices must be promoted to lower elevation to enhance biodiversity conservation in agroforestry land use system.

Keywords: Diversity; Endemic; Homegarden; Indigenous; Parkland; Woodlot

Introduction

Ethiopian highlands are typically characterized by high population density, small land holdings and associated land degradation [1]. This aggravates unsustainable land management and drastically affects the contribution of agriculture [2]. This is also true in Southern Ethiopia particularly to Gununo area: with high population density. Therefore, the watershed is prone to land degradation and resource depletions such as soil erosion, flooding, loss of biodiversity and associated impacts on household economy [1,3,4]. In relation to this, the local people have been using different strategies to combat such degradations. One of the strategies is a traditional agroforestry practices [5]. Traditional agroforestry practices with it woody species diversity, have been serving different protective and productive roles in Gununo watershed.

Woody vegetation is characterized by its plant morphological characters (structure) or the recognized plant species (composition). Structure denote the vertical arrangement of different plant form and its associated canopy layers whereas composition refers to the number of species and its associated diversity in a system [6]. The structure of tropical agroforestry looks a forest like appearance (complex multilayer structure) and their plant diversity is rich i.e. comparable to that of natural forest [7]. This is due to selective and repeated planting and management of useful woody species from a spontaneous regeneration [7,8,9].

Therefore, because of their high plant diversity, structural complexity, and management (possibly that favor for useful woody species) agroforestry practices are very essential in conservation and management of tropical forest landscapes [8], and species richness at regional and global scales [10]. Homegardens and agroforests are a valuable example for this [8,11]. Structure and composition of tropical agroforestry is reported to be rich by many authors [7,9,12].

Many studies mainly based on floristic composition indicated that pattern of vegetation and floristic diversity is generally governed by climate, elevation, moisture availability, nutrient and topographic variables. Yitebitu, [13] has reported as elevation gradient have effect on the structure and composition of woody species. Nuberg [14] has also found as the species diversity tend to decrease with altitude. Further, the farm characteristics such as farm size, shape, species adaptability, nature of cropping pattern, and management variation also affect the structure and composition in agroforestry [7,15]. Therefore, this study was conducted with the objective to determine the variation of woody species structure and composition among agroforestry practices and along elevation gradients in the watershed.

***Corresponding author:** Bajigo A, Jigjiga University College of Dryland Agriculture (Natural Resource Management Department), Jigjiga, Ethiopia, Tel: 251913687159; E-mail: bajigoaklilu05@gmail.com

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Materials and Methods

Study area description

Wolayitta zone is in southern nations, nationalities and peoples (SNNP) region of Ethiopia with a total land area of 4537.5 sq kms is located between 6°4′N to 7° 1′N latitudes and 37°4′E to 38°2′E longitudes. It is located 22 km from Sodo town and about 330 km from Addis Ababa (Figure 1). The watershed has an area of about 544 hectare with three rural districts namely: Demba Zamine (middle elevation), Doge Hunchucho (lower elevation) and Chew kare (upper elevation).

Gununo watershed has plain lands, plateaus, hills and rugged mountains topography with an altitude ranging from 1937 to 2100 meter above sea level [16,17]. The mean annual temperature of the site is 19.2°C and the mean annual rainfall is 1335 mm with bimodal rain pattern [17].

Soil of the watershed is Eutric Nitosol according to FAO/UN classification system [4]. Soil erosion in watershed is severe due to conversion of natural forests to other land uses. The study area has high population pressure i.e. around 450 person per km^2 [17], and an average land holding is about 0.25 ha per household and drive farmers to cultivate slope lands [16]. Agroforestry is one of the major land uses at the area. Different species (tree crops and woody species) such as *Enset ventricosum Musa accuminata, Moringa oleifera* and *Brassica oleracea* serve as primary food source while *Croton macrostachyus* and different Acacia species are the dominant trees in the degraded natural forest of Wolayitta [17].

Sampling procedures

Since the area is with steep slopes and undulating topographic, the watershed was classified in to three transects. Consequently, upper (2006 to 2040), middle (1972 to 2006) and lower zone (1937 to 1971) meters above sea level (m.a.s.l.) ware considered. At each zone, the middle point was chosen for horizontal transect walk i.e. at 2023, 1989 and 1954 m.a.s.l. for upper, middle and lower transect respectively. These transect lines thatch all the three districts that the watershed contains.

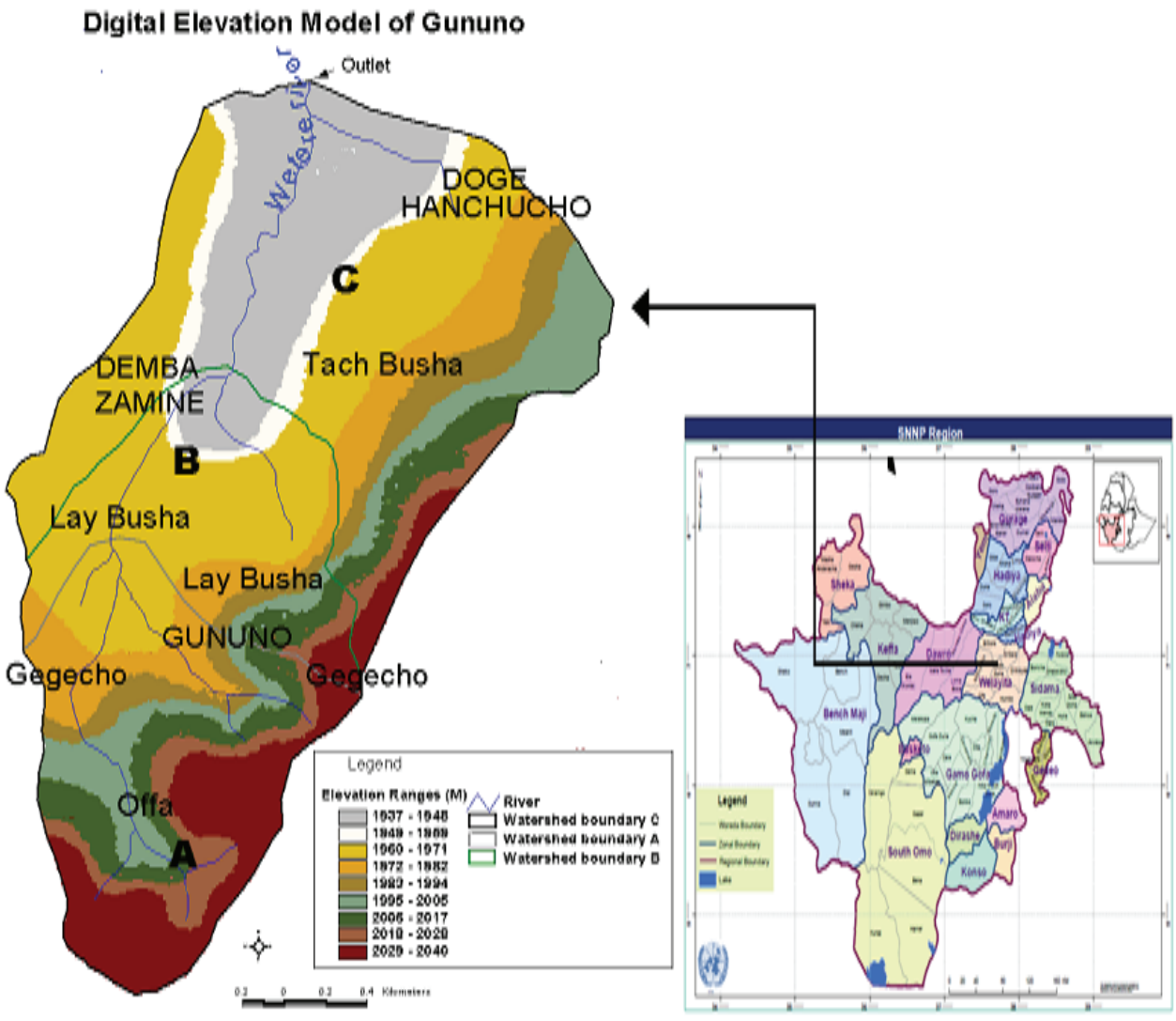

Figure 1: Map of Wolayitta Zone and Gununo watershed, Southern Ethiopia (adopted from Mowo et al., 2011).

The distance of each transect line was measured from the delineated watershed map and sampling points were distributed proportionally. Accordingly, at each horizontal transect line the first sampling point was randomly selected i.e. some distance away from initial standing point. Then the next sampling point (quadrate) was allocated systematically at every two kilometer by using GPS. Therefore, along each transect line, three agroforestry practices (homegarden, parkland and woodlots) with three replications, a total of 27 sampling points were used. These sampling plots per land use/agroforestry practices were found sufficient according to the plot number-species accumulation curve done after data collection. No quadrates were laid in homegarden; rather a complete enumeration of woody species with average area of 900 m^2 following Motuma [18]. In parklands vegetation data was collected from 50 m × 100 m sample size quadrates [19], and for woodlot 10 m × 10 m sample quadrates were taken [20].

All the woody species in each sample plot greater than or equal to five centimeter DBH was taken [18]. Height less than 1.5 m was considered as seedlings while height between 1.5 and 3 m was taken as sapling and height greater than 3 m was taken as tree [20]. The average height of woody species was used for homegardens (average of upper and middle story). Woody species very close to the sampling points were taken for species richness estimation [21]. At every sampling point, number of individuals per plot counted, DBH was measured by caliper, height by hypsometer, and crown diameter by measuring tape, were measured recorded.

Plant species determination was done with the help of local communities, and identification of the scientific names of species was carried out using books of Edwards [22], and Woldemichael [23,24].

Data analysis

The structure and composition of woody species were determined through quantitative analysis. For the determination of species structure, parameters such as height, important value index (IVI), which includes relative frequency, relative density, and relative dominance, were calculated following Leul [25], and Newton [26]. Basal area, frequency, density and canopy cover were also measured. To determine the species composition, diversity indexes (Shannon diversity index, Simpson diversity index, and evenness) were computed following Newton [26].

Crown area was calculated following (Crown area= π (0.5 * average crown diameter)^2). The Shannon diversity index was calculated as:

$$H' = \sum_{i=1}^{s} (P_i)(\ln P_i)$$

Where: H′=index of species diversity, S=number of species, pi=proportion of total sample belonging to the i^{th} species, ln=natural log. Simpson diversity index was also calculated as:

$$SI = \sum_{i=1}^{s} P_i^2,$$

Where: SI = Simpson's index of species diversity, S = number of species, pi = proportion of total sample belonging to the i^{th} species. Evenness (E') was calculated as Begon [27]:

$$E = \frac{H'}{\ln S}$$

where H'=is the Shannon diversity index, S=is the number of species in a particular elevation contour.

Two way ANOVA was carried out at P<0.05 with the help of (SPSS versions 16), agroforestry practices and elevation were considered to analyze the structure and composition of woody species. Least significance difference (LSD) test was used to separate the means.

Results

Dominant agroforestry practices in the watershed

The common agroforestry practices in the watershed are homegardens, parklands, woodlots and boundary plantation. However, there is also alley cropping and soil erosion control with woody perennials in some households. The homegarden (HG) of the study site is *Enset-coffee* based. Woody species such as *Persea americana*, *Croton macrostachyus*, and *Cordia africana* are mainly dominating the upper story while *Enset ventricosum, Coffee arabica*, *Rhamnus prinoides* and *Musa accuminata* dominate the middle story. Whereas, different vegetables, root and tuber crops and pulses such as *Brassica integrifolia*, *Capsicum frutescens*, *Solanum tuberosum, Ipomoea batatas*, *Dioscorea alata, Colocasia esculenta, Phaseolus vulgaris,* and *Pisum sativum* dominate the lower strata/on ground.

The main crop component in homegardens and parklands are *Dioscorea alata, Colocasia esculenta*, *Solanum tuberosum, Ipomoea batatas*, *Phaseolus vulgaris*, *Manihot esculenta* (*kassava*), *Brassica oleracea* (cabage), *Enset ventricosum, Musa accuminata*, *Pisum sativum*, *Coffee arabica* and *Zea mays*. The most important agricultural crops such as *Eragrostis tef*, *Enset ventricosum, Ipomoea batatas*, *Solanum tuberosum*, and *Phaseolus vulgaris,* and plantation crop such as *Coffee arabica*. These crops were integrated together in the same land management unit, except *Eragrostis tef* and *Phaseolus vulgaris* which are poorly integrated in simultaneous agroforestry practices.

Among the tree component of traditional agroforestry practices, *Cordia africana*, *Acacia sieberiana*, *Maesa lanceolata*, *Croton macrostachyus*, *Ficus* species (in the upper and middle slope) and *Moringa oleifera* (in the lower slope) are the most chosen woody species in homegardens and parklands for multiple products and services.

Structure and composition

A total of 32 woody species belonging to 19 families were recorded in the three agroforestry practices. The family Fabaceae was 28%, (9 species) which was the dominant family of the woody species recorded in the study area. Following this, Euphorbiaceae was 13%, (4 species) which was the commonly observed family among woody species. However, many of the families were represented by single species. From this species, 69% (22 species) were indigenous and 31% (10 species) were exotic (Table 1). From the indigenous species, two were endemic to Ethiopia (*Erythrina brucei* and *Millettia ferruginea)*. The largest indigenous species were recorded in homegardens; followed by parklands while woodlots were absent in indigenous species.

In terms of woody species distribution across agroforestry practices, 54% (14 species) of woody species existed only in homegardens, 19% (five species) occurred only in parklands whereas 4% (one species) occurred only in woodlot. Again, 23% (6 species) were found in both homegardens and parklands, whereas no species were found in common to all agroforestry practices (Table 2). Consequently, homegardens were highest in species diversity (20); followed by parklands (11) and woodlots (only one).

Seven woody species (27%) existed in common among the three elevations. Six unique woody species (23%) were recorded in upper contour. Again, five unique woody species (19%) were recorded in middle elevation, whereas one species was uniquely recorded only in the lower elevation. Common woody species in upper/middle and

Woody species	Vernacular name	Family name	Origin
Asteracantha longifolia nees.*	Xuxuwa	Acanthaceae	E
Acacia senegal (L.) Willd.*	Gaammo Gaadiya	Fabaceae	I
Acacia sieberiana DC.	Gara	Fabaceae	I
Albizia gummifera (J.F. Gmel.) C.A. Sm.	Shuwa/ Chata	Fabaceae	I
Annona senegalensis Pers.	Eta	Annonaceae	I
Brucea antidysenterica J.F. Mill.	Shulshudhya	Simaroubaceae	E
Carica papaya L.	Papaya	Caricaceae	E
Casimiroa edulis Llave & Lex.*	Kasmiree	Rutaceae	E
Citrus sinensis L.	Birtukaniyaa	Rutaceae	E
Coffea arabica L.	Tukkiyaa	Rubiaceae	I
Cordia africana Lam.	Moqotta	Boraginaceae	I
Croton macrostachyus Del.	Anka	Euphorbiaceae	I
Entada abyssinica Steud. ex A. Rich.*	Kontre	Fabaceae	I
Erythrina abyssinica Lam.Ex.Dc.	Korra/ Quarra	Fabaceae	I
Erythrina brucei schweinf.	Korch /Bortwa	Fabaceae	I(en.)
Eucalyptus camaldulensis Dehnh.	Zafiya	Myrtaceae	E
Euphorbia candelabrum Kotschy	Akirsa	Euphorbiaceae	I
Euphorbia tirucalli L.	Maaxxuwa	Euphorbiaceae	I
Faidherbia albida (Del.) A. Chev.	Odoruwa	Fabaceae	I
Ficus sycomorus L.	Wolaa	Moraceae	I
Ficus thonningii Blume*	Etta	Moraceae	I
Maesa lanceolata Forssk.*	Gergecuwa/ Gergecho	Myrsinaceae	I
Mangifera indica L.	Manguwa	Anacardiaceae	E
Manihot esculenta Crantz	Cassava /Mita Boyiya	Euphorbiaceae	E
Millettia ferruginea (Hochst.) Baker	Zage/ Zagiya	Fabaceae	I (en.)
Moringa oleifera Lam.	Moringa	Moringaceae	E
	Mayluwa	Fabaceae	I
Olea africana Mill.	Wogara	Cuspidate	I
Persea americana Mill.	Avocadosiya	Lauraceae	E
Podocarpus falcatus (Thunb.)* R.Br. ex Mirb.	Ziga	Podocarpaceae	I
Prunus africana (Hook.f.) Kalkm.	Garbia	Rosaceae	I
Rhamnus prinoides L'Hérit.	Geeshuwa	Rhamnaceae	I

Note: The letter I is for indigenous, E for exotic whereas en. is for endemic species. Similarly T is for tree and S is for shrub. * Sign is for woody species that exist very adjacent to the sample plot and used for species richness estimation in the area

Table 1: Woody species in traditional agroforestry practices of Gununo watershed.

Elevation	Agroforestry practices	Simpson	Shannon	Evenness
Upper	Homegarden	0.88	2.23	0.61
	Parkland	0.8	1.63	0.5
	Woodlot	0	0	0
Middle	Homegarden	0.84	2.16	0.52
	Parkland	0.81	1.56	0.5
	Woodlot	0	0	0
Lower	Homegarden	0.83	1.67	0.48
	Parkland	0.8	1.54	0.5
	Woodlot	0	0	0

The highest relative frequency exhibited in homegarden was for *Coffea arabica, Persea*

Table 2: Tree species diversity in agroforestry practices of Gununo Watershed.

middle/lower were two (8%), and five (19%) respectively. No common woody species were encountered to the upper and lower elevation. The upper and middle elevations have fewer common species than the middle and lower contours. Consequently, the middle elevation was highest in species richness (19): followed by upper (15) and lower elevation (13).

The Shannon, Simpson and evenness diversity index were highest in homegardens (average H'=2.02, Simpson index=2.55 and evenness=0.54), parklands (average H'=1.58, Simpson index=0.8 and evenness=0.5) and woodlots (average H´=0, Simpson index 0 and evenness=0) in decreasing order. Since, the woodlots is composed of single species, the diversity index was relatively zero. Comparing homegarden and parkland, diversity indices were highest in homegarden particularly to upper, middle and lower elevation in decreasing order (Table 2).

americana and *Cordia africana* while the highest relative density was recorded for *Coffea arabica, Cordia africana* and *Croton macrostachyus*. The relative dominance was highest for *Coffea arabica*, *Euphorbia candelabrum* and *Rhamnus prinoides*. The important species according to important value index was *Coffea arabica*, *Euphorbia candelabrum* and *Coffea africana* in deceasing order (Table 3).

The highest relative frequency was exhibited for *Cordia africana, Euphorbia tirucalli* and *Moringa oleifera* in parkland while the highest relative density was recorded for *Ficus sycomorus* and *Millettia ferruginea*. In addition, the highest relative dominance was recorded for *Coffea arabica*, *Faidherbia albida* and *Moringa oleifera* in parkland. Further, the important species in parkland according to important value index was *Cordia africana*, *Moringa oleifera* and *Euphorbia tirucalli* in deceasing order (Table 4).

and Homegarden (7.15 m). There was significant difference in density and crown cover among agroforestry practices. Hence, woodlots were the highest in density and crown cover (Table 5).

Significant difference in density/ha across elevation gradients was observed between middle and lower elevations. Consequently, the highest density/ha was in the middle elevation (Table 6).

Discussions

Structure and composition of woody species

Homegarden, parkland and woodlot are the most commonly used traditional agroforestry practices in Gunono watershed. The traditional agroforestry practices of the watershed are among the commonly known agroforestry practices in Southern Ethiopia [28,29] and throughout tropics [9]. Consequently, within these traditional agroforestry practices different woody species were dominating the upper and middle story. The dominancy of fruit and timber trees in the upper story is related to farmers' tree species preference. Consequently, the woody species, plantation crops and agricultural crops are chosen due to their shade, soil fertility improvement, less competitive effect to middle and lower story, and income generation such as timber production. For example *Enset* is chosen because of its drought resistance, good in erosion control, soil fertility enhancement and staple food source in the area. Fruit tree (*Persea americana*) and timber tree (*Cordia africana*) were also reported to mainly dominate the shade canopy layer in the traditional coffee agroforests of South Ethiopian [13] while species of *Enset* and coffee was also reported to dominate the middle story in Dryland regions. In addition, different vegetables, root and tuber crops and pulses found in lower strata/on the ground in the study area. This is in line with [30].

Species name	RD	RF	RDOM	IVI
Coffea Arabica	92.02056	18	22.25151	132.2721
Euphorbia candelabrum	0.057623	2	21.96966	24.02728
Cordia Africana	2.542204	10	10.55404	23.09625
Persea americana	0.606166	12	3.281196	15.88736
Rhamnus prinoides	0.576232	4	10.98483	15.56106
Croton macrostachyus	1.091808	6	7.708653	14.80046
Annona senegalensis	0.276591	6	5.858576	12.13517
Mangifera indica	0.712433	10	0.976438	11.68887
Brucea antidysenterica	0.293355	6	2.662989	8.956343
Erythrina brucei	0.115246	2	6.590898	8.706144
Manihot esculenta	0.834549	6	0.631329	7.465878
Erythrina abyssinica	0.057623	2	2.196966	4.254589
Acacia sieberiana	0.230493	4	0	4.230493
Euphorbia tirucalli	0.288116	2	1.098483	3.386599
Citrus sinensis	0.038415	2	1.220537	3.258952
Carica papaya	0.115246	2	0.732322	2.847568
Prunus africana	0.057623	2	0.732322	2.789945
Myluwa (local name)	0.057623	2	0.366161	2.423784
Olea africana	0.028812	2	0.183081	2.211892

Note: RD means relative density, RF means relative frequency, RDOM means relative dominance, IVI means important value index

Table 3: Importance value index of woody species for homegarden in Gununo Watershed.

Species	RD	RF	RDo	IVI
Cordia Africana	44.74034	41.66708	37.45729	123.8647
Moringa oleifera	15.97869	8.333417	20.50582	44.81793
Euphorbia tirucalli	18.64181	16.66683	2.734109	38.04275
Faidherbia albida	5.99201	8.333417	23.58169	37.90712
Maesa lanceolata	6.657789	8.333417	5.468218	20.45942
Ficus sycomorus	3.994674	8.333417	6.151745	18.47984
Millettia ferruginea	3.994674	8.333417	4.101163	16.42925

The highest woody species length was observed on woodlot (19m) followed by parkland (10.3m)

Table 4: Important value index of woody species in parkland agroforestry practice in Gununo Watershed.

AFP	Den/ha	Cc/ha (%)
Homegarden	1,125.23 ± 334.6 b	15.81 ± 3.06 b
Parkland	8.79 ± 1.3 c	0.74 ± 0.14 c
Woodlot	28,600.13 ± 1772 a	94.35 ± 4.09 a
P value	P<0.0001	P<0.0001

Note: Mean value is shown for agroforestry practices and values next to ± indicate the standard error of the mean. ns refers to not significant. Den/ha and Cc/ha means density per hectare and crown cover per hectare, respectively. These values were the transformed into log scale for comparison before ANOVA

Table 5: Woody species structural parameter within agroforestry practices in Gununo Watershed.

Elevation	Den/ha	Cc/ha (%)
Upper	10,277.98 ± 5072.3 ab	32.41 ± 14
Middle	11,012.54 ± 5383.547a	37.93 ± 15.2
Lower	8,443.64 ± 3697.6 b	40.55 ± 14.9
P value	P=0.027	Ns

Note: Mean value is shown along elevation level and values next to ± indicate the standard error of the mean. ns refers to not significant. Den/ha and Cc/ha means density per hectare and crown cover per hectare, respectively. These values were transformed into log scale for comparison before ANOVA

Table 6: Woody species structural parameter along elevation gradient in Gununo Watershed.

The majority of woody species in the watershed was represented by the family of Fabaceae and Euphorbiaceae. These families were also dominant in the south-eastern rift valley escarpment of Ethiopia [31], Southern Tigray [25] and other tropical region such as SW china [25]. Among these family woody species such as *Erythrina brucei* and *Millettia ferruginea* are under red list of endemic trees of Ethiopia [32]. The existence of these species in traditional agroforestry practices showing that it has given the advantage of conserving these species.

Variation in structure and composition of woody species among agroforestry practices in the study area is attributed to the complex nature of homegarden; which is related to the diverse products expected from it. Whereas, simple structure of woodlot is due to that it is composed of single species. Misana [33] also found species diversity and richness differences among agroforestry practices. In relation to this, higher diversity indexes in homegarden (followed by parkland and woodlot) is attributed to difference in distribution of number of individuals and species richness as a result of variation in woody species efficiency and farmers species preference. Consequently, higher species diversity and richness of homegarden than parkland and woodlot is consistence with the claim of high tropical homegarden complexity, species richness and diversity than other agroforestry practices in both vertical and horizontal arrangement [9,12]. In addition, highest even distribution of woodlot than parkland and homegarden is related to the dominant of single species in woodlot i.e. *Eucalyptus* tree.

The average Shannon index for tree diversity (H´=2.02) and evenness (1.61) in homegarden of the study area was higher than previous *Enset-Coffee* agroforestry systems of the Southern Ethiopia (H´=1.41). However, species richness in homegarden of the study area was lower than Sidama agroforestry (120), Southern Central Highlands of Ethiopia (64) [18] and fruit tree diversity (104) in homegarden of Western Amhara of Ethiopia [34]. In addition, evenness of homegarden of the study area was lower than fruit tree diversity (0.69) in homegarden of Western Amhara of Ethiopia [34].

Parkland agroforestry of the study area had lower Shannon index as compared to the parklands in the region of semi-arid West Africa (H´=1.737) [19], Northern Togo (H´=4.53) [35] and Queens County, New York (H´=2.17 and Simpson=0.162) [36]. The species richness in parkland of the study area was observed to be lower than Northern Togo (21) [35] and Queens County, New York (13 to 19) [36]. Consequently, these variations of species diversity among different areas could be associated with difference in species structure and composition of woody species i.e. due to variation in topographic variables, moisture availability, nutrient availability [14]. In addition, species adaptability in different area, farm characteristics such as farm size, shape and nature of cropping pattern [15,7] and age of agroforestry practices can also determine the species diversity in this agroforestry practice.

Additionally, lower species diversity in the agroforestry practices of the study area as compared to reports of Southern Ethiopia could be probably related to higher population growth, land shortage and deforestation. Although, homegardens are appreciable in conserving the species diversity of the area and to reduce deforestation, population growth was reported to be the main cause for land degradation in Gununo area [4].

High species diversity and richness in middle/upper elevation can also be attributed to population pressure i.e. expansion of settlement from lower to higher elevations. High population growth and pressure in the lower elevations is mentioned to be the cause for deforestation and land scarcity (focus group discussion with elders). Gautam [37] has also found species diversity and richness was decreased in the lower elevation than upper. Variation in structure and composition of woody species along elevation is linked to environmental variability such as elevation/topographic effect [13], soil type/depth, species adaptability and management variation etc. [15].

Variation of IVI for various woody species among agroforestry practice is related to difference in species preference by farmers, difference in growth performance of species, number/existence of individual/dominance per plot, basal area and agroforestry plot area. For example high relative frequency of woody species could be linked with high species preference by farmers i.e. those frequently existed woody species are considered to be fairly fast growing, shade tree, tolerable for different managements and provide different uses like firewood, timber, etc.

The greater tree height in woodlot is linked to fast growing Eucalyptus species dominating woodlots in the study area. The high planting density increases competition for light among individuals and facilitates taller height growth in woodlots [6]. High dominance/density of *Eucalyptus* is due to high market access and value of eucalyptus in lower elevations. The market demand of Eucalyptus species, is coupled with land scarcity in the lower elevation to force farmers to plant fast growing and high market value Eucalyptus species.

Highest woody species density per hectare in the middle elevation is linked with species richness of the elevation and more land cover. Also, high crown area in the lower elevation is attributed to the dominancy of Eucalyptus woodlot in lower elevation with closer spacing (about 0.5 m spacing).

Conclusions

Homegarden, parkland and woodlot are the main agroforestry practices in the land use systems of Gununo watershed, Wolayitta, Ethiopia. The natural vegetation in the watershed is removed due to high population growth and associated deforestation for crop production. Land degradation is still widespread in the watershed despite some efforts made for tree planting and agroforestry development activities are promising. The agroforestry practices in the area holding and conserving more woody species and saved the endemic and endangered species.

The structure and composition of woody species vary among agroforestry practices: homegardens had shown higher complexity in structure and species diversity, while woodlots being monoculture, mostly *Eucalypus* and *Gravellia* species. The effect of elevation gradient on some of the studied parameters was not significant. However, woody species density/ha and species richness found to be highest in middle elevation.

Recommendations

Based on the result and discussion, the three dominant traditional agroforestry practices in the study area should be continued with professional advice to encourage it as a means of biodiversity conservation and sustainable land use system. Agroforestry practices with high species diversity, such as homegarden practices must be promoted to lower elevation where species diversity is very limited due to conventional agriculture system and tree plantation with single species as woodlots.

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