Research Article
Open Access
CrossMark

Management and socioeconomic determinants of woody species diversity in parkland agroforestry in Tembaro District, Southern Ethiopia

Abstract

Parkland agroforestry farming system is widely practiced by smallholder farmers in semi-arid West and East Africa. Parkland agroforestry plays an important role in product diversification and biodiversity conservation. The study carried out to examine the management and socioeconomic determinants of woody species diversity in parkland agroforestry in Tembaro district, Southern Ethiopia with objectives (i) assess woody species diversity, (ii) identifying farmers management practices and (iii) socioeconomic determinants of woody species diversity in parkland agroforestry. Two administrative kebeles were selected purposively. A total of 120 households were randomly selected for socioeconomic data and woody species inventory. Based on the analysis, 90% of households are males, and 54.2% are in medium wealth class. A total of 27 woody species were recorded in the study area. The Shannon, Simpson and evenness were1.83±0.18, 0.78±0.046 and 0.77±0.07, respectively. Woody species density per quadrate at Waro site (15.58±5.47) was significantly higher than Bechira site (13.47±5.77) ($p<0.05$). The mean basal area of woody species at Waro was slightly higher (2.521.38ha^{-1}) than at Bechira (2.2±1.36ha^{-1}), the difference not statistically significant ($p>0.05$). At the study sites, farmers retained (planted) woody species in their parkland agroforestry for the purpose of fuel wood, improving soil fertility, fodder, timber, shade, construction, etc. The important socioeconomic determinants influencing woody species richness in the study area were family size, farm size, wealth, education level, access to extension services, and access to the road. The diversity of woody species in parkland agroforestry plays a great role in provisioning and regulation functions.

Keywords: agroforestry, diversity, Ethiopia, species dominance

Volume 2 Issue 5 - 2018

Belayneh Lemage,[1] Abayneh Legesse[2]
[1]Southern Agricultural Research Institute, Ethiopia
[2]Ethiopian Biodiversity Institute, Ethiopia

Correspondence: Abayneh Legesse, Ethiopian Biodiversity Institute, PO Box 30726, Addis Ababa, Ethiopia, Tel +251 913999571, Email abunalag99@gmail.com

Received: October 15, 2018 | **Published:** October 23, 2018

Introduction

Agroforestry practices are major features of the land-use systems in the dry lands of Eastern and Central Africa. Trees are used for a variety of purposes in both cropped lands and in livestock grazing systems. Trees in the land and homestead find various domestic and commercial applications for both wood and non-wood products.[1] The multipurpose trees are purposefully selected and maintained when conversion of woodland to farmland for various benefits.[2,3]The woody species in Parkland agroforestry farming (PAF) favors the survival of native forest plants. Dispersed trees grown in farmlands characterize a large part of the Ethiopian agricultural landscape. Trees would be grown in a scattered form over a crop field, usually between 1–20 trees per hectare to minimize the impact on the companion crop.[4]

The parkland agroforestry' species composition is influenced by ecological and economic factors in a given socio-cultural environment.[5–8] The dominant socio-economic factors that determine the diversity of woody species on farms are farm size, wealth status of the household, access to the market, and availability of labor.[9–11] Thus, this study attempts to assess the management and socioeconomic determinants of woody species diversity in parkland agroforestry in Tembaro district, Southern Ethiopia

Materials and methods

Description of the study area

The study was conducted in Tembaro district in Kembata Tembaro Zone, Southern Ethiopia. Geographically, it is located between 37º36'32'' to 37º21'5''E and 7º11'8''N to 7º21'51''N. The altitude of the study area ranges from 800 to 2600 m.a.s.l. (Figure 1).[12]

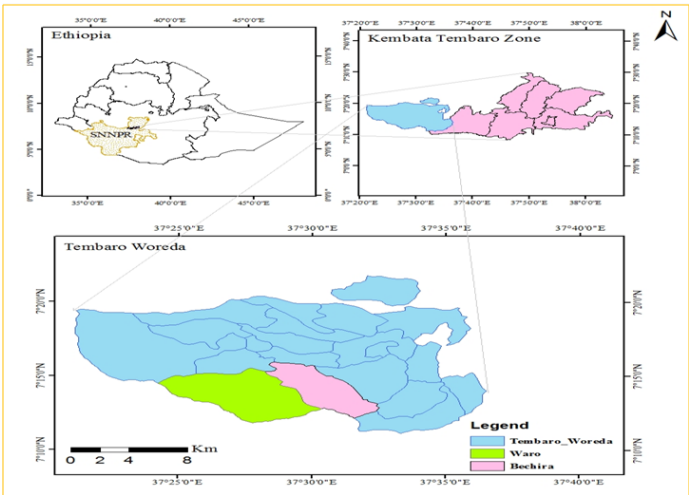

Figure 1 The map of the study area.

Study site selection

Tembaro district encompasses three agro-ecological zones, from which Kola and Woyenadega cover the largest proportion. Two kebeles were selected purposively namely Waro from lowland and Bechira

from midland agro-ecological based on the presence of extensive parkland agroforestry practice. Before the field data collection, a preliminary reconnaissance survey and direct field observations were conducted to gather information about the woody species distribution in PAF and socioeconomic characteristics of the study area.

Data collection

Formal survey data collection was conducted on the sample households with the structured questionnaires in each selected village. Information about biophysical and socio-economic characteristics data was gathered. To assess farmers' management practices and socioeconomic factors affecting the woody species diversity in Parkland agroforestry within the study area, households at each village was ranked based on wealth status into rich, medium and poor using local criteria by the help of key informants. Following stratification of households into wealth category, from selected villages, a total of 120 respondents were randomly selected from the two study sites for the household survey.

From each farm household, one sample plot with 25*50m^2 sizes was used for species inventory. Inventory of woody species on PAF was inventoried by taking one quadrate sample from a household farm based on the approaches of[8] with some adjustment. For an inventory of woody species with DBH≥5cm (at 1.3m height) were measured using caliper and/or diameter tape.[13] For trees /shrubs forking at or just above 1.3m is measured both stems above the fork and the average was taken or treats as one tree. For woody species forked below 1.3m, individual stems were separately measured and then average DBH was taken. For woody species or trees/shrubs with DBH below 5cm, only stem count was made to know a number of abundances.[13]

The local name of the plant species found in the sample plots was identified and recorded with the help of key informants and scientific nomenclature was carried out using a reference[14–16] and plant identification manuals.

Data analysis

Woody species diversity in parkland agroforestry of the study sites was determined using the Shannon diversity (H'), Simpson diversity and Shannon evenness index.

Shannon diversity index (H')

It relates the proportional weight of the number of individuals per species to the total number of individuals for all species.[17] Shannon diversity index was calculated as:

$$H' = \sum_{i=1}^{s} pi * \ln$$

Where H'= Shannon-Wiener Diversity Indexes' = number of species, Pi = Proportion of individuals or abundance of the ith species expressed as a proportion of the total cover. Ln = log base$_n$ (natural logarithm).

Equitability (evenness) index

Evenness (equitability) index (J) was calculated as:

Equitability (j) = $\frac{H}{H\max} = \frac{H}{\ln s}$, Where: E = Evenness; H' = Shannon-Wiener Diversity Index; H_{max} = lnS; S=total number of species in the sample.

Simpson's diversity index

Simpson's diversity (D) was calculated as: $D = 1 - \sum pi2$

Where D = Simpson's diversity index, Pi = Proportion of individuals or abundance of the ith species expressed as a proportion of the total cover.

Importance value index

Importance value index was calculated as:

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all species}} X100$$

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} X100$$

$$\text{Relative dominance} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} X100$$

Importance value index (IVI) = relative dominance + relative density + relative frequency

Dominance refers to basal area = $\sum\prod D2/4$

Measurements of similarity

Similarity indices measure the degree to which the species composition of different sites is alike. The Sorensen coefficient of similarity (S_s) was calculated as:

$$Ss = \frac{2a}{2a+b+c}$$

Where S_s = Sorensen similarity coefficient

a = number of species common to both areas (1 and 2)

b = number of species in area 1

c = number of species in area 2

The coefficient is multiplied by 100 to give a percentage.

Estimation of wood production in parkland agroforestry

The density of each woody species in the parklands is then determined by converting the total number of individuals of the species encountered in all the quadrates to a unit area of 1 hectare (individuals' ha^{-1}), and the Basal area is the cross-sectional area of tree stems diameter at breast height. In general, it is a measure of dominance where the term "dominance" refers to the degree of coverage of a species as an expression of the space it occupies and calculated as:

$BA = \pi d^2/4$, Where BA = Basal area in m^2 per hectare

d= diameter at breast height (m), Π = 3.14

Analysis of quantitative and qualitative data regarding woody species diversity, traditional management practices and socioeconomic factors influencing woody species diversity in parkland agroforestry analyzed by using one-way ANOVA and Microsoft Excel 2007.

Results

Household and socio-economic characteristics

From a total of 120 households interviewed for this study, 90% were male and 10% were female, 53.3% of the households were within the age class of 41 to 50 years and 28.3% belonging to 31 to 40 age class. From the total respondents, 41.7% cannot read and write, 11.7% read and write, 13.3% primary 1st cycle(grade1 to 4) complete, 23.3% were a 2nd cycle (grade 5 to 8) and the rest 10% were high school (10 to 12) and above. The majority of the household family size 52.5% and some proportion of 32.5% of the households family size was in the ranged from 5 to 6 and 3 to 4 members, respectively. The family size greater than six family members had 14.2% proportion. Agriculture was the primary occupation for all of the households, which represents about 95.8%. The mean land holding size of the poor, medium and rich was estimated to 1.15, 1.8 and 2.2 hectare respectively (Table 1). The landholding size among the wealth status showed variation (F-test; $p<0.05$; Table 1).

Table 1 Landholding size (ha) of the respondents corresponding to wealth categories (N=120)

Wealth class	Mean	Minimum	Maximum
Poor	1.15^{c}±0.47	0.5	2
Medium	1.8^{a}±0.83	0.5	5
Rich	2.2^{b}±0.63	1	3.5
Overall mean	1.71±0.6450		

Source: survey, 2014

Woody species diversity and composition

A total of 27 woody species, belonging to 15 families were recorded in the PAF of the study area. Among the woody species, trees constituted 63% and shrubs 37%. At the site level, a total of 24 and 20 woody species were recorded in Waro and Bechira, respectively. Among the families, Fabaceae and Euphorbiaceae were the first and second more diverse species represented by 7 and 3 respectively, while the families Asteraceae, Boraginaceae and Moraceae were represented by 2 species each (Table 2).

Table 2 List of all woody species in parkland at both sites, Tembaro district, Ethiopia

Scientific name	Families	Habitat	Site
Acacia abyssinica	*Fabaceae*	Tree	Midland
Acacia bussei	*Fabaceae*	Tree	Lowland
Albizia gummifera	*Fabaceae*	Tree	In both site
Cajanus cajan	*Fabaceae*	Shrub	In both site
Citrus aurantifolia	*Rutaceae*	Tree	In both site
Coffea arabica	*Rubiaceae*	Shrub	In both site
Cordia africana	*Boraginaceae*	Tree	In both site
Croton macrostachyus	*Euphorbiaceae*	Tree	In both site
Ehretia cymosa	*Boraginaceae*	Tree	In both site
Erythrina abyssinica	*Fabaceae*	Tree	In both site
Ficus sycomorus	*Moraceae*	Tree	Lowland
Ficus vasta	*Moraceae*	Tree	In both site
Grevillea robusta	*Proteaceae*	Tree	In both site
Jatropha curcas	*Euphorbiaceae*	Shrub	Lowland
Justicia schimperiana	*Acanthaceae*	Shrub	Midland
Mangifera indica	*Anacardiaceae*	Tree	Lowland
Moringa oleifera	*Moringaceae*	Tree	Lowland
Persea americana	*Lauraceae*	Tree	In both site
Prunus africana	*Rosaceae*	Tree	In both site
Rhamnus prinoides	*Rhamnaceae*	Shrub	In both site
Ricinus communis	*Euphorbiaceae*	Shrub	In both site
Senna didymobotrya	*Fabaceae*	Shrub	Lowland
Sesbania sesban	*Fabaceae*	Shrub	Lowland
Solanum dulcamara	*Solanaceae*	Shrub	Midland
Trichilia emetica	*Meliaceae*	Tree	In both site
Vernonia amygdalina	*Asteraceae*	Tree(S)	In both site
Vernonia auriculifera	*Asteraceae*	Shrub	In both site

The mean of Shannon diversity index of woody species was 1.91 for PAF at Waro and 1.75 for Bechira kebele. The Shannon diversity index was higher in Waro than Bechira. Simpson and evenness were significantly higher at Waro than Bechira, with the mean of (0.8 and 0.81), and (0.75 and 0.74) respectively ($p<0.05$) (Table 3). Diversity indices were calculated for the three wealth classes in both sites. Shannon diversity index of woody species was significantly higher in rich than poor in both study sites. Similarly in medium wealth households at Waro site, but not in Bechira case. The evenness of woody species was significantly higher in rich than medium and poor at both sites. Simpson value showed the high significant difference in rich than medium and poor wealth class at Bechira site. Generally, the Shannon, Evenness and Simpson indices were higher in rich than the medium and poor households in both study sites. Woody species richness and abundance were significantly higher in wealthy households than medium and poor classes in the study sites. Similarly, these were significantly higher for the medium than poor. From all wealth categories, the highest species richness and abundance were recorded in Waro for rich and the lowest in Bechira for poor households (Table 4). Woody species diversities vary from village to village within the same site, for instance at Waro the value of Shannon diversity was higher at Lay-Wacho than Tach-Wacho and also in Bechira Lay-Mesale has higher in species diversity than that of Tach-Buho and Meliko-Olona (Table 5).

Table 3 Mean (±SD) diversity indices and richness of woody species in parkland agroforestry at Bechira and Waro, Tembaro district, Ethiopia

Sites	Shannon	Evenness	Simpson	Species richness
Bechira	1.75^{a}±0.15	0.74^{a}±0.067	0.75^{a}±0.046	4.9^{a}±1.8
Waro	1.91^{b}±0.17	0.81^{b}±0.066	0.81^{b}±0.036	5.7^{b}±1.7
Grand mean	1.83±0.18	0.77±0.074	0.78±0.046	5.3±1.7

Note: small letter indicates differences ($p<0.05$) between study sites.

Table 4 Mean (±SD) diversity indices of woody species in parkland agroforestry among the three wealth categories

Sites	Wealth	Shannon	Evenness	Simpson	Richness	Abundance
	Poor	1.68^{aA}+0.24	0.73^{aA}+0.09	0.75^{aA}+0.06	3.9^{cC}±1.9	10.3^{cC}±5.1
Bechira	Medium	1.75^{bA}+0.10	0.72^{aA}+0.09	0.74^{aA}+0.04	5.1^{aA}±1.6	13.3^{aA}±5.5
	Rich	1.82^{bA}+0.12	0.76^{bA}+0.02	0.77^{bA}+0.05	6.2^{bA}±1.2	17.1^{bA}±3.4
	Poor	1.78^{cB}+0.07	0.77^{aB}+0.05	0.78^{aB}+0.05	4.8^{cC}±1.6	11.1^{cC}±3.4
Waro	Medium	1.89^{aA}+0.17	0.76^{aB}+0.02	0.79^{aB}+0.03	5.6^{aA}±1.5	15.9^{aB}±5.0
	Rich	2.06^{bB}+0.15	0.88^{bB}+0.04	0.82^{aB}+0.04	7.3^{bB}±1.1	21.7^{bB}±5.4

Note: Small letter indicates differences (p<0.05) among each wealth classes within the study site. The capital letter indicates differences (p<0.05) within similar wealth classes between study sites.

Table 5 Mean (±SD) diversity indices, richness and abundance of woody species in parkland agroforestry among villages

Sites	Village	Shannon	Evenness	Simpson	Richness	Abundance
	Tech-Buho	1.79^{aA}±0.07	0.76^{aB}±0.03	0.73^{aA}±0.04	4.2^{aA}±1.9	11.4^{aA}±5.8
Bechira	Meliko-Olona	1.61^{aA}±0.18	0.67^{aA}±0.07	0.74^{aA}±0.06	5.2^{bB}±1.8	14.6^{aA}±5.5
	Lay-Mesale	1.85^{bA}±0.05	0.78^{bB}±0.03	0.79^{bA}±0.01	5.2^{bB}±1.6	13.1^{aA}± 4.8
	Tech-Besa	1.93^{aB}±0.10	0.83^{aB}±0.08	0.77^{aA}±0.01	5.9^{aB}±1.6	18.4^{bB}±5.7
Waro	Lay-Wacho	1.93^{aB}±0.13	0.78^{aB}±0.09	0.79^{aA}±0.03	5.5^{aB}±1.9	14.8^{aA}±6.5
	Tech-Wacho	1.88^{aA}±0.30	0.81^{aB}±0.04	0.84^{bB}±0.02	5.6^{aB}±1.7	14.03^{aA}±5.7

Note: small letters indicate differences (p<0.05) among villages within the same study site. Capital letters indicate differences (p<0.05) among villages between study sites.

Species similarity between agro-ecologies

There was no much variation in the species composition in parkland agroforestry at the two study sites. Accordingly, the Sorensen similarity index was 77.27% across the study agro-ecologies. Out of the all 27 woody species recorded on both sites, 17 woody species were found to be common to both sites (Figure 2).

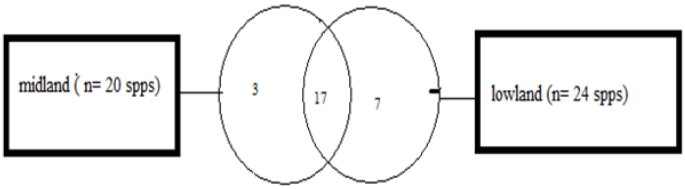

Figure 2 Venn diagram of species richness pattern in PAF at lowland and midland agro ecologies.

From the woody species recorded in Waro, *Cordia africana*, *Croton macrostachyus*, *Cajanus cajan* and *Albizia gummifera* were the most frequent species and *Jatropha curcas, Sesbania sesban,* and *Ricinus communis* were the least recorded woody species. Similarly, in Bechira, *Cordia africana, Croton macrostachyus*, *Cajanus cajan* and *Albizia gummifera* were the most frequent species and *Prunus africana, Trichilia emetica* and *Ehretia cymosa* were the least recorded woody species.

Importance value index (IVI)

Cordia africana, Cajanus cajan, Croton macrostachyus, *Albizia gummifera*, *Grevillea robusta* and *Acacia bussei* were the top six important woody species from the 24 species in Waro (Table6). Whereas, in Bechira *Cordia africana*, *Cajanus cajan, Croton macrostachyus*, *Albizia gummifera*, *Gravillia robusta* and *Ficus vasta* were the top six important woody species among the 20 woody species (Table 7).

Table 6 Summary of IVI value of woody species in the PAF in Waro

Species	RA%	RF%	RDO%	IVI
Acacia bussei	3.965	6.164	5.79	15.92
Albizia gummifera	4.515	9.247	6.78	20.54
Cordia Africana	28.744	19.178	4.3	52.22
Croton macrostachyus	11.343	17.123	4.55	33.02
Citrus aurantifolia	0.11	0.342	1.37	1.82
Ehretia cymosa	0.33	1.027	4.213	5.57
Erythrina abyssinica	1.762	3.424	9.646	14.83
Ficus sycomorus	0.881	2.397	7.937	11.22
Ficus vasta	1.762	4.11	8.455	14.33
Grevillea robusta	6.057	6.849	4.213	17.12
Mangifera indica	0.33	1.027	5.545	6.902
Moringa oleifera	0.661	2.055	5.574	8.29
Persea americana	0.551	1.712	5.545	7.81
Prunus Africana	0.11	0.343	6.424	6.88
Trichilia emetic	0.22	0.685	12.87	13.78
Vernonia amygdalina	0.551	1.712	2.615	4.89
Vernonia auriculifera	1.432	2.74	0.678	4.85
Other species (7)	36.67	19.86	3.49	59.99

Note: RA, relative abundance; RF, relative frequency; RDO, relative dominance; IVI, importance value index

Table 7 Summary of IVI value of woody species in the PAF in Bechira

Species	RA%	RF%	RDO%	IVI
Acacia abyssinica	3.911	7.721	6.078	17.71
Albizia gummifera	4.563	9.191	9.98	23.734
Citrus aurantifolia	0.261	0.735	2.394	3.39
Cordia Africana	33.507	21.323	5.109	59.94
Croton macrostachyus	10.691	15.808	4.88	31.38
Ehretia cymosa	0.13	0.367	3.448	3.95
Erythrina abyssinica	1..304	2.941	13.041	17.29
Ficus vasta	1.434	3.309	14.473	19.22
Grevillea robusta	6.389	8.456	4.654	19.51
Persea Americana	0.652	1.838	8.574	11.064
Prunus Africana	0.13	0.367	14.624	15.12
Trichilia emetic	0.261	0.367	8.132	8.76
Vernonia amygdalina	0.652	1.103	1.552	3.31
Vernonia auriculifera	1.825	3.676	1.743	7.244
Other species (6)	34.286	22.794	1.318	58.378

Wood production in parklands

Number of stems

The overall mean numbers of stems per quadrate and per hectare in the parkland agroforestry of the two study sites were 14.34 and 111.67, respectively. The number of stems per quadrate and per hectare varied significantly between the two study sites (F test; $p<0.05$) in Waro and Bechira (Table 8).

Table 8 Mean (±SD) number of stems of woody species per quadrate and ha in PAF at Bechira and Waro

Sites	Stem per quadrate	Stem per hectare
Bechira	13.47^{a}±5.77	102.27^{a}±44.56
Waro	15.58^{b}±5.47	121.07^{b}±45.34
Overall mean	14.34±5.74	111.67±45.69

Basal area

The average basal area of woody species in PAF at the two study sites were 0.31m^2 per quadrate and 2.4m^2 per ha (Table 9). The mean basal area of woody species per quadrate and per ha did not show a significant difference between sites ($p>0.05$). The mean basal area of woody species in PAF of per quadrate and ha at Waro site was 0.33m^2 and 2.52m^2, respectively (Table 9). Whereas, Bechira had a mean basal area of 0.29m^2 and 2.2m^2 per quadrate and per ha respectively (Table 9).

Table 9 Mean (±SD) basal area per quadrate and hectare at Bechira and Waro

Sites	Basal area per quadrate	Basal area per hectare
Bechira	0.29±0.16	2.20±1.36
Waro	0.33±0.18	2.52±1.38
Overall mean	0.31±0.17	2.4±1.37

Woody species preference and management

Species preference

Woody species preference was in the order of *Cordial africana*, *Croton macrostachyus*, *Albizia gummifera, Cajanus cajan, Ficus vasta* to Waro and *Cordial africana*, *Croton macrostachyus*, *Albizia gummifera, Cajanus cajan, Acacia abyssinica* to Bechira. Woody species preference was based on the contribution to ecological and economic services that species provided and multiple uses.

Management of woody species

The most common management practices used by the farmers at the study area included coppicing, pollarding, lopping, pruning, and thinning in parkland agroforestry. According to the respondents, the purposes of managing woody species in their parkland were to increase growth, minimize competition and for diverse purposes including fuel wood, construction materials, fodder, soil fertility improvement and the like.

Socioeconomic factors that affect woody species diversity in parkland agroforestry

Woody species diversity can be influenced by many household related socio-economic characteristics. The most influencing factors of woody species in the study area were family and farm size, wealth status, education level and extension service (Table 10). The species abundance and richness had a significant positive correlation with family size, wealth status, education and access to extension service. Family size noticed as positively correlated with abundance ($p<0.01$) and richness of woody species ($p<0.05$). A similar trend was observed for access to road and market. There was a significant positive correlation between age and abundance of woody species per farm of the household ($p<0.01$), but not significant correlation with species richness.

Table 10 Pearson correlation results of abundance and richness of woody species

Factors	Abundance	Species richness
Household age	0.168*	0.027ns
Gender	-0.127ns	0.038ns
Family size	0.273**	0.155*
Farm size	0.446**	0.457**
Wealthy status	0.498**	0.446**
Education	0.274**	0.235**
Extension service	0.319**	0.243**
Access to road and market	0.219**	0.184*

Note: ns, not significant; *, **, Correlation is significant at $p<0.05$, $p<0.01$ respectively

Discussion

Woody species diversity and composition

Retaining and planting of trees and shrubs determined by, the availability of the space, compatibility with agricultural crops and household objectives. The species composition, as well as diversity,

is higher in the PAF at Waro than at Bechira (Table 3). This result is in line with findings of[18] who reported 32 woody species on crop fields of Beseku in Arsi Negelle and[8] who reported 41 woody species at the cultivated lands of Burkina Faso. The Shannon, evenness and Simpson diversity indices showed higher values in PAF at Waro as compared to the PAF at Bechira. This was because of the high species richness and evenness of woody species in the PAF at Waro, which were the components of diversity (Table 3).

To assess the extent of similarity of woody species in parkland agroforestry, Sorenson's similarity index was used and the result showed a high similarity in woody species composition between the two study sites. This is because the woody species in PAF at both study sites are native and remnants from the clearance of natural forest as a result of the increase of agricultural land except few exotic woody species. The result of the present study revealed, 70.4% of the species were native (indigenous). Out of 27 woody species recorded in the PAF in the two study sites, 26% were found only in Waro and 11% was only found in Bechira. The remaining 63% of the woody species in PAF were common to both study sites.

Woody species frequency, importance value index and wood production

The present study revealed that variations in abundance and frequency distribution of woody species between the study sites and villages. This is due to the farm household species preference, compatibility of the species to farmland and the opportunity that afford the farmer to maintain the woody species on own farm.

Our finding has showed that the plant species including *Cordia africana* (93.3%), *Croton macrostachyus* (83%), *Cajanus cajan* (63.3%), *Albizia gummifera* (45.7%), *Grevillia robusta* (33.3%) and *Acacia bussei* (30%) were the top six frequently verified species are the most frequent plant species found in Waro Parklands. Whereas *Cordia africana* (96.7%), *Croton macrostachyus (*71.7%), *Cajanus cajan* (58.3%), *Albizia gummifera* (41.7%), *Grevillea robusta* (38.3%) and *Acacia abyssinica* (35%) are the most frequent plant species found in Bechira Parklands. Concerning the importance of the species to the household in PAF, *Cordia africana, Cajanu scajan, Croton macrostachyus, Albizia gummifera, Albizia gummifera,* were the top five important species in the two studied sites. The occurrence of these species in the parklands due to their importance for shade, improving soil fertility and positive association or compatibility with food crops. Similar studies have also reported the popularity of these trees as an important coffee shade in Eastern Ethiopia.[19]

The result of the present study revealed that the mean number of stems per quadrate and hectare had variations in Parkland agroforestry of both study sites. For example, the overall mean number of stem per quadrate and hectare were 14.34 and 111.67, respectively. The average number of stems recorded at both study sites were found to be 111.67 per ha which is larger as compared with the findings of[8] in PAF at Burkina Faso with mean values of 40.74 per ha and mean values of 32.76 per ha in PAF at Beseku, in Arsi Negelle.[18] *Trichilia emetica, Erythrina abyssinica, Ficus vasta, Ficus sycomorus, Albizia gummifera, Prunus africana, Acacia bussei, Persea americana* and *Moringa oleifera* weighed the greater proportion (73.3%) of the species found in Waro, whereas at Bechira the largest proportion (75.9%) of the basal area occupied by *Prunus africana*, *Ficus vasta*, *Erythrina abyssinica*, *Albizia gummifera*, *Persea americana*, *Trichilia emetica* and *Acacia abyssinica*. The present study reviled that basal area per hectare (2.36m^2) is larger as compared to the study done.[8] in PAFs at Burkina Faso with mean values of 1.102m^2 per ha, but it is relatively comparable with the finding.[18] who reported mean values of 2.81m^2 per ha in PAF at Beseku, in Arsi Negelle woreda.

Socioeconomic factors affecting woody species diversity in parkland agroforestry

The result of the present study showed variation in species richness, abundance and diversity between the study sites. Socio-economic related issues are influencing factors that affecting the diversity of on-farm woody species in the PAF system. Household age is the determinant factor that influences species diversity in parkland agroforestry in the study area. Age has a positive correlation with a mean number of stem per farm ($P< 0.01$), but there was no significant correlation with species richness. This showed that when the farm household becomes aged, they are limited to integrate additional woody species rather than maintaining the existing one. Household family size played an important role for woody species abundance and richness in parkland agroforestry. There was a significant positive correlation ($P<0.05$) between the species richness and households' family size ($p<0.05$) and the same is true for stem per farm ($P<0.01$). Farm size is widely influencing abundance and richness, as well as the diversity of woody species across the study sites. Woody species abundance and richness increase as farm size increase. The possible justification is that the number of woody species requires sufficient land and farmers with more land size are favored for diversifying woody species. Our finding corporates the earlier study reported small farm size as the main barrier to tree-planting and increasing of species diversity.[20,21] Wealth category is another essential factor that influences woody species diversification in parkland agroforestry at the study area. The present study revealed that wealth category was positively correlated with species abundance and richness. This is due to wealthy farm households were capable to retain and plant woody species on their farm better than that of medium and poor farmers and also rich farmers had the opportunity to buy seedlings either from the market or elsewhere, and better experience of handling of existing woody species. Education was highly positively correlated with abundance and richness of the woody species. The result showed that as the household becomes more educated, the number of species and density of woody species increase. This is due to the more educated are more responsive to manage woody species in their land holdings and easily apply the knowledge that obtained from experts. Extension service was an important factor that influences woody species richness. In the present study, there was a significant positive correlation ($P<0.01$) between the extension service and species richness, and density of woody species. This result is supported[21] who reported forestry extension programs are responsible for promoting the management of agroforestry by providing technical advice and inputs such as improved seedlings and extension activities. In the present study, access to road and market were positively correlated with the abundance ($p<0.01$) and species richness ($p<0.05$) of woody species. This is may be due to farm households who had the access to the road can supply farm output to market easily and by exchanging the output and they have got the access of input material for diversification and the wide opportunity of obtaining viable seedlings and other establishment input materials. Related to this, previous studies have also found that farming that high mean number of tree species per farms closer to the local market than farm far away.[11]

Conclusion

Species abundance and richness had a significant positive correlation with family size, wealth status, education and access to extension service. There was variation in species richness, diversity indices, density and frequency and this endowed with ecological and farm household characteristics. Woody species in parkland agroforestry played an important role in the way of diversifying use items of the farm household. Farmers employed different management practices like coppicing, pollarding, lopping, pruning and thinning to facilitate growth, reduce competition and to reduce shade effect. Family size, farm size, wealth, education, access to extension service, and access to road and market to be the most important determinant socio-economic factors that affect the diversity of woody species in the parkland. In General, the further detailed study of explicit examining of the contribution of parkland woody species for livelihood diversification is needed to fully understand the roles of parklands in improving human wellbeing.

Acknowledgements

We would like to extend our great appreciation to Bechira and Waro farmers', District and local experts for devoting their precious time to provide us information and sharing their knowledge for this study. We also would like to thank Zebene Asfaw (PhD) and Abdella Gure (PhD) for their assistance during research work.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

1. Zeila A, Jama B. *Agroforestry in the drylands of eastern Africa: a call to action*. World Agroforestry Centre; 2005.
2. Teklehaimanot Z. Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and Vitellaria paradoxa in sub-Saharan Africa. *Agroforestry Systems*. 2004;61(1–3):207–220.
3. Bayala J, Kindt R, Belem M, et al. Factors affecting the dynamics of tree diversity in agroforestry parklands of cereal and cotton farming systems in Burkina Faso. *New Forests*. 2011;41(3):281–296.
4. Bishaw B, Abdelkadir A. Agroforestry and community forestry for rehabilitation of degraded watersheds on the Ethiopian highlands. International symposium on contemporary development issues in Ethiopia, Ethiopia, 2003; 22 p.
5. Sinclair FL. A general classification of agroforestry practices. *Agroforestry Systems*. 1999;46(2):161–180.
6. Boffa JM. *Agroforestry Parklands in Sub-Saharan Africa*. FAO Conservation Guide 34, FAO, Rome, Italy; 1999.
7. Bonkoungou EG, Alexandre DY, Ayuk ET, et al. Agroforestry parklands of the West African semi-arid lands. Conclusions and recommendations of an international symposium. Ouagadougou; 1994. pp. 25–27.
8. Nikiema A, van der Maesen LJG, Hall John B. Woody species composition of Sudan savanna parklands in relation to rural land use gradients in Burkina Faso. PhD Thesis, Wageningen University, Wageningen; 2005. 102 p.
9. Zebene A. Tree species diversity, top soil condition and arbusecular mycorrhizal association in the Sidama traditional agroforestry land use, southern Ethiopia. Swedish University of Agricultural Science; 2003.
10. Abebe T. *Diversity in Homegarden Agroforestry Systems of Southern Ethiopia*. Wageningen University; 2005.
11. Reshad M. Farm characteristics and tree species diversity in Arbegona district, highlands of southern Ethiopia. M.Sc. Thesis, Hawassa University, Wondo Genet College of Forestry and Natural Resource, Ethiopia; 2006.
12. TWAO. Tembaro Woreda Agricultural Office planning section report (Unpublished). 2011.
13. Abed T, Stephens NC. *Tree measurement manual for farm foresters*. 2nd ed. National Forest Inventory, Bureau of Rural Sciences, Canberra; 2003.
14. Edwards S, Tadesse M, Hedberg I. Flora of Ethiopia and Eritrea, The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala; 1995.
15. Hedberg I, Edwards S. Flora of Ethiopia. The National Herbarium, Addis Ababa and Uppsala University, Uppsala; 1989.
16. Bekele-Tesemma A. *Useful Trees of Ethiopia: Identification, Propagation and Management in 17 Agro- ecological Zones*. World Agroforestry Centre, Nairobi, Kenya; 2007.
17. Kent M, Coker P. *Vegetation Description and Analysis: A Practical Approach*. John Wiley & Sons, Chichester; 1992. 363 p.
18. Tolera M. *Woody Species Diversity of Agricultural Land Scapes in Arsi Negelle District, Ethiopia: Impact for Biodiversity Conservation*. MSc. Thesis, Hawasa University, Wondo Genet College of Forestry, Ethiopia; 2006.
19. Teketay D, Tegineh A. Traditional tree crop based agroforestry in coffee producing areas of Harerge, Eastern Ethiopia. *Agroforestry Systems*. 1991;16(3):257–267.
20. Lemessa D, Legesse A. Non-crop and crop plant diversity and determinants in homegardens of Abay Chomen District, Western Ethiopia. *Biodiversity Int J*. 2018;2(5):433–439.
21. Omati J, Parton KA, Sinden JA, et al. Monitoring changes in the land use practices following agrarian de-collectivization in Ethiopia. *Agriculture, ecosystems and environments*. 1999;72(2):111–118.
22. Salam MA, Noguchi T, Koike M. Understanding why farmers plant trees in the homestead Agroforestry in Bangladesh. *Agroforestry systems*. 2000;50(1):77–93.