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Assessment of Farm Characteristics and Woody Species Diversity in Hadiya Zone, Southern Ethiopia

Yohanneshoramo More[1] • Kibemo Detamo Aga[2*]

[1]*Department of Natural Resource Management, Wachemo University, Ethiopia*
[2]*Department of Geography and Environmental Studies, Wachemo University, Ethiopia*

*Corresponding Author Email: kibemodetamo86@gmail.com

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Abstract: Diversification of trees and other agricultural crops allowed the traditional agroforestry systems of southern Ethiopia to be considered as sustainable farming systems. But their sustainability has been threatened overtime. The study was conducted in Hadiya zone, southern Ethiopia with the aim to characterize tree species diversity on farms and to investigate link of tree species diversity to farm characteristics. A complete on-farm tree inventory was carried out on farms of 108 randomly selected households. A total of 108 trees and shrub species were recorded, of which 24% were exotics. The mean number of tree species per farm was 29, ranging between 11– 65. The highest number of tree species was recorded relatively closest to the market center. Thirteen different farm field types were identified, of which "enset" was with largest number of tree species. The highest and lowest mean number of tree species was identified and recorded. Dissimilarity in composition of tree species among the districts ranged between 0.30 – 0.45. A significant correlation (P<0.05) was found between farm size, wealth status and distance of farms from the market.Woody species diversity is well acknowledged in the study area but further studies of woody species in relation to usage diversity seem important.

Keywords: Trees • Diversity • Similarity • Correlation • Wealth status

Introduction

In most parts of the developing world, rural people recognize the role of trees in providing a number of important goods and services (Mensah et al., 2016; Kewessa, 2020). Farmers actively planting or protecting trees on their farms can be seen as an indicator of the fact that they appreciate trees in their farming systems (Endale et al., 2017). Farmers in many situations have historically taken up the planting and management of trees on their lands, to provide the needed outputs. In a study conducted in the Middle Hills of Nepal, there was a fourfold increase in the density of trees on farms in crop-growing areas, particularly fodder- and fruit-tree species (Christensen et al., 2019). Similar trends have been observed in Kenya and other regions of the tropics (Ajayi et al., 2020). Farmers generally do care for diversity in their farming systems. Increasing environmental degradation, particularly deforestation, thus calls urgently for increasing tree planting of the right species at the right place for the right purpose or for improvement of the management system of existing tree resources on farmlands, rangelands and other areas (Ayyam et al., 2019). Diversification of construction-wood and timber production may be more relevant, although expected relevance will need to be tested with communities in the first place (Schyra et al., 2019).

Studies in several other areas showed that farmers are using their lands for planting tree species of economic value on the farm, usually around the houses, working out overtime the most efficient and sound mixture and structure of different species (Haque et al., 2018). A study by Kacholi (2018) on the analysis of farmers' preferences for niches for integration of trees into an existing landuse system, revealed that species considered high in value and fragile, are preferably integrated

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into home-gardens (species, which are the sources of cash income to the farmers). According to the survey conducted by Kehlenbeck et al. (2016) on the incidence of indigenous tree planting in the humid tropics of West and Central Africa, it appears that the majority of trees occurred in perennial tree-crop systems in coffee agro forests and home-gardens, and rarely in the food crop fields.

To investigate the distribution of tree species on farmlands for various products and services, it may be beneficial to investigate the relationships of some farm and household characteristics with tree species richness and use-diversity (Schyra et al., 2019). This general issue, in Hadiya zone where information on the relationships of farm characteristics with on-farm tree species diversity among farms is not studied. Only a number of studies, however, have been conducted on the agroforestry landuse systems of home-garden species diversity (Kebebew, 2019; Pietsch et al., 2019) and other studies at farm-level tree-species diversity (Mengistu and Asfaw, 2016). However, none of them have conducted their studies in Hadiya zone on how farm related characteristics are correlated with on-farm tree-species diversity. The focus of this study is therefore to understand the relationship of farm characteristics with integration of tree species on different farms with aim to characterize tree species diversity on farms and to investigate tree species diversity are linked to farm characteristics.

Materials and methods

Description of the Study Area: The study area is geographically located in $7^0$07'- $7^0$92'N Latitude and $37^0$29'-38^0 13'E Longitude. Topography of the study area is rugged high land and hilly areas with range of slope from 2-35 percent. Generally the terrain is mountainous, undulating and broken type that is very much prone to soil erosion. The administrative town of Hadiya zone is Hosanna which is situated North of Hawassa (capital city of South Nations Nationalities Regional State), 198 km away from it.

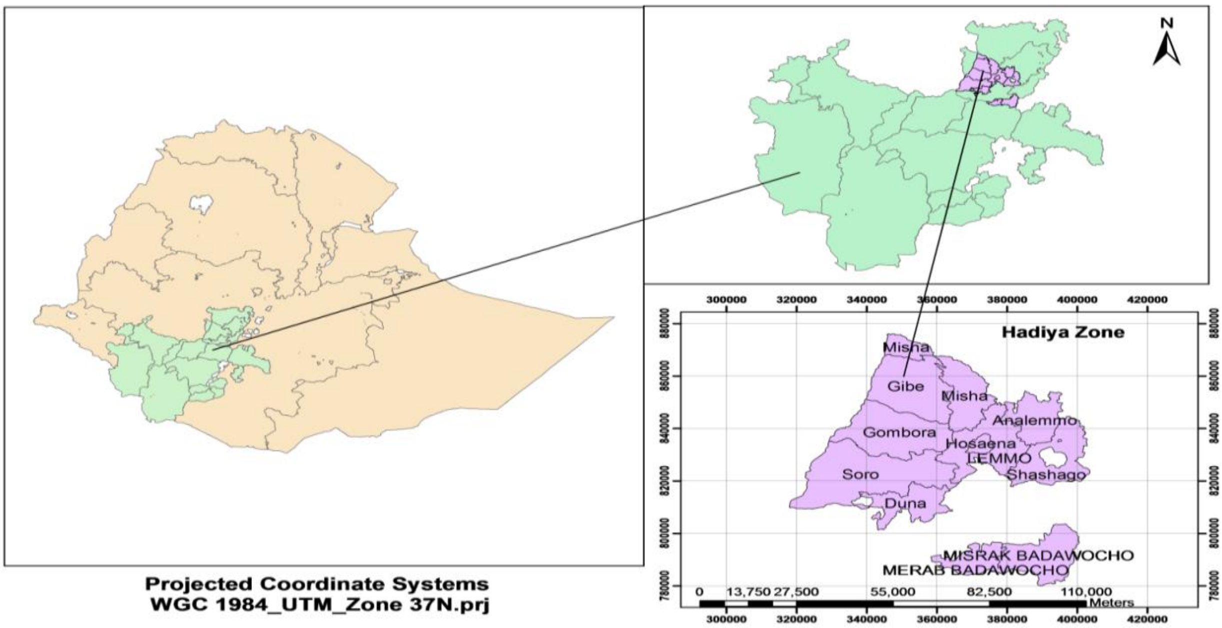

Figure 1 Map of study area (Source: Own survey, 2020)

Historically, dense indigenous natural forests cover Hadiya zone, but the distribution of natural vegetation is declining from time to time, owing to human interference. Currently forest coverage of the study area is only 14% of the total land area (DAaNRD, 2012). Tree species scattered on farms include, *Podocarpus falcatus*, *Ekbergia capensis*, *Hagenia abyssinica*, *Cordia africana*, *Milletia ferruginea*, *Croton macrstachyus*, *Schfflera abyssinica*, *Ficus sur*, *Prunus africana* and

Erythrina abyssinica while *Eucalyptus spp* are grown around the boundaries, life fences and woodlots.

Agriculture is the principal source of livelihood for the community. It is characterized by subsistence-level mixed farming of rain-fed crops, and livestock production together with trees planted for agroforestry. In the zone crops such as "enset" (*Enset venrtricosum*), barley, maize, wheat and "teff" are the most commonly cultivated crops in order of their importance. "Enset" is the staple food crop for the majority while coffee (*Coffee arabica*) and "chat" (*Chata edulis*) are the dominant cash crops in some peasant associations. Climatically, the district is classified into mid-altitude and high-altitude, and the highland part holds more than 60% of the total land area. It has a bimodal rainfall distribution with a mean annual precipitation varies between 801 - 1400mm and a mean annual temperature of 10.54°C - 22.54°C(DAaNRD, 2012).

Sampling Techniques

In order to have a fair representation of sites, stratified purposive sampling procedure was used. From the zone, four representative districts (Lemo, Soro, Misha and Duna) and 108 households were selected for this study. 20 key informants of which 5 key informants per district were selected for classifying households in to three main wealth categories (poor, medium and rich). Main criterion used by the key informants (selection was done by adapting techniques used by Den-Biggelaar and Gold (1995).

Table 1: Characterizing wealth status

	Study districts and rank[a]			
Criteria	Lemo	Soro	Misha	Duna
Farm size	1	1	1	1
Size of enset field	2	3	2	2
Grazing field	4	4	4	4
Size of cattle	3	2	5	5
Size of coffee field	5	5	3	3
Family size	6	6	6	6

Within-districts the ranking criteria range from 1, being the most important, to 6 being the least important (Source: Field survey, 2020)

For wealth status characterization totally 671 households were proportionally selected from four districts (Lemo 180, Soro 230, Misha 145 and Duna 135). Households in the district had been classified as poor, medium and rich based on the size of farm and grazing land, number of "enset" and coffee planted and number of cattle which are criterion given by the key informants to classify wealth status (Table 1).

Data Collection

A complete on-farm tree inventory (trees defined as woody or ligneous plants including shrubs) was made on farms of 108 households by adapting technique of Schyra et al. (2019). At farm level, the total area of the farm and the area of each farm field were measured, and the different tree species grown on it were counted and listed, including local and scientific names. In identifying tree species occurring on farmers' fields, local names provided by the owners were identified in the herbarium. Data were collected by the researcher and enumerators (agricultural technicians employed for the purpose of data collection).

Data Analysis

To examine the relationship between diversity indices and farm characteristics, farms were quantified and characterized in terms of their degree of diversity. Analysis of data was carried out using Statistical Package for Social Sciences (SPSS) Version 25. To assess the relationships between farm characteristics and tree diversity and number of trees on farm, Pearson Correlation with Tukey-test and indices were used in consideration of Important Value Index (IVI) (Cayuela et al., 2006; Strong, 2016; Magurran et al., 2018).

Table 2: Characteristics of study sites (n=108)

Factors	Mean	Min-max[1]	Std.
Family size (persons)	8.81	3.00 - 18.00	3.72
Farm size (ha)	1.09	0.18 - 4.00	0.88
Distance of the farm from the forest (km)	7.49	0.50 - 14. 50	4.36
Distance of the farm from the market (km)	7.74	0.50 - 15.00	4.53
Age of HH head (Years)	50.44	24.00 - 95.00	18.61
Sex of the head of HH (%)	4% female	96 % male	
Year of possession of the farm (years)	29.81	4.00 - 76.00	17.70
Farm labor force (persons)	5	1- 15	3.6
Education status of the HH head (class)	4.1	0 – 10	3.1

Measurement of Diversity

The species diversity on crop fields, home gardens and natural forest were estimated using species richness, Shannon diversity index, Simpson diversity index, Fisher's α (alpha) and Shannon evenness. Species richness is the total number of species in the community (Ampoorter et al., 2020). The Shannon-Wiener function is the most widely used type of diversity index (Abdulhakim et al., 2017). It measures the uncertainty that, how difficult it would be to predict correctly the species of the next individual collected in the sample (Ampoorter et al., 2020). Two components of diversity are combined in the Shannon diversity index: (1) the number of species and (2) equitability or evenness of allotment of individuals among the species. The Shannon diversity index is calculated as:

$H' = - \sum p_i \ln p_i$ where;

H' = Shannon diversity index,

P_i = proportion of individuals found in the i^{th} species.

Values of the index (H') usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (Abdulhakim et al., 2017).Usually, Shannon diversity index place most weight on the rare species in the sample.It is also moderately sensitive to sample sizes (Magurran et al., 2018). The Simpson's diversity index was derived from probability theory and it is the probability of picking two organisms at random which are of different species (Magurran et al., 2018; Ampoorter et al., 2020). We get Simpson's diversity (D):

$$D = 1 - \sum p_i^2$$

Where D = Simpson's diversity index

P_i = as described above

Fisher's *α* (alpha) is a widely used and popular diversity index size. It is less sensitive to variations in sample size and it is completely independent of sample size if N > 1000 size. The index is obtained from the equation (Goenster et al., 2009; Senbeta et al., 2013; Magurran et al., 2018).

$$\alpha = \frac{N(1-x)}{x}$$

Where α = Fisher's alpha

N = the total number of individuals

x is estimated from the iterative solution of;

$$\frac{S}{N} = \frac{1-x}{x[-\ln(1-x)]}$$

Although as a heterogeneity measure Shannon and Simpson diversity indices take into account the evenness of abundance of species, it is possible to calculate a separate additional measure of evenness. The ratio of observed Shannon index to maximum diversity (Hmax = ln S) can be taken as a measure of evenness (E) (Abdulhakim et al., 2017; Magurran et al., 2018; Ampoorter et al., 2020). Equitability (evenness)

$$J = \frac{H'}{H'_{max}} = \frac{\sum_{i=1}^{s} p_i \ln p_i}{\ln s}$$

Where s = the number of species

H', and P_i = as above

The higher the value of J, the more even the species is in their distribution within the sample (Abdulhakim et al., 2017).

Results and Discussion

Farm Characteristics and Woody Species Diversity: The average farm sizes of the sampled farms at the study sites were 1.1 ha per household, ranging "between" 0.18 to 0.87 ha for poor, 0.54 to 1.23 ha for medium and 1.12 to 4 ha for rich households (Table 3). Overall, when compared at site level, there was significant difference in average farm sizes belonging to the different wealth categories (P<0.05). Comparison at both sites showed that wealthy households had more farm sizes than both medium and poor households but farm sizes from the same wealth status were not significantly different. Mean of farm size (ha) of sample farms of three wealth categories at two study sites were summarized in the (Table 3).

Table 3: Characterization of farm lands

Study sites	Wealth status	Farm size (ha)		
		Mean	Std	Min – max
Wosheba	Poor	0.35c[1)]	0.14	0.18 – 0.64
	Medium	0.92b	0.19	0.65 -1.23
	Rich	2.17a	0.67	1.20 – 3.25
Ana-ballessa	Poor	0.36c	0.22	0.18 – 0.87
	Medium	0.77b	0.18	0.54 – 1.10
	Rich	2.06a	0.927	1.12 – 4.00
Overall mean		1.1		0.18 – 4.0

1) Different letters following vertical mean values indicate significant difference between categories (P<0.05) at sites (Source: Field survey, 2020)

Distribution of Major Farm Fields

Farmers in the study sites divide their farms in to different farm fields. In this study about thirteen major field types were identified. When the overall average field types are considered, the highest proportion of field areas were allocated to the "enset" field followed by maize and homestead respectively (Figure 2). The percentage of the field was taken out of the total 64 ha of farms surveyed. The different field types also vary with the wealth status of the household (Figure 2).Wealthy households have larger field of all types.

Species Richness and Diversity of Trees

A total of 99 species of trees and shrubs were recorded. The average number of tree species per farm was 29 with values ranging from 11 to 65 (Table 4). Frequency of occurrence of species across the farms was rather variable. Percentage frequency of tree species with lists of their names is presented in Fig 3. More than 25 species of trees and shrubs including the fruit tree *Persea americana* occurred in more 50% of the sampled farms.

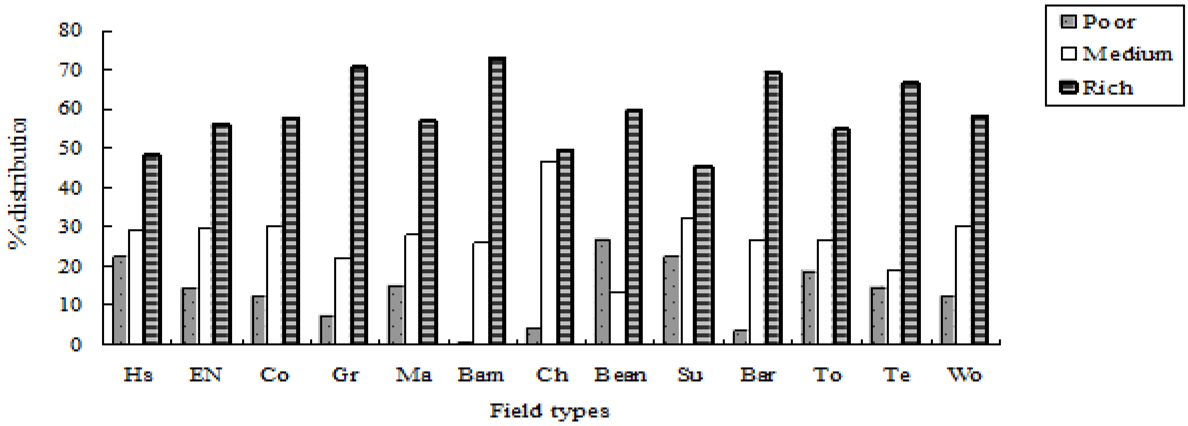

Figure 2: List of tree species identified in the study area (Source: Field survey, 2020)
Bar: barley, Ma:maize, Su:sugarcane, Bam:bamboo, Co:coffee, Gr:grazing, To:tobacco, Hs:homestead, EN:enset, Te:teff, Ch:chat and Wo:woodlots

Croton macrostachyus was the most frequent tree species, and occurred in 97% followed by *Vernonia auriculifera*, *Milletia ferruginea*, *Euphorbia abyssinica* and*Vernonia amygdalina*, each occurring in 95%, 94%, 93%, 92% and 91% of the sampled farms respectively, while 13 tree species were very rare each occurring only on one of the farms (Figure 3). Of the total number of species, 34 were exotics, while the remaining 65 species were indigenous. The highest number of exotic tree species was recorded at Lemo district, which is relatively closer to the local market, while the lowest was at Mishadistrict.

The number of tree species varied between sites (F-test, P<0.05; Table 5) and among districts (P<0.05; Table 6). When values of tree species richness at site (peasant association) level are compared, higher mean tree species richness per farm was recorded at the Ana-ballessa site (Table 5). Regarding wealth categories at the site level, a higher mean value of tree species richness was recorded on farms of wealthy households at the Ana-ballessa site with more access to the local market. At both sites, wealth status significantly influenced the number of tree species per farm.

The diversity of tree species in different farms is influenced by a number of factors. Derero et al. (2020) mentioned significant correlation of farm size, distance to major roads and area of woodlots with tree-species richness. Kewessa (2020) provided some examples of correlation of wealth status, farm size and access to markets and farmers' knowledge regarding the maintenance of tree-species diversity. Sthapit et al. (2016) mentioned that gender, age, wealth or social status, action and access to resources, were important to the maintenance of crop diversity. Sthapit et al. (2014) also listed farm size, family size, access to resources and infrastructure and years of education as significant explanatory factors for farmer variety choice. The results from present study showed that farm size, distance of the farms from the forest and market, and wealth status of the households were the most important factors affecting on-farm tree species richness and diversity.

The size of landholding has an important influence on the choice of tree species, arrangement and density, as well as on overall management. The result indicated that the farm sizes varies from 0.18 to 0.87 ha for poor; 0.54 to 1.23 ha for medium and 1.12 to 4 ha for rich households. The farm sizes of poorer households were significantly smaller than those of both medium and wealthy households. Within the farms of different wealth categories, about thirteen major field types were identified. Such a presence of different field types in farms was reported by (Derero et al., 2020; Kewessa, 2020).

The size of fields varied among the households and the type of crops grown. Despite this variation, "enset" and maize fields, together with homestead and "teff" fields, covered about 60% of the farm areas. "Enset" alone accounted for about

25% of the farms because of its high socioeconomic (it is the staple food crop in the area) and ecological importance. The remaining 40% of the areas is composed of other fields, of which coffee and grazing fields make up about 10%. In terms of tree-species richness, fields of coffee and "enset" are the richest. Although the chances of getting more species increases with increasing size of the field, deliberate planting and management also occurs. The use of different types of tree species as shade in coffee and "enset" made these fields to be the richest in terms of tree species. The larger field size and its permanent nature made field of "enset" to have the largest number of tree species. Fields of "teff", barely and chat on average had 2, 3, and 2 species respectively. These fields even when large in area were poor in terms of tree species, since trees are deliberately reduced or avoided on these fields, to reduce or prevent the effect of shade. The same is true to the field of sugarcane where on average only 3 species were found. Fields of homesteads includes front yards that are used for growing and cultivation of different medicinal trees, as burial grounds and for ceremonies. In the front yards, the burial ground is surrounded by different species of trees and shrubs which, for cultural reasons, the local people usually do not cut down. Life fences of *Euphorbia abyssinica*, *Eucalyptus spp*., *Vernonia auriculifera* and *Adathoda schemperiana* serve as boundaries of front and back yards. On the other hand, the woodlots have an average of only 2 species, against the expectation that a field composed of only trees could be the richest in species. This is because of the fact that most woodlots are usually dominated by single species. Field of woodlot even though smallest in terms of area share less than 0.5% and poor in species as compared to other field types, they contributed the highest number of trees (stems) next to "enset" field since trees are densely planted in woodlots. The distribution of major fields among the three wealth categories was not the same. It correlates with the wealth status of the households. On an average, more than 50% of each field types were belonged to the wealthier farmers, but the proportion of chat field on medium farmers' farms was comparable to that of wealthy farmers' farms since it is highly needed cash crop in the study area. Shortage of land was the main hindrance for the very small or absence of some fields such as bamboo on poor farmers' farms.

An attempt was also made to assess the influence of farm size on the number of tree species. Thus, a significant ($r=0.88$; $P<0.01$) positive relationship between farm size and number of tree species per farm was observed. Farm size was also found to be positively correlated with Shannon-Wiener diversity index ($r=0.61$; $P<0.01$). The result showed that higher species richness per farm was found on larger farms. This is because farmers who are constrained by shortage of land, concentrate on fewer species of great utility, and allocate more of their land to food crops, while larger landholders can afford to include different types of tree species. The pattern of increasing tree species richness with increasing landholding was also reported by Sthapit et al. (2016). The significant, positive correlation of farm size and tree species richness per farm also indicates that farm size might play an important role in influencing the farmer's management strategies for diverse tree species.

In this study, the tree species richness was also correlated with wealth status of the households. The highest species richness and Shannon index of diversity per farm were found on farms of wealthier households rather than medium and poor farmers' farms. The difference in farm size among the households was mentioned as a measure of wealth and this was the main factor for wealthy households to have more number of tree species on their farms and this is similar to the results of the study by Sthapit et al. (2014).

The distance of farms from the forest was the other factor found to influence tree species richness and diversity. The results showed that increasing distance of the farms from the forest was positively correlated with tree species richness ($r=0.43$) and with the Shannon-Wiener index of diversity ($r=0.54$). Misha district had a small number of tree species, while Soro district, which is far away from the forest, was highest in terms of mean tree-species richness per farm. This is in agreement with reports of Jara et al. (2017) which indicated that tree-species richness increases as access to natural stocks declines. The closer the village is to the forest, the lower is the interest in tree cultivation. Scarcity of, and access to, off-farm tree resources in a given area was found to influence tree-species diversity at farm level. As population density increases, and as access to off-farm tree resources declines, there is an increase not only in the number of trees, but also in the number of tree species and planting locations in the farming systems (Jara et al., 2017).

Unlike increasing distance of farms from the forest, increasing distance of farms from the market was found to be negatively correlated with tree-species richness and Shannon index of diversity. The highest mean number of tree species per farm was recorded at Lemo, a district which is closer to the zonal capita city. A larger number of exotic tree species was also observed in this village. This is in agreement with the conclusion that tree planting and the number of species may increase with increasing access to markets (Cui and Zheng, 2016; Tenzin et al., 2016; Plieninger et al., 2020), but contradicts the findings of (Derero et al., 2020; Kewessa, 2020), which indicated that species diversity in districts close to market areas is low, because farmers focus on a few commercial crops, especially wealthy farmers with larger farms.

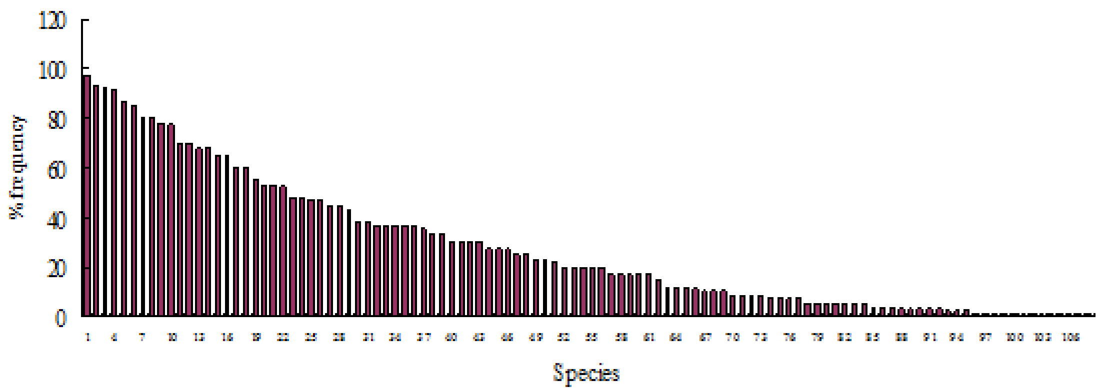

Figure 3: List of tree species identified in the study area (Source: Field survey, 2020)

Table 4: List of Tree Species in the study area

No	Botanical name	No	Botanical name	No	Botanical name	No	Botanical name
1	*Croton macrostachys*	29	*Oleacapensis*	55	*Grevillearobusta*	82	*Cajanuscajan*
2	*Vernoniaauriculifera*	29	*Albizziagummifera*	56	*Anningeriaaltissima*	83	*Callistemon citrinus*
3	*Euphorbia abyssinica*	30	*Juniperusprocera*	57	*Borassusaethiopum*	84	*Embeliaschimperi*
4	*Millettiaferruginea*	31	*Podocarpusfalcatus*	58	*Pinuspatula*	85	*Erythrinabrucei*
5	*Vernoniaamygdalina*	32	*Arundinariaalpine*	59	*Acacia saligna*	86	*Eucalyptus citrodora*
6	*Bersamaabyssinica*	33	*Calpurinaaurea*	60	*Hageniaabyssinica*	87	*Jacaranda mimosifolia*
7	*Ricinuscumminis*	34	*Dracaena steudneri*	61	*Schffleraabyssinica*	88	*Psidiumguajava*
8	*Prunusafricana*	35	*Cassia didimobotrya*	62	*Lippiaabyssinica*	89	*Clausenaanisata*
9	*Rhamnusprinoides*	36	*Leucenaleucocephal a*	63	*Arundodonax*	90	*Casuarinaequisetifolia*
10	*Tecleanobilis*	37	*Ehretiacymosa*	64	*Eucalyptus citriodora*	91	*Diospyrosabyssinica*
11	*Eucalyptus globulus*	38	*CoffeaArabica*	65	*Euphorbia tirucalli*	92	*Ficusthonningi*
12	*Euca. camaldulensis*	39	*OleaAfricana*	66	*Pterolobiumstellatum*	93	*Rosa abyssinica*
13	*Ekbergiacapensis*	40	*Rubussteudineri*	67	*Prunuspersica*	94	*Flacourtiaindica*
14	*Polysciasfulva*	41	*Sesbaniasesban*	68	*Casimiroaedulis*	95	*Ocoteakenyensis*
15	*Syzigeemguineense*	42	*Annonareticulate*	69	*Morus alba*	96	*Oliniarochetiana*

16	*Erythrinaabyssinica*	43	*Chataedulis*	70	*Perseaamericana*	97	*Passifloraedulis*
17	*Perseaamerican*	44	*Syzygeumguineense*	71	*Carica papaya*	98	*Phytolacadeodecandra*
18	*Cordiaafricana*	45	*Musa paradisiaca*	72	*Hypericumrevoltum*	99	*Erica arborea*
19	*Cupressuslusitanica*	46	*Sapiumelipticum*	73	*Schinusmolle*	100	*Ficusvasta*
20	*Diphasiadainelli*	47	*Rubusapetalus*	74	*Acacia melanoxylon*	101	*Premnaschimperi*
21	*Euphorbia pulcherrima*	48	*Maytenusarbutifolia*	75	*Acokantheraschimperi*	102	*Buddlejapolystacha*
22	*Chamaecytisuspalmensis*	49	*Rapaneasimensis*	76	*Dododaeaangustifolia*	103	*Caesalpinadecapetala*
23	*Maesalanceolata*	50	*Acacia decurrens*	77	*Mimusops kummel*	104	*Celtisafricana*
24	*Ficussur*	51	*Citrus sinensis*	78	*Agavaesisalana*	105	*Adathodaschemperi*
25	*Doviyalisabyssinica*	52	*Delonixregia*	79	*Carissa edulis*	106	*Mysrineafricana*
26	*Rhusgultinosa*	53	*Proteagaguedi*	80	*Phoinexreclinata*	107	*Malusdomestica*
27	*Balanitesaegyptica*	54	*Mangiferaindica*	81	*Lantana salvifolia*	108	*Lippiajavanica*

Table 5: Woody species diversity of study sites

	Number of species		Shannon index	Evenness
Site	Mean	Std	(H[1])	(E)
Wosheba	26.00b [1)]	10.49	2.3b	0.53b
Ana-ballessa	32.23a	12.27	2.7a	0.58a
Overall mean	29.17	11.76	2.52	0.58

[1)] Different letters following vertical mean values indicate significant difference (P<0.05) between sites(Source: Field survey, 2020)

The total number of tree species per district varied from 69 at Misha to 84 at Soro (Table 6). Soro district had the highest number of tree species (84) accounting for 78% of the total number of species. Here the mean number of tree species per farm was 32. But one farm in this district had 65 species and it accounted for 60% of the total number of species in all districts. The smallest number of tree species per farm was 11 at Misha where the district average was also lower (Table 6). At all districts, when the overall mean number of tree species per farm is compared, the values were, 23.5, 28.6, 32 and 33 for Misha, Duna, Soro and Lemo respectively. The highest and the lowest mean number of tree species per farm were from Lemo and Mishadistricts respectively (Table 6). Mean tree diversity of farms belonging to three wealth categories at two study sites. Ten farms from each wealth categories were analyzed at each site. The overall contrast of the number of tree species for all wealth categories showed that more number of tree species was found on farms of wealthy households (Table 7).

Table 6: Woody species diversity of study districts

	Number of tree species			Shannon Index (H/)		Evenness
District	Total	Mean	Min-max	Mean	Min-max	E
Misha	69b	23.53b[1)]	11 – 41	2.30b	1.30 - 1.86	0.54b
Duna	75	28.64 a	14 – 54	2.38b	1.5 - 3.02	0.56b
Soro	84a	32.00 a	15 – 65	2.68a	1.70 - 3.50	0.59a
Lemo	80	33.00a	19 – 49	2.74a	2.09 - 3.26	0.61a
Total	108	29.17	11 – 65	2.52	1.30 - 3.5	0.58

[1)] Different letters following vertical mean values indicate significant (P<0.05) difference between districts. (Source: survey, 2020)

Table 7: Wealth status and woody species diversity

Site	Wealth status	Number of species		Shannon index	Evenness
		Mean	Std	H^1	E
Wosheba	Poor	16.50c[1)]	4.53	2.08c	0.56b
	Medium	25.10b	3.48	2.40b	0.58
	Rich	37.56a	9.19	2.55ab	0.60a
Ana-ballesa	Poor	20.40c	4.50	2.27d	0.54b
	Medium	29.70b	4.50	2.70b	0.60a
	Rich	46.60a	7.23	3.15a	0.61a

[1)] Different letters following vertical mean values indicate significant difference (P<0.05) between categories
(Source: Field survey, 2020)

Diversity Indices

Diversity of tree species also varied between sites (Table 5). A comparison of values of diversity indices at the site level showed that higher mean Shannon-Wiener and Shannon Equitability (evenness) indices were from the Ana-ballesa site. The mean values of Shannon -Wiener and evenness at the Ana-ballessa site were 2.7 and 0.58, respectively, while at Wosheba , values were 2.3 and 0.53, respectively. The indices also indicated that farms at the Ana-ballesa site had more species diversity and species richness than those at Wosheba. The Shannon-Wiener index of diversity showed a mean value of 2.52, while the measure of evenness was 0.58. This means that the relative homogeneity of the species in the samples was 58% of the maximum possible even population. Species evenness varied “between” 1.30 - 3.50. The least uniform composition of tree species with evenness value of 0.54 was calculated on farms at Misha district where the number of tree species was lowest. There was variation (P<0.05) in Evenness values at site level (Table 5), district level (Table 6) and wealth categories (Table 7).

With regards to wealth categories, a high mean value of the Shannon-Wiener index was found on farms of wealthy households (Table 7).Variation was detected when Shannon-Wiener index of diversity was compared at the village level, showing that farms at Lemo district which, is closest to the local market, had the highest mean Shannon-Wiener index, while those farms at Misha district had the lowest mean Shannon-Wiener index (Table 6).

Tree Species Diversity in Major Farm Field Types

Variation in tree species diversity at field level was also observed. “Enset” fields were richest in tree species (Figure 4). Although getting more woody species increases with the size of farm fields. The coffee fields, although it covers a small proportion of the area as compared to maize, “teff”, and homestead, was richest in tree species next to “enset” field. “Enset”, coffee and homesteads fields together accounted for more than 40% of the total number of tree and shrub species recorded. Fields of “teff”, barley and chat, even when large, are low in tree species or have no tree species at all.

Fields also vary in their contribution to the number of individual trees (abundance). The distribution of the mean number of stems on the main field types followed a typical pattern (Figure 5). The proportion of stems was highest on “enset” field followed by woodlot and homestead. Fields of “enset”, woodlots, homestead and coffee together accounted for about 60% of the number of individual stems while maize, sugarcane, barley and grazing fields accounted for about 24%. The remaining fields shared 16% of the number of individual stems on farm.

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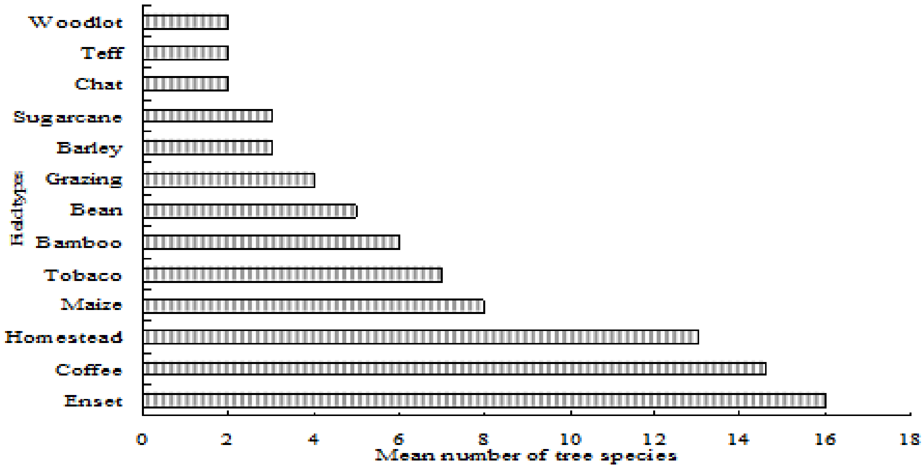

Figure 4: Overall percentage distribution of number of stems on major farm fields: (Source: Field survey, 2020)

Relationship between tree diversity and farm characteristics

Diversity of tree species at farm level was variable among the study districts and household categories, mainly owing to some farm and household characteristics. The correlation analysis revealed that not all factors are important in influencing on-farm tree species richness and diversity. Farm size, wealthy status and market were among the most important factors that influence tree species richness and diversity. In the (Table 8) each factor and its correlation with the number of trees and diversity indices are summarized.

Table 8: Pearson correlation with farm characteristics

Farm characteristics	No. of trees per farm	No. of trees per ha	Shannon index(H1)	Species richness per farm	Evenness
Farm size	0.82**	-0.23(ns)	0.61**	0.88**	0.10(ns)
Number of farm labor force	0.19(ns)	-0.03(ns)	0.19(ns)	0.24(ns)	0.06(ns)
Family size	0.21(ns)	-0.10(ns)	0.19(ns)	0.25(ns)	0.04(ns)
Distance from the forest	0.44**	0.17(ns)	0.54**	0.43**	0.35*
Distance of farm from market	-0.42**	-0.19(ns)	-0.52**	-0.43**	-0.36*
Sex of the head of HH	0.22(ns)	-0.21(ns)	0.05(ns)	0.18(ns)	0.06(ns)
Education status of the HH	-0.16(ns)	0.17(ns)	-0.06(ns)	-0.15(ns)	0.06(ns)
Wealth status of the HH	0.81**	-0.18(ns)	0.63**	0.83**	0.12(ns)
Year of possession of the farm	0.23(ns)	-0.14(ns)	0.16(ns)	0.22(ns)	0.02(ns)
Number of livestock	0.21(ns)	-0.01(ns)	0.17(ns)	0.14(ns)	0.10(ns)
Age of HH	0.125(ns)	-0.21(ns)	0.135(ns)	0.082(ns)	0.043(ns)

Note: ns=not significant; *, **= Correlation is significant at P<0.05, P<0.01 respectively HH=head of the household(Source: Field survey, 2020)

Farm size*:* There was a significant positive correlation between farm size and the number of trees per farm, species richness, and Shannon index of diversity (H/). But correlation of farm size with Evenness or Shannon equitability index was not statistically significant.

Distance of farms from the market: An increasing distance of farms from the market was negatively correlated with the number of trees per farm, Shannon diversity index, species richness and evenness. **Wealth status:** Wealth status is the other factor expected to influence diversity of tree species on farms. The wealth status of farmers was highly correlated with farm size and the variation among the different wealth categories is explained by the size of the farm. The wealth status of households in the study area, which was mainly characterized by the size of the farm, was positively correlated with the number of trees, Shannon index (H/) and species richness per farm. Other socio-economic factors, such as family size, number of farm labor force, age, year of possession of the farm, educational status, sex of the household and number of livestock, have no significant correlation with diversity indices and number of trees per farm. **Dissimilarity in Composition of Tree Species among the Districts**

The variation in composition of tree species among the districts ranged between 30 to 45 % (Table 9). The Misha district had the least dissimilarity (only 30%), which means that they shared 70% of the tree species. On the other hand Lemo district and Misha were 45% dissimilar in tree species composition. Dissimilarity in tree-species composition increased with increasing distance amongdistricts. The dissimilarity of tree species composition among districts were less than 50% which may be because of the fact that they are found within in the same agro-ecology and similar cropping patterns

Table 9: Pair-wise ranking result among districts

No.	Districts	Soro	Lemo	Duna	Misha
1	Soro	--------	0.32	0.35	0.45
2	Lemo	-------	-------	0.38	0.40
3	Duna	-------	-------	-------	0.30
4	Misha	-------	-------	-------	------

(Source: Field survey, 2020)

Farmlands were found to be an important part of the landscapes in terms of their species richness. In the present study, a total of 108 tree and shrub species were recorded. Of the total recorded tree and shrub species, 34 % were exotics (the highest proportion being at Soro district followed by Lemo (38%). The exotic fruit-tree species were also predominant at Lemo district mainly owing to access to market, to information and to extension inputs. This is in agreement with earlier reports of UAS (2017) and Kewessa (2020). In terms of the total number of tree species at the district level, Soro district accounted for 84 species. The fact that the district with the largest number of tree species (Soro) contained 78% of the total number of species shows that districts only contain subsets of all species that occurred in the survey.

The average number of tree species per farm was 29. This figure is comparable to that in a study report by Derero et al. (2020), stated the number of tree species per farm was 21, but higher than the number of tree species per farm as reported by Kewessa (2020). It is also comparable to similar earlier studies conducted elsewhere. Example, Bukomeko et al. (2019) reported a total of 119 tree species for Cameroon farms and by Naidu and Kumar (2016)for Kerala, India where number of tree species per farm ranged “between” 11 to 39. The total and average number of tree species recorded in the present study is also higher than similar studies reported elsewhere: For example, Guillemot et al. (2018) had reported a total of 83 tree species for Nicaragua, and Naidu and Kumar (2016)had reported 16.6 tree species per farm ranging “between” 15.7 to 17.5 for western Kenya. This large number of trees and shrub species recorded in the present study puts farms of the study area among the agro-ecosystems that are rich in tree species. The higher tree species richness and diversity on farms of the present study seems to be related to four factors: the lower degree of commercialization of crop products, the low marketing of wood products that resulted in less intensive exploitation of tree species on farms, the poor road network infrastructure which would otherwise forces farmers to focus on a few selected tree species, together with the culture of the local people in conserving tree species on their farms. The effect of improved road infrastructure on tree-species richness was reported by Kewessa (2020) and Derero et al. (2020). But the number of tree species recorded in the present study is less when compared with the earlier report of Naidu and Kumar (2016) from Meru, Kenya, in which the average number of species per farm was 54 ranging "between" 28 to 97.

Ninety-eight percent of the farms in the present study had more than 11 tree species, the maximum being 65, which was recorded on the largest farm size at Soro district. This figure is in line with earlier report of Derero et al. (2020), in which 88% of the farms had more than 10 tree species, and with the report of Sthapit et al. (2016) for Rwanda, where the number of tree species per farm ranged "between" 12 to 34. The high number of tree species on farms of the present study, about 70 % of which are indigenous to the area, indicates the significant role of these farms in conservation of biological diversity, as reported by from studies on farms elsewhere (Jara et al., 2017).

The Shannon-Wiener index of diversity for tree species on farms of the present study ranged between 1.3 to 3.5 with a mean value of 2.52, while the evenness values ranged between 0.30 to 0.73 with mean value of 0.58. The evenness values are not enough to justify uniformity in composition of tree species. This is expected because not all trees are equally needed by farmers. A similar study, conducted in Kerala, India, yielded Shannon-Wiener diversity indices comparable to the result of the present study, ranging between 1.12 to 3 (Naidu and Kumar, 2016). A mean evenness value of 0.58 indicates that the relative homogeneity of tree species of the sampled farms was 58% of the maximum possible even population. These evenness values are comparable to similar study reported by Naidu and Kumar (2016) where the evenness values ranged "between" 0.24 to 0.71.

The frequency of distribution of tree species on farms was variable. Tree species with a greater economic or ecological value or both were found to be frequently distributed across the farms. *Croton macrostachyus* was the most frequently distributed tree species with an occurrence on 97% of the sampled farms, followed by *Vernonia auriculifera*, *Milletia ferruginea*, *Euphorbia abyssinica* and *Vernonia amygdalina*, each of which occurred in more than 50% of the farms. Thirteen tree species occurred only on one of the farms with low abundance. The low abundance of these species could indicate that the population size might be too low to sustain these species within the agro-ecosystem unless their abundance is increased, as reported by Kindt et al. (2006). Since tree-species diversity is required for the long-term survival of species, tree integration on farms could be one of the areas for conservation. Considerations of tree species diversity may also indicate that the corridors in the farmlands are required to connect fragmented populations in the remaining natural ecosystem.

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