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DIVERSITY, DENSITY AND MANAGEMENT OF TREES IN DIFFERENT AGRO-FORESTRY PRACTICES OF YEM SPECIAL DISTRICT, SOUTHERN ETHIOPIA

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ABSTRACT: Conserving tree species diversity cannot be restricted to forest areas because of increasing encroachment to remaining forests. Agricultural landscapes can also maintain tree species diversity where the native habitats are heavily diminished and/or merit conservation. The present study was conducted in the agroforestry practices of Yem Special District, Southern Ethiopia, to determine the diversity, composition and density of trees, and assess farmers' tree management practices. The data were collected through two consecutive field surveys involving structured household questionnaires administered in 126 households, and making inventory of the woody species. Data were analyzed using one way ANOVA, and Chi-square, Kruskal-Wallis, and Mann-Whitney tests. The status of tree species richness and diversity were quantified for the different agroforestry practices. A total of 100 tree and shrub species belonging to 57 families and 83 genera were recorded in the different agroforestry practices of individual household farms, of which 11 (or 11%) were exotic and 89 (or 89%) native species. The mean value of tree species per household for the overall agroforestry practices was 14.04 and it was found to be significantly different among sites, mainly due to differences in agroecology and road access. Tree species richness was influenced by distance to major roads, wealth status, farm size and family size. The study revealed that the agroforestry practices contribute to the conservation of agrobiodiversity.

Key words/phrases: Agrobiodiversity, basal area of trees, species richness, tree management practices, Yem

INTRODUCTION

One of the major driving forces for unsustainable exploitation and destruction of forests is the growing population and its increasing demand for food and wood products (Geist and Lambin, 2002; Woldeamlak Bewket, 2003; Paré, 2008). Agricultural expansion is, by far, the prominent cause of land cover change associated with deforestation (Geist and Lambin, 2002; Gessesse Dessie, 2007). This in turn is likely to result in fragmentation of natural habitats and degradation of the surrounding ecosystems. Agroforestry is seen as a promising approach to restore damaged agroecosystems, sustain agricultural production, restore soil fertility, and enhance biological conservation (Aronson *et al*., 2002; Neupane *et al*., 2002; Jose, 2009). According to Young (1997) and Atangana *et al*. (2014), agroforestry is simply defined as the deliberate growing or retention of trees on farms through either spatial or temporal arrangements. The patterns of tree stocks and tree cover that emerge on farmlands are quite different from those found in natural forests (Arnold and Dewees, 1999).

Agroforestry systems are classified based on their component composition as, a) agrisilviculture (crops and trees/shrubs), b) silvopastoral (animals and trees), c) agrosilvopastoral (crops, pasture/animals and trees), and d) other systems (multipurpose tree lots, apiculture with trees/shrubs and aquaculture with trees) (Nair, 1985; 1993). Agroforestry practices that commonly occur on farmlands include, scattered trees (agrisilvicultural), boundary planting (agrisilvicultural) (trees on edges of plots/fields), live fencing (silvopastoral), homegardens (Agro-

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silvopastoral) and multipurpose farm woodlots (other forms of agroforestry) represent particular kind of agroforestry practiced on farmlands (Nair, 1993; McAdam *et al*., 2009; Atangana *et al*., 2014). Scattered trees in cropland refers to trees that are planted or naturally left during land clearing, randomly distributed in cropped land, in an open, mixed spatial system (Young, 1997). The term 'Parkland agroforestry' is also used interchangeably to refer to the regular presence of well-grown trees scattered on the cultivated or recently fallowed fields (Kessler, 1992). Boundary planting refers to tree growing along farm boundaries or demarcation within farms (Tejwani, 1987). The term 'Live fence' refers to a dense line of trees or shrubs managed to form a low, impenetrable barrier to the movement of animals (Scherr *et al*., 1990). Homegardens are multispecies agroecosystems around homes, where different trees, crops and livestock are managed in an intimate association. Woodlots refer to any area of farmland with block of trees fulfilling important needs such as fuel wood and round wood, purposes of which are more than just providing shade and shelter (Evans, 1992).

Management of biodiversity in agricultural landscapes has become more important as the area covered by natural ecosystems decreases (Méndez, 2007). Biodiversity can be maintained in agroecosystems either through human mediation or without any human involvement. The associated biodiversity does have an important agroecosystem function. The term 'biodiversity' embraces the whole variety of life forms, the genes they contain and the ecosystems of which they form part (Main, 1999). In this paper, we deal with biodiversity in agricultural systems, particularly on diversity of tree and shrub species.

Traditional agroforestry practices in Ethiopia involve planting trees in various spatial and temporal patterns to meet the wood, fuel and fodder requirements of farmers. Previous studies (Zemede Asfaw and Ayele Nigatu, 1997; Badege Bishaw and Abdu Abdelkadir, 2003; Zebene Asfaw, 2003; Tesfaye Abebe, 2005; Motuma Tolera *et al*., 2008) have documented tree and shrub species diversity in the traditional agroforestry practices of Southern Ethiopian highlands. Farmers in Yem special district of Southern Ethiopia have been retaining trees in agroforestry systems for centuries, but there is no information on how they manage tree resources and maintain tree species diversity on their farms. The present study was conducted to; (a) identify and describe the diversity, composition and density of trees in the different agroforestry practices, namely, farm boundary, live fencing, woodlots and scattered trees on cropland/agroforestry parklands, and (b) to assess on-farm tree management practices of farmers.

MATERIALS AND METHODS

The study area

The study was conducted in Yem special district, located in the north-western apex of the Southern Nations, Nationalities and Peoples Regional State (SNNPR) of Ethiopia (Fig. 1), within coordinates of 7°37′N to 8°02′ N and 37°40′ E to 37°61′ E. Yem occupies a surface area of 724.5 km² (IEP, 2010).

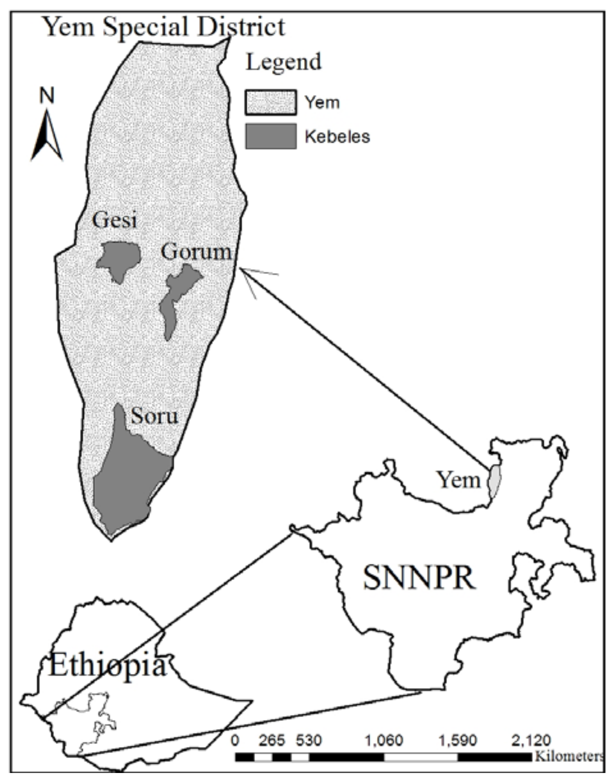

Figure 1. Location of Yem Special District and the study sites.

The district lies within elevations of 920–2939 meters above sea level (masl) and has three traditional agroclimatic zones; namely, *Dega* (cool highlands) (18.4%), *Weyna Dega* (tropical highlands) (57.6%) and *Kolla* (lowlands) (24.0%)

(ERTTP, 2003). It receives a mean annual rainfall of 900–2200 mm in a bimodal pattern, from mid-February to April, and June to September. The mean annual temperature is in the range of 12–30°C (IEP, 2010). The topography of Yem district is characterized by rolling mountains, long gorges, steep slopes and flat to undulating plateaus. The physiographic features of the district are characterized by high peaks and mountains and partly by deep gorges of Gibe River to the east (IEP, 2010). The major soil types in the district are, eutric nitosols, luvisols and vertisols (ERTTP, 2003).

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The total population of the district as per 2007 population census is estimated to be 80,647 of which 50.3% are male and 49.7% female (PCC, 2008), and the population density is 111.3 persons/km^2. Rain-fed agriculture is the main-stay of the district, the dominant crops being cereals and *enset*. *Enset* is the main staple; the full set of annual field crops cultivated include wheat, barley, *teff*, maize, sorghum, and pulses (USAID, 2005).

Methods of data collection

Different methods of data collection were used to gather information on tree species diversity, density and management. These included, key informant interview, household survey and woody species inventory.

Key informant interview

A semi-structured questionnaire was prepared to gather data from key informant (KI) farmers in the *Kebeles*[1]. KIs were selected using snowball method following a guided walk within each *Kebele.* During the guided walk, a farmer encountered in each *Kebele* was randomly asked to give names of KIs, and six farmers with the highest scores were selected as KIs. In total, 18 KIs were selected for the whole study sites. Using a wealth ranking technique, households in each *Kebele* were categorized into poor, average and better-off (Cramb *et al.*, 2004). Classification of the respondents into different wealth categories was made on the basis of land holding size, livestock size and number of *enset* (*Enset ventricosum* (Welw.) Cheesman) plants owned (Appendix 1).

Sampling

Agroclimatic differences affect the diversity and density of trees in agroforestry systems, since climatic and soil conditions of a particular area influence the type and growth performance of plants. Distance to major roads of farms can also have the same effect since access to road facilitates marketing of tree products, eventually affecting tree species diversity and density (Tesfaye Abebe, 2005; Correia *et al*., 2010). Thus, in order to have fair representation of the agroforestry practices in the district, the different agroclimatic zones, and distance of the *Kebeles* to major roads were considered as criteria to select the research sites. In the sampling, first, all *Kebeles* in the district were stratified into three categories based on their distance to major roads, *i.e.,* close to road (< 8 Kms), medium (8–23 kms) and far (23–41kms). Then, from each distance category, *Kebeles* with similar agroclimatic zone were re-grouped and one sample *Kebele* was randomly selected from the dominant agroclimatic zone in each distance category. Accordingly, 1) Gesi, representing sites *(Kebeles)* close to road, and having *Woyna Dega* (tropical highlands) agroclimatic zone, 2) Gorumna Hangeri (hereafter Gorum), medium distance to road, and *Dega* (cool highland) agroclimatic zone and 3) Soru Gon (hereafter Soru) far from road,

[1] A *Kebele* is the lowest administrative unit in rural Ethiopia and it has an area of about 800 hectares.

and *Kolla* (Lowland) agroclimatic zone, were selected to conduct the study. The selected three *Kebeles* made up 10% of the total *Kebeles* in the district.

In the second stage of sampling, a total of 126 households (74, 26 and 26 for Gesi, Gorum and Soru *Kebeles*, respectively) were selected randomly based on the proportion of households in the *Kebeles* (≈ 10%). The sample household size for Gesi *Kebele* was big because of the proportionally large number of households. In the sample, gender balance was maintained in accordance with the proportion of female-headed households to the total household heads (≈ 16%).

Household survey

From each sample household, data were collected on household characteristics (family size, age, gender, educational status), other socioeconomic characteristics (farm size, number and herd composition of livestock, labour availability, distance to major roads), institutional characteristics (contact with extension agent) and farmer's tree management practices and constraints to tree growing and management.

Woody species inventory

Woody species surveys were carried out in order to understand farmers' tree holdings and tree management practices. Trees that are found as boundary plantings, live fencing, woodlots and scattered on croplands/agroforestry parklands, all exotic and indigenous trees, were enumerated. On each farm, all trees (>1.5 m in height) were identified and counted (Paré, 2008). At the same time, only trees with a minimum diameter at breast-height (dbh) of 5 cm were measured in each plot (Tesfaye Abebe, 2005). Those trees with dbh (5 cm) and a height (< 1.5 m) are considered to be seedlings (Schinkel, 1995; Omeja *et al*., 2004; Correia *et al*., 2010), and they were used only in diversity calculations. The parameters that were recorded include, area occupied by each tree planting pattern, the number of individuals of each tree species per plot, and diameter at breast height of trees.

Biophysical parameters such as slope percentage and altitude were also recorded. Measurements of dbh, slope, and altitude were carried out using diameter tape, Suunto clinometer, and altimeter, respectively. Species composition as well as length and width of boundary tree plantings and live fencing were determined using a method adapted from Kuyper and Bradley (Lauriks *et al*., 1999) but modified to suit our situations. Accordingly, in each selected boundary planting and live fencing, a 60 m section were sampled in which length (L) and width (W) of the boundary and live fencing were measured at 0, 15, 30, 45 and 60m (central measuring line) using diameter tape. The composition and frequency of each tree and shrub species was recorded in a 4m×4m (16m^2) sub-sample plot from 0 to 60 m length at 15 m intervals. When the assumed length becomes less than 15 m or greater than 60 m in some cases, the actual length was determined (Fig. 2). But Lauriks *et al.* (1999) previously used a 100 m section, and subsamples were determined at 20 m intervals for border hedges may be because of their longer section. Trees and shrubs at the border of the sub-sample were included if 50% of the canopy fell within the subsample. With respect to woodlots, 10% of the land size was sampled using 2m x 5m sample plot (Zebene Asfaw, 2003). For Parkland agroforestry practices, all tree/shrub species occurring in each sampled cropland were identified and recorded.

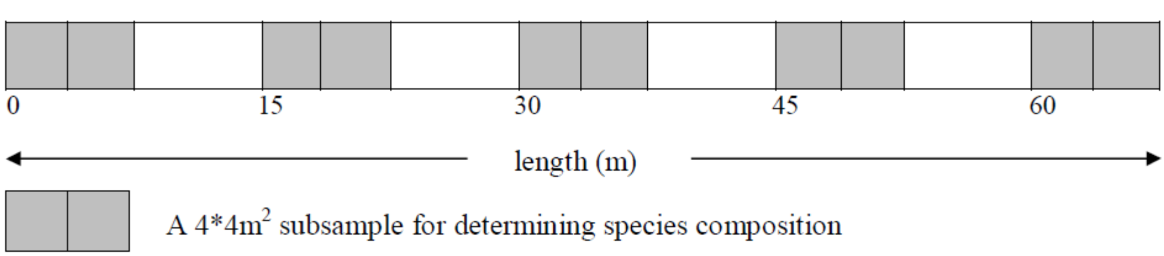


Figure 2. Schematic top-view of the 60m sections with central measuring points and sub-samples for determining species composition and basal area in boundary and live fencing.

Data analysis

Species diversity measures take into account two factors: species richness, that is the number of species, and evenness (sometimes known as equitability), that is how equally abundant the species are (Magurran, 1988). Among the several indices, Shannon diversity index and species evenness index were employed in this study (Magurran, 1988; Huston, 1994). Mean value of tree species per farm and per agroforestry practice were calculated for each wealth category and *Kebele*s.

Shannon diversity index (H′) was calculated with $H' = -\sum p_i \ln p_i$ (Magurran, 1988) where p_i is the proportion of individuals found in the *i*th species in the collection, and the summation is overall total of the species. The proportions p_i are given by n_i/N (Usher, 1983), where there are n_i individuals of the *i*th species. From that, Species evenness index (E) was calculated by $E = H`/H_{max} = H`/\ln S$ (Magurran, 1988), where E is contained between 0 and 1, with 1 representing a situation in which all species are equally abundant; H_{max} is the maximum diversity and 'S' is the number of species.

Between-habitat (β) diversity was calculated using Jaccard's coefficient of similarity, given by $\beta = 1–C_j$, (Magurran, 1988), where Jaccard's similarity index, $C_j = (j/(a+b-j))$ (j = the number of species common to both sites; a = the number of species in site A, and b = the number of species in site B). Importance value index (IVI) was estimated following Zobel *et al.* (1987) where IVI = relative density + relative frequency + relative basal area. Stem basal area of each tree was calculated using the formula, $a = 0.7854^* (dbh)^2$, where a = basal area of each tree in m^2 (Anderson and Ingram, 1989). In addition, tree species preference ranking was computed following Nguthi (2007), but with slight modification, such that scores of each tree species were calculated using the following formula,

$$OS_1 = \sum_{i=1}^{n} Freq(O_i) * (13 - i)$$

where,

OS_1 = the overall score for species 1

I = Rank position (1, 2, 3, …12)

Freq (O_i) = Number of times species 1 is mentioned in rank position i

Species identification was carried out using species identification guide books, namely the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards *et al.*, 1995; Edwards *et al.*, 2000; Hedberg *et al.*, 2003) and Useful trees and shrubs for Ethiopia (Azene Bekele-Tesema, 2007). For tree and shrub species that couldn't be identified at field level, specimens were collected and identification made at the National Herbarium Centre of Addis Ababa University.

The data collected during household interview and woody species surveys were statistically analyzed using appropriate tools (descriptive statistics, Chi-square tests, and one way ANOVA) using Statistical Package for Social Sciences (SPSS, Version 16) software. *Post-hoc* pair-wise comparisons were made with Fisher's Least Significance Difference (LSD) tests at $\alpha=0.05$ to isolate group means that show significant differences. Assumptions of normal distribution and homogeneity of variances were tested by Levene test. Where necessary, quantitative data were log-transformed in order to meet assumptions of normality and homogeneity of variance, otherwise non parametric Kruskal-Wallis and Mann-Whitney U tests were made when assumptions of normality failed to be satisfied.

RESULTS AND DISCUSSION

Overall tree and shrubs species richness of the agroforestry practices

A total of 100 tree and shrub species belonging to 57 families and 83 genera were recorded from the different agroforestry practices of sample households (Appendix 2), of which 11 (or 11%) were exotic and 89 (or 89%) native species. The tree and shrub species encountered on farms were either purposely left from deforestation and/or planted by the farmers. The farmers have experiences of planting both indigenous and exotic tree and shrub species. The family Fabaceae ranked on top of the list represented by eight species, followed by Euphorbiaceae (seven spp.), Myrtaceae (five spp.), and Asteraceae, Rosaceae and Rubiaceae (each with four spp.). The overall tree species richness of agroforestry practices in the present study (100) is lower than the one reported by Tesfaye Abebe *et al.* (2013) for Sidama agroforestry practices of Southern Ethiopia (120) in similar agroecology but higher than that of Zebene Asfaw (2003) (87), also in Sidama zone (87). The agroforestry practices of Yem district have considerable similarly with those of Sidama in terms of species composition. In total, 56 tree and shrub species encountered in this study are reported in Sidama agroforestry practices (Tesfaye Abebe, 2005). The farming system in Yem special district is categorized under the cereal and *enset* livelihood zone (USAID, 2005). As *enset*-dependent people, the life and culture of Yem is very much tied with *enset* farming in a similar manner to that of Sidama and Gedeo people, which makes them share common farming features besides the similarity in agroclimatic conditions. In these farming systems, farmers commonly retain and manage old-aged trees inside their homesteads, on *enset* plots as well as on other farmlands situated farther away from homes.

The very large proportion (89%) of native trees and shrubs in the traditional agroforestry practices of Yem demonstrates the role of agroforestry as repositories of genetic diversity, as it was reported elsewhere (Michon *et al.*, 1983; Soemarwoto and Conway, 1991; Nair, 1993; Tesfaye Abebe *et al.*, 2006). The top ranking species-rich family in the present study was similar to the findings of Lalisa Alemayehu and Hager (2010), who reported that the family Fabaceae had the largest number of tree and shrub species in the agricultural landscapes of the Central Ethiopian highlands.

Species richness across sites and agroforestry practices

The total number of species at *Kebele* level was highest at Gesi with 80 species, while Gorum and Soru had 59 and 52 species, respectively (Table 2). Gesi is located in the tropical highlands, locally known as *Weyna dega*, which are known to have favorable climatic and soil conditions to accommodate different species of plants (Westphal, 1975; Amare Getahun, 1978; Constable, 1985), and this climatic suitability might have contributed to the highest number of species at Gesi. Among the agroforestry practices, boundary planting had the highest number with 69 species of trees and shrubs followed by live fencing (60) (Table 1). Woodlots are dominated by eucalypts trees, but there are also other planted exotic and native species, and also remnant trees of the native vegetation.

Table 1. Tree and shrub species richness of sites and agroforestry practices.

Agroforestry practices	Total	Sites		
		Soru	Gorum	Gesi
Observations total (n=98)	100	52	59	80
Boundary planting (n=49)	69	38	44	48
Live fencing (n=69)	60	31	25	40
Woodlots (n=48)	45	15	22	37
Agroforestry parklands (n=78)	43	28	28	38

Farm-level species richness of trees and shrubs

The average value of tree and shrub species per household for all sites was 14.04±6.94 (mean value ± SD), ranging from 2 to 36: The number varied significantly among *Kebeles* (ANOVA: $F_{(2, 46)}$ =9.07, p=0.0001) (Fig. 3). Although Soru *Kebele* has relatively drier climate (Tropical), farms in the *Kebele* had a markedly higher mean value of tree species than the other sites, probably due to larger land-holdings and its remote location where the limited road access has reduced excessive exploitation of the trees. On the contrary, farms close to major roads have fewer species of trees probably due to overexploitation for consumption and marketing.

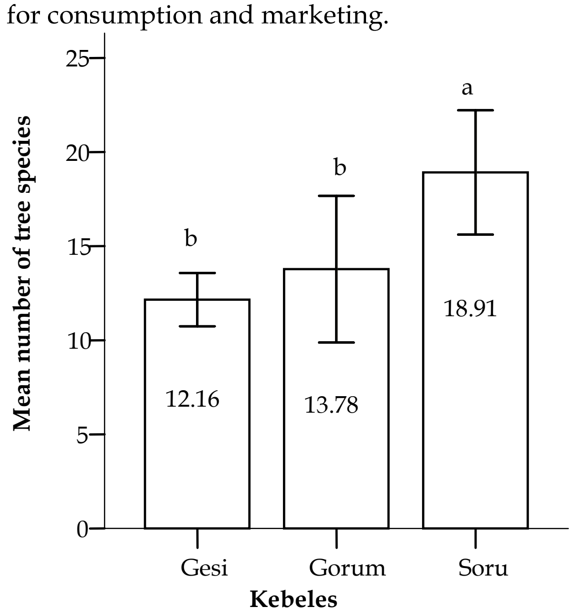
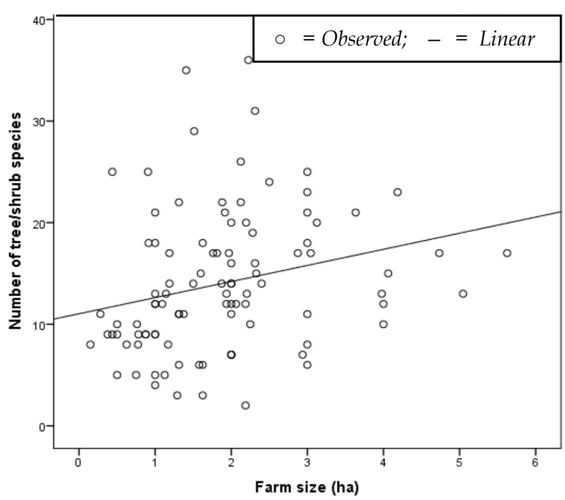


Figure 3. Mean value of tree species per household across *Kebeles*. Error bars show 95% CI of mean. The letters indicate results of pairwise comparison with LSD test.

Results of Spearman's rho and Pearson bivariate correlation analysis indicate that on-farm tree species richness was influenced by socioeconomic and biophysical factors. The characteristic variables which positively and significantly affected farm tree species richness were wealth (Spearman's rho r_s=0.21, p=0.038, N=98), farm size (Pearson correlation r_p=0.25, p=0.013, N=98), family size (Pearson correlation r_p=0.269, p=0.007, N=98) and distance to major roads (Pearson correlation r_p=0.421, p=0.0001, N=98) (Fig. 4). Similar findings which dictate variation in tree species richness between sites and household farms were reported elsewhere including wealth and farm size (Lengkeek, 2003; Zebene Asfaw, 2003; Kindt *et al*., 2004; Tesfaye Abebe, 2005; Tesfaye Abebe *et al.*, 2013), family size (Lengkeek, 2003; Kindt *et al*., 2004) and distance to major roads (Zebene Asfaw, 2003; Tesfaye Abebe, 2005). A decline in tree species richness of farms is observed with proximity to major roads, implying that farms located nearer to roads are intensively exploited due to commercialization and/or major share of fast growing and highly demanded species such as *Eucalyptus spp*. (Tesfaye Abebe, 2005; Tesfaye Abebe *et al*., 2013). The influence of family size on species richness may be attributed to family preferences to different types of tree products (Kumari, 2009).

Shannon diversity index (H`) for live fencing showed significant difference between sites ($F_{(2, 66)}$ =9.574, p=0.001) (Table 2). In this regard, Gesi had the highest mean index with H`=0.77 and Gorum the lowest with H`=0.40. The higher tree species diversity of live fences at Gesi could be attributed to the location of live fences around the homestead where ornamental and medicinal species are widely grown (Henry *et al*., 2009). On the other hand, the lower diversity index in the other sites could be attributed to dominance of few species and their disproportionate abundance. The other agroforestry practices (boundary planting, woodlots and agroforestry parklands) did not show significant difference between sites for any of the diversity indices.



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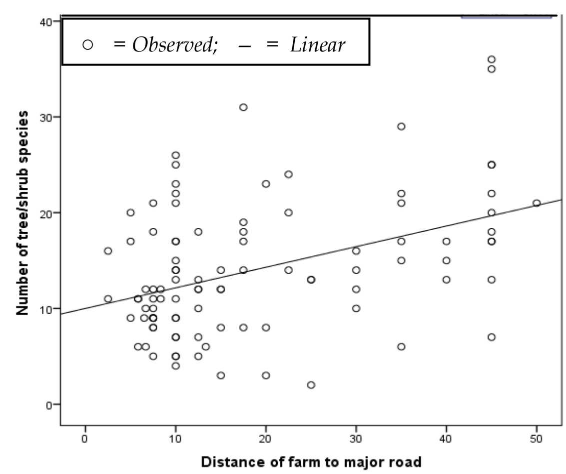

4b

Figure 4. Relationship between farm size (4a) and distance to major roads (4b) with tree species richness.

Table 2. Mean (± SD) Shannon diversity index (H') of different agroforestry practices across sites. All tests used analysis of variance and df = 2.

Indices	Sites				Significance£¶
	Total	Gesi	Gorum	Soru	
Mean Shannon diversity index					
Boundary planting	0.544±0.310	0.587±0.334	0.382±0.359	0.566±0.259	NS
Live fencing£	0.672±0.318	0.767[a]±0.305	0.397[b]±0.254	0.590[ab]±0.168	**
Woodlot	0.359±0.332	0.349±0.295	0.595±0.471	0.235±0.241	NS
Scattered trees	1.226±0.584	1.142±0.581	1.341±0.637	1.324±0.536	NS
Mean evenness index					
Boundary planting	0.834±0.100	0.836 ±0.102	0.834 ±0.065	0.813±0.104	NS
Live fencing	0.813±0.118	0.811±0.106	0.853±0.112	0.772±0.178	NS
Woodlot	0.410±0.340	0.285±0.267	0.620±0.315	0.532±0.399	NS
Scattered trees	0.811±0.138	0.801±0.150	0.789±0.150	0.859±0.077	NS

£ Significant tests between households across different wealth categories and sites, df=2; ** = p< 0.01; *= p< 0.05; NS =Not significant p> 0.05 (different superscript letters in rows indicate significant difference).

Similarity of tree species across sites

Similarity of tree and shrub species across the sites (Beta diversity) was analyzed, and the sites (*Kebeles*) were found to share 53–70% of species in common. The highest dissimilarity (β=0.47) was recorded between the *Woyna Dega* (tropical highland) site of Gesi and the *Kolla* (lowland) site of Soru (Table 3), and this could be attributed to different agroecological requirement of the species.

Table 3. Beta diversity of tree species in the overall agroforestry practices.

Sites	Soru	Gorum	Gesi
Soru	*		
Gorum	0.41	*	
Gesi	0.47	0.30	*

Density of trees in farms

The mean value of trees recorded per household farm in all agroforestry practices was 565, while it was 589 on a hectare basis (Table 4). Density of trees (individuals/ha) varied amongst households of wealth classes ($F_{(2,95)}$=3.651, p=0.03) (Table 4), but there was no significant difference across *Kebeles* ($F_{(2,95)}$=0.532, p=0.589). Better-off farm households had higher mean value of trees than the average and poor ones. This might be attributed to the larger farm size of wealthy farmers who have enough land left to plant more trees after growing sufficient food and cash crops (Tesfaye Abebe *et al*., 2006).

The mean value of trees per hectare reported in this study (589) is higher than the values reported by Tesfaye Abebe (2005) for the agroforestry practices of Sidama, Southern Ethiopia (475) and Lalisa Alemayehu and Hager (2010) for the Central Ethiopian highlands (98.5). However, the value is substantially lower than the one reported by Zebene Asfaw (2003) who recorded a mean value of 1610 trees per hectare in the *Eucalyptus* spp. dominated farms of Leku district in Sidama, Southern Ethiopia.

Out of the total number of trees grown on farms, about 64% were planted, and the rest were retained. The agroforestry practices, namely, boundary planting, live fencing and woodlots possess higher proportion of planted trees with respective values of 80%, 71% and 71%, but trees scattered in farms/agroforestry parklands are predominantly (75%) retained ones. The high percentage of planted trees in most of these agroforestry practices illustrates active tree planting tradition of farmers in the study area. In terms of total number of trees grown, a higher proportion of indigenous tree/shrub species (68%) were recorded in the overall agroforestry practices compared to exotics (32%). For further details of overall species composition refer to Table 7.

Table 4. Mean (± SD) value of trees in the agroforestry practices by wealth category. All tests used analysis of variance and df = 2.

Mean values	Wealth category				
	Total	poor	Medium	Better-off	significance¶
Mean value of trees per household					
Overall AFP	565.2±1154	245.4^{b}±311	342.4^{b}±377	924.6^{a}±1682	*
Boundary planting£	179.4±180	133.7^{ab}±117	97.2^{b}±118	267.1^{a}±207	**
Live fencing£	201.4±177	132.7^{b}±153	169.8^{ab}±140	258.1^{a}±198	*
Woodlot	636.3±1571	240.9±290	400.3±455	885.0±2089	NS
Scattered trees	30.0±53	11.92±7	22.5±34	41.3±69	NS
Mean value of trees per ha					
Overall AFP	588.9±1475	450.4±519	525.4±579	715.6±2194	NS
Boundary planting	436.5±585	359.3±286	314.3±375	570.1±774	NS
Live fencing	622.6±656	620.9±728	540.2±481	684.6±742	NS
Woodlot	9634±5837	8816±4492	10749±8318	9285±4625	NS
Scattered trees	35.9±47	24.8±18	30.5±27.4	43.3±60.7	NS

¶ *Significant tests between households across different wealth categories and sites, df=2; ** = p< 0.01; *= p< 0.05; NS =Not significant p> 0.05 (different superscript letters in rows indicate significant difference).* £ *Data were ln transformed to compare them across wealth categories.*

Basal area of trees and shrubs

The mean basal area of trees and shrubs per hectare for the different agroforestry practices ranged from 2.65 m^2 for live fencing to 28.04 m^2 for woodlots (Tables 5 and 6). The values did show significant difference only across sites rather than that of wealth groups. As regards to scattered trees, this result is quite comparable to other Parkland agroforestry studies done in Togo where the basal area was reported to range between 1.60 to 30.89 m^2 ha^{-1} (Folega *et al.*, 2011), but it was about two times larger than the one reported from Costa Rica (Villanueva *et al.*, 2004). In respect with live fences, the basal area obtained in the present study especially in poor households (0.62 m^2 ha^{-1}) was comparable to the values reported in Costa Rica (0.61 m^2 ha^{-1}) (Villanueva *et al.*, 2004). Among the different agroforestry practices, the basal area of woodlots in the present study (28.04 m^2 ha^{-1}) is highest, and this might be attributed to the corresponding high tree density dominated by *Eucalyptus* spp. that allows narrow spacing (Kaya *et al.*, 2002; Tesfaye Abebe, 2005; Tripathi and Singh, 2009). The variation could also be ascribed to differences in composition, age structure, degree of management and environmental (climate and soil) conditions (Deb *et al.*, 2008; Mesele Negash, 2013). Earlier studies conducted in South West Ethiopia also report a much higher basal areas of trees in small holder farms (Getachew Tadesse *et al.*, 2014).

Importance value index

The first five dominant tree species with highest importance value (IVI) were *Ficus sur* Forssk., *Eucalyptus camaldulensis* Dehnh., *Juniperus procera* Hochst ex Endl., *Erythrina brucei* Schweinf., and *Croton macrostachyus* Del. (Table 7).

Table 5. Mean (± SD) basal area of trees in agroforestry practices by wealth category.

Mean basal area (m^2 ha^{-1})	Wealth category				Significance¶
	Total	Poor	Medium	Better-off	
Boundary planting£	3.02±4.80	1.42±2.28	3.64±6.81	3.06±6.81	NS
Live fencing	2.65±5.76	0.62±0.84	3.86±8.39	2.74±4.49	NS
Woodlot	28.04±19.23	19.84±17.88	22.99±17.01	33.28±19.77	NS
Scattered trees£	4.04±5.34	3.61±4.31	3.46±3.62	4.58±6.52	NS

Table 6. Mean (± SD) basal area of trees in agroforestry practices among sites.

Mean basal area (m^2 ha^{-1})	Sites				Significance¶
	Total	Gesi	Gorum	Soru	
Boundary planting	3.02±4.80	1.54^a ±2.29	7.07^b ±8.97	2.62^a±2.96	*
Live fencing	2.65±5.76	2.88±6.45	1.21±1.29	3.85±6.33	NS
Woodlot	28.04±19.23	31.97±21.34	22.49±11.34	23.31±17.52	NS
Scattered trees	4.04±5.34	2.27^b±2.46	6.16^a±7.06	6.29^a±7.03	**

*¶ Significant tests between households across different wealth categories and sites, df=2; ** = p< 0.01; *= p< 0.05; NS =Not significant, p> 0.05, (different superscript letters in rows indicate significant difference). £ Data were ln transformed to compare them across wealth categories.*

Table 7. Importance value index (IVI) of the 10 dominant tree and shrub species in the overall agroforestry practices.

Species	Rf	Rden	Rbas	IVI
Ficus sur	3.05	1.93	49.10	54.08
Eucalyptus camaldulensis	8.62	18.04	2.69	29.35
Juniperus procera	8.21	8.45	3.45	20.11
Erythrina brucei	5.77	3.33	8.54	17.64
Croton macrostachyus	5.69	4.88	2.90	13.47
Acacia abyssinica	2.43	1.44	9.05	12.92
Eucalyptus globulus	4.49	5.63	1.17	11.29
Cupressus lusitanica	4.99	4.95	0.56	10.50
Grevillea robusta	4.79	4.65	0.06	9.50
Calpurnea aurea	4.21	5.15	0.06	9.42

Note: Rf-relative frequency; Rden-relative density; Rbas-relative basal area.

Farmers' preference of tree species for planting

The study indicated that farmers in the locality have individual preferences for tree species to be planted in their farms, and the choice of tree species is influenced by the functions the trees are expected to serve. Farmers' most favorite tree species for planting, in descending order of importance were, *Ficus sur*, *Cordia africana*, *Eucalyptus spp.*, *Erythrina brucei*, *Croton macrostachyus* and *Grevillea robusta* (Table 8).

Four out of the five species with the highest IVI, remarkably coincided with that of the top five tree species preferred by farmers. These included *Ficus sur*, *Eucalyptus spp.*, *Erythrina brucei*, and *Croton macrostachyus* (Table 8). *E. camaldulensis,* which is the only exotic species among the top-listed important trees, is increasingly becoming more popular also in the other parts of Southern Ethiopia due to its fast growth and straight stems (Zebene Asfaw, 2003; Tesfaye Abebe *et al.*, 2006).

Ficus sur is the most preferred species in the study area, and it is managed for its contribution to soil fertility amelioration, erosion control and provision of shade. It is also used for house construction and fuelwood. This result is supported by the findings of Tesfaye Abebe (2005) who reported that farmers in Southern Ethiopia preferred *Ficus spp.* for its specific qualities and roles which include timber production, provision of shade, control of erosion, and improvement of microclimate. *Cordia africana* is the second best preferred species and it is grown for its highly valued timber, firewood, maintenance of soil fertility, erosion control and shade. This is in agreement with the report of Abebe Yadessa *et al*. (2009) and Nardos Phillipos (2013) who noted that smallholder farmers in different parts of Ethiopia, often retain scattered *Cordia africana* trees for various reasons such as timber, firewood, and soil amelioration. *Eucalyptus spp.* is preferred for construction, fuel wood and income generation.

Farmers' tree management practices

Reasons for growing and retaining trees

Farm households in the study area manage trees on their farms to obtain different benefits. The most frequently mentioned purposes for which farmers grow trees and gave better responses were, soil fertility maintenance (70.63%), firewood production (65.87%), income generation (65.08%), production of construction materials (61.9%) and fruit/food production (49.2%). The findings on purposes of tree planting by farmers is in agreement with previous studies undertaken in Ethiopia (see Kahurananga *et al.*, 1993; Zemede Asfaw and Ayele Nigatu, 1997; Woldeamlak Bewket, 2003; Selamyihun Kidanu, 2004; Tesfaye Abebe *et al*., 2013).

Tree growing locations within the farms

Trees and shrubs grown on farms of sample households had various spatial arrangements and locations. Among the households, 79.6% preferred to grow trees scattered in crop lands, followed by boundary planting and live fencing (70.4%) and as woodlots on degraded areas and gullies (49%). As opposed to the present finding, smaller proportions (39%) of farmers in Kenya maintained trees in or around cropland (Scherr, 1995).

Table 8. Preference ranking of the first ten most important tree and shrub species by tree grower farmers based on the overall benefits trees provided for them.

Species	Priority												Score	Rank
	1	2	3	4	5	6	7	8	9	10	11	12		
Ficus sur	32	21	10	2	4	1	1	-	-	-	-	-	778	1
Cordia africana	35	14	4	4	1	-	-	-	-	-	-	-	658	2
Eucalyptus camaldulensis	3	9	17	6	7	3	-	-	-	-	-	-	436	3
Erythrina brucei	2	15	8	8	3	3	2	-	-	-	-	-	398	4
Croton macrostachyus	8	6	5	5	5	6	4	-	4	-	-	-	353	5
Grevillea robusta	6	11	7	5	-	-	-	-	-	-	1	-	310	6
Juniperus procera	2	4	4	8	4	2	-	-	1	-	-	-	230	7
Acacia abyssinica	3	2	4	3	1	1	3	-	1	-	-	-	162	8
Cupressus lusitanica	3	3	3	2	3	1	-	1	-	-	-	-	137	9
Persea americana	5	3	2	-	1	-	-	-	-	-	-	-	121	10

Silvicultural management of trees

The overwhelming majority (95%) of tree growers in the study area claimed that they carry out tree management practices such as coppicing, pruning, pollarding, lopping and thinning (Table 9). Pruning is the most common tree management practice undertaken by 95% of the respondents, followed by coppicing (58%). According to the respondents, pruning is conducted to reduce shading effect of trees, to produce good quality boles, to increase diameter growth of the tree and to avoid weaver birds. The farmers coppice the trees primarily to produce fuel wood and boles for construction. The other reasons for carrying out coppicing are, to get multiple sprouts, to avoid weaver birds, and to reduce competition of the tree with other components.

Table 9. Tree management practices undertaken by sampled households.

Management practices	HH	Percent
Households who did not conduct tree management practices	5	5.30
Households who conducted tree management practices	93	94.70
- Coppicing	51	57.95
- Pruning	84	95.45
- Pollarding and lopping	25	28.41
- Thinning	30	34.09

A small proportion of respondents (28.4%) reported that they practice pollarding and lopping of trees to improve diameter growth of the stem, to avoid weaver birds and to reduce competition between agroforestry components. Likewise, thinning was carried out by 34% of the farmers to increase diameter growth, and to produce good quality boles. Farmers' objectives of tree management in the study area are in agreement with previous reports (Warner, 1993; Arnold and Dewees, 1995; Tesfaye Abebe, 2005).

SUMMARY AND CONCLUSION

The presence of a large number of tree species in the different agroforestry practices of Yem district in Southern Ethiopia indicated the significant roles of human-dominated agricultural landscapes in conservation of species diversity. The practice of growing different tree species by farmers to obtain multiple products and services could indicate the potential for tree diversification and expansion of appropriate agroforestry technologies. Tree species richness was influenced by distance of farms to major roads and land holding and family size of farmers. The study revealed that the agroforestry practices contribute to the conservation of biodiversity, while providing multiple products and services.

The following recommendations are made to fill observed gaps. 1) Since the topography of Yem district is characterized by rolling mountains and steep slopes, increased efforts have to be made to assess the role of agroforestry in soil and water conservation. 2) While conserving tree species diversity in the agricultural landscapes is deemed necessary, planting of indigenous and introduced tree species that have better qualities and multiple outputs need to be promoted.

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Appendix 1. Wealth classification criteria of farmers in Yem district

Criteria	Wealth status		
	Better-off	Average	Poor
Land holding (ha)	>3.5	1.5–3.5	<1.5
Number of livestock	≥10	3-9	<3
Number of mature *enset* plants	>45	15–45	≤14

Appendix 2. Botanical and local names of trees & shrubs record in agroforestry practices in Yem district.

Botanical name	Family name	Local name	
		Yemsa	Amharic
Acacia abyssinica Hochst. ex Benth.	Fabaceae	Ezu	Bazra Grar
*Acacia decurrens*Willd.	Fabaceae		Yeferenj tsatsi
Acacia melanoxylon R. Br.	Fabaceae		Omedla
Acacia spp.	Fabaceae	Wai`a	Omedla
Agave sisalana(Perrine ex Engel.)	Agavaceae	Kai`a	Qacha
Albizia gummifera (J.F.Gmel.) C.A.Sm.	Leguminoseae	Siso	Sesa
Annona senegalensis Pers.	Annonaceaea	Gishta	Gishta
Apodytes dimidiata E. Mey. ex Arn.	Icacinaceae	Worma	
Arundinaria alpina K. Schum.	Poaceae	Wosha	Kerkeha
Arundo donax L.	Gramineae	Shemboko	Shembeko
Bersama abyssinica Fresen.	Melianthaceae	Bo`a	Azamir
Brachystelma lineare A. Rich.	Asclepiadaceae	Alwo	
Brucea antidysenterica J.F.Mill.	Simaroubaceae	Tolo	
Buddleja polystachya Fresen.	Loganiaceae	Fastu	Anfar
Calpurnea aurea (Ait.) Benth.	Papilionoideae	Zimsa	Digta
Carissa edulis (Vahl.)	Apocynaceae	Elelu	Agam
Catha edulis (Vahl) Forssk. ex Endl.	Celastraceae	Jimma	Chat
Celtis africana Burm.F.	Ulmaceae	Kawai`a	Kewut
Chamaecytisus proliferus (L.f.) Link	Fabaceae	Kawai`a	Tree lucern
Clausena anisata (Willd.) Benth.	Rutaceae	Kamekesa	
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae	Totu	Fiyel fej
Clutia lanceolata Forssk.	Euphorbiaceae	Nag`na	
Coffea arabica L.	Rubiaceae	Buna	
Combretum molle R. Br.ex G.Don	Combretaceae	Geya	
Cordia africana Lam.	Boraginaceae	Waza	Wanza
Croton macrostachyus Del.	Euphorbiaceae	Weshkela	Bisana
Cupressus lusitanica Mill.	Cupressaceae	Ferenjini rkewa	Yeferenj tid
Cussonia ostini Chiov.	Araliaceae		
Discopodium penninervium Hochst.	Solanaceae	Fururu	
Dodonea viscosa (L.) auct. mult., non Jacq.	Sapindaceae	Titira	Kitkita
Dombeya torrida (J.F. Gmel) P.Bamps	Sterculiaceae	Borabosha	Wulkefa
Dovyalis abyssinica (A.Rich) Warb.	Flacourtiaceae	Ki`eso	Koshim
Dracaena steudneri Engl.	Dracaenaceae	Tosso	Etse-patos
Embelia schimperi Vatke	Myrsinaceae	Temeqo	Enkoko
Entada abyssinica Steud. ex A.Rich.	Fabaceae		Kontir
Ehretia cymosa Thonn.	Boraginaceae	Ouch`kepa	Game
Ekebergia capensis Sparrm.	Meliaceae	Oroma	Lol
Eucalyptus camaldulensis Dehnh.	Myrtaceae	She`a bahirzafi	Key bahir zaf
Eucalyptus citriodora Hook.	Myrtaceae		Shito bahirzaf
Eucalyptus globulus Labill	Myrtaceae		Nech bahirzaf
Euclea divinorum Hiern	Ebenaceae	Mare`a	
Euclea racemosa subsp. schimperi (A.DC.) F. White	Ebenaceae	Orewa	Dedeho
Euphorbia abyssinica Gmel.	Euporbiaceae	Akma	Kulkual
Euphorbia cotinifolia L.	Euphorbiaceae	Key kinchib	
Euphorbia tirucalli L.	Euphorbiaceae		Kinchib
Erica arborea L.	Ericaceae	Ai`ayu	Asta
Erythrina brucei Schweinf.	Papilionaceae	Kocho	Korch
Erythrina abyssinica Lam.ex DC.	Leguminosae	Yehabesha Kocho	Korch
Ficus spp.	Moraceae	Odo	Bamba
Ficus sur Forssk.	Moraceae	Teya	Shola
Ficus vasta Forssk.	Moraceae	Kasha	Warka
Flacourtia indica (Burm.f.) Merr.	Flacourtiaceae	Sona	Yeqebero betir
Galiniera saxifraga (Hochst) Bridson	Rubiaceae	Burano	Yetota kula
Grevillea robusta R. Br.	Protacea	Gravilla	Temenja Zaf
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	Fofa	Kosso zaf
Hypericum quartinianum A.Rich.	Hypericaceae	Arenshisho	
Ilex mitis (L.) Radlk.	Aquifoloiaceae	Botewa	Misir genfo
Juniperus procera Hochst ex Endl.	Cupressaceae	Arkewa	Yehabesha tid
Justica schimperiana (Hochst.ex Nees.) T.Anders	Acanthaceae	Atabiyo	Sensel/Smiza
Lipia spp.	Verbenaceae	Shasha	Kese
Maesa lanceolata Forssk.	Myrsinaceae	Tegewa	Kelewa
Mangifera indica L.	Anacardiaceae	Mango	Mango
Maytenus sp.	Celastraceae	Korma	
Milletia ferruginia (Hochst.) Bak.	Fabaceae	Zagu	Birbira

Appendix 2. (Contd.)

Botanical name	Family name	Local name	
		Yemsa	Amharic
Myrica salicifolia A. Rich.	Myricaceae	Buzo	Shinet
Ocimum urticifolium Roth	Lamiaceae	Zerio	
Olea capensis subsp. macrocarpa (C.A. Wright)Verdc.	Oleaceae	Zigja	Damot weira
Olea europeana L. subsp. *africana* (Mill.) P. S. Green	Oleaceae	Geron buna	Weira
Olinia rochetiana A. Juss.	Oliniaceae	Fegegu	Tife
Osyris quadripartita Decn.	Santalaceae	Mekakuma	Keret
Pavetta abyssinica Fresen.	Rubiaceae	Wetagibo	
Pentas schimperiana (A. Rich.) Vatke	Rubiaceae	Otomiya	
Persea americana (Mill.)	Lauraceae	Avocato	Avocado
Phoenix reclinata Jacq.	Arecaceae	Deya	Zembaba
Phyllanthus ovalifolius Forssk.	Euphorbiaceae	Futwai`a	qechemo
Phytolacca dodecandra L'Hérit	Phytolaccaceae	Andode	Indod
Pittosporum viridiflorum Sims	Pittosporaceae	Toshu	
Plectranthus sp.	Lamiaceae	Bokeri	
Podocarpus falcatus (Thunb.)R. B. ex Mirb.	Podocarpaceae	Gedewa	Zigba
Premna schimperi Engl.	Verbenaceae	Wegnera	Chocho
Prunus africana (Hook.f.) Kalkm.	Rosaceae	Ona	Tikur enchet
Prunus persica (L.) Bastch	Rosaceae	Kuko	Kok
Psidium guajava L.	Myrtaceae	Zeituna	Zeituna
Rhamnus prinoides L'Herit.	Rhamnaceae	Geshe	Gesho
Rhus glutinosa A. Rich.	Anacardiaceae	Kamo	Qamo
Ricinus cummunis L.	Euphorbiaceae	Kobo	Gulo
Ritchiea albersii Gilg.	Capparidaceae		
Rosa abyssinica Lindley	Rosaceae	Garona	Qega
Sapium ellipticum (Krauss) Pax	Euphorbiaceae	Zerara	
Sesbania sesban (L.) Merr.	Fabaceae	Sesbania	Sesbania
Solanecio mannii (Hook.f.) C. Jeffrey	Asteraceae	Osmitcho	
Spathodea campanulata P. Beauv.	Bignoniaceae		
Stephania abyssinica (Dillon & A. Rich.) Walp.	Menispermaceae	Minminu	Etse-Eyesus
Syzigium guineense (Willd.) DC.	Myrtaceae	Shawu	Dokma
Schefflera abyssinica (Hochst. Ex A. Rich.) Harms	Araliaceae	Daga	Geteme
Senecio gigas Vatke	Asteraceae	Domorisa	Yeshikoko gomen
Tetradenia riparia (Hochst. in C. Krauss) Codd	Lamiaceae	Benejo	
Vernonia amygdalina Del.	Asteraceae	Suqeru	Grawa
Vernonia sp.	Asteraceae	Soyoma	
Ximenia americana L.	Olacaceae		Enkoy