academicJournals

Vol. 6(4), pp. 301-307, April 2014
DOI: 10.5897/IJBC2014.0677
Article Number: 5A65AD446753
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Plant species diversity of homegarden agroforestry in Jabithenan District, North-Western Ethiopia

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Receive 2 January, 2014; Accepted 24 February, 2014

Homegarden agroforestry is believed to be more diverse due to the combination of crops, trees and livestock. The aim of this study was to assess plant species composition and diversity of homegarden agroforestry in Jabithenan district, North-western Ethiopia. Two sites purposively and two villages randomly from each site were selected. Plant species diversity inventories were carried out for 48 homegardens. All woody species and herbaceous species were counted and recorded in 10 x 10 m and 2 x 2 m plots, respectively. A total of 69 plant species (44 woody and 25 herbaceous) belonging to 40 families were recorded in the study homegarden. About 6-8 different species of plants per plot were recorded. Plant species such as *Musa paradisiaca* and *Brassica integrifolia* among herbs and *Coffea arabica* and *Cordia africana* among woody were the most frequently recorded species in the study Kebele. Of all woody species, *C. arabica* and *C. africana* showed the highest importance value index. Generally, according to the calculated diversity indices, the studied homegarden was found to be diverse

Key word: Composition, diversity, importance value index.

INTRODUCTION

Background and justification

A large percentage of the Ethiopian population (80%) depends upon agriculture for its livelihoods, which contributes 42-45% of the total gross domestic product of the country (Zenebe et al., 2011). But currently, the agricultural production falls under a risk due to a number of factors, such as climate change, soil erosion, soil fertility loss and severe soil moisture stress which is partly the result of loss of trees and organic matter (Salvatore et al., 2011). The whole effect of the above problem is loss of biodiversity, financial insecurity, food insecurity, subsequent increases in rates of malnutrition, which are becoming the major tribulations of human well-being, so having plant diversity for this serious problem should be necessary. The loss of biodiversity in turn has a range of ecological and societal consequences. Loss of biodiversity can have significant impacts on ecosystem function and reduces opportunities to avert production related risks (World Bank, 2008).

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Despite this, one of the solutions to meet diverse people's requirement with fixed/plot of land is through the application of agroforestry which has more diverse species than monocropping (Mcneely and Schroth, 2006).

Homegarden is an agroforestry practice known to be ecologically sustainable. Homegarden agroforestry is commonly defined as a land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole tree-crop, and animal unit is being intensively managed by family labour (Kumar and Nair, 2006).

Despite its vast coverage homegarden agroforestry practice in tropical country, in Ethiopia inventory and documentation of homegarden diversity and species composition are very few and focused in south and south-western parts of the country (Zemede and Zerihun, 1997; Zebene, 2003; Bekele, 2007; Mengistu, 2008). Therefore in the present study, we assess and quantify plant species diversity and composition in the homegarden agroforestry system of the Jabithenan district in Ethiopia.

MATERIALS AND METHODS

Study area

This study was conducted in the Jabithenan district, west Gojjam zone of Amhara National regional state, Ethiopia (10° 40′N; 37° 11′E). The topography of the district is generally characterized by flat gentle slope (65%), mountainous (15%), undulating terrain (15%) and valley (5%), with an altitudinal range from 1500 - 2300 m.a.s.l (JWARDO, 2012). The major soil types found in the district are Vertisol and Nitosol (JWARDO, 2012).

Climatically, the district falls within midland and lowland. The mean annual temperature is about 23°C, with maximum temperatures slightly above 32°C, and minimum of 14°C. The mean annual rainfall ranges between 800 - 1250 mm (JAWRDO, 2012).

The total human population of the district is 277,590, of whom 139,616 individuals are males and 137,974 are females. An estimated population density of the district is about 455.32 people per square kilometers (JAWRDO, 2012).

Agriculture is the principal source of livelihood for rural population. It is characterized by subsistence mixed farming of rain-fed, irrigated crops, and livestock. Besides crop plants, the common vegetation in the district includes tree species of *Croton macrostachys, Ficus sur, Albizia gummifera, Cordia africana, Acacia abyssinica, Rosa abyssinica* and *Erythrina abyssinica* which are found as scattered in most farm lands, whereas *Eucalyptus* spp. and *Gravillea robusta* are grown as boundaries, live fences and woodlots (JWARDO, 2012).

Sampling method

Site selection

Two Kebele Administrations (KA) namely, Mankusa Abdegoma and Jiga Yelmdar were selected purposefully based on the extensive presence of both homegarden agroforestry (HGAF). During preliminary surveys with the district agricultural office and development agent, Debohela and Waza villages from Mankusa Abdegoma KA and Atahagne and Tikurwuha villages from Jiga Yelmdar KA were randomly selected making a total of four villages for this study

Data collection

To assess the diversity and composition of plant species in the HGAF, two 10 x 10 m sample main plots were laid in 48 randomly selected homegardens (12 from each village). The first plot was selected randomly and the second plot was selected systematically in order to cover all species types occurring in the garden. Tree species with diameter at breast height (DBH) were measured (DBH>=5 cm while recording and counting those DBH<5 cm). Using ''X'' design within the main plot, either from the corners or at the middle one 2 x 2 m sub-plots were laid to catch herbs interspersed between woody plants. Since almost all herbaceous plants (spice, vegetable, tubers and roots) were concentrated near an individual house alone, another two sub-plots near/close to home were laid (randomly for the first plot and systematically for the second plot) to cover all herbaceous species in the garden and making a total of four sub-plots per garden/household. Plant species identification and data collection was carried out using knowledgeable persons from the local community, and the researcher himself.

In this study, plant species nomenclature follows flora of Ethiopia and Eritrea (Edwards et al., 1995; Hedberg et al., 2004, 2006) and a glossary of Ethiopian plant names (Kelecha, 1980). In order to show diversity across wealth category, the owner of the homegardens were classified according to local wealth category criteria.

Data analysis

HGAF plant diversity between villages was subjected to one-way ANOVA and mean differences between groups were considered significant at $p < 0.05$ using Turkey's test.

To estimate plant species diversity, several ecological indices were used: Shannon diversity index (H^1), equitability index (E), Simpson diversity index (D) and important value index (IVI) were used.

RESULTS

Plant species diversity in homegarden agroforestry

In the study villages, a total of 69 plant species (44 woody and 25 herbaceous), belonging to 40 families and different functional groups were recorded (Appendix 1 and 2). Among the woody species, families Euphorbiaceae, Myrtaceae, Mimosoideae and Rutaceae were the most diverse each having four species. The contribution of remaining families to species richness was in the order of: Rosaceae with three species > Moraceae and Anacardiaceae each of them contain two species, and the rest of families with one species each. Among herbs, the family Poaceae were the most diverse with four species, followed by Solanaceae with three species while others, Lamiaceae, Musaceae, Fabaceae, Brassicaceae and Alliaceae had two species. All the remaining families contained only one species. The

Table 1. Overall woody and herbaceous species richness of homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Species richness		
	Woody	Herbaceous	Total
Waza	28	18	46
Debohela	28	15	43
Tikurwuha	31	15	46
Atahagne	34	17	51

Table 2. Mean woody species richness and abundance per plot in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Richness	Abundance
	Mean (± Std)	Mean (± Std)
Tikurwuha	7.87^{b} ± 0.50	32.31^{a} ± 3.96
Atahagne	8.37^{b} ± 0.35	34.83^{a} ± 4.45
Waza	6.69^{a} ± 0.21	31.66^{a} ± 3.38
Debohela	6.37^{a} ± 0.40	16.29^{b} ± 3.22
Overall mean	7.32 ± 0.37	28.77 ± 3.69

Single different small letters on mean values indicate significant difference at $P < 0.05$ between the four study villages.

Table 3. Mean woody species richness per plot in homegarden agroforestry belonging to three wealth classes at four villages, Jabithenan district, Ethiopia.

Village	Richness		
	Rich	Medium	Poor
Waza	6.37^{a} ± 0.15	7.57^{a} ± 0.25	6.13^{a} ± 0.22
Debohela	7.63^{a} ± 0.86	5.87^{ab} ± 0.58	5.62^{b} ± 0.41
Atahagne	5.92^{a} ± 0.32	8.21^{b} ± 0.40	10.97^{c} ± 0.32
Tikurwuha	5.45^{a} ± 0.73	8.92^{b} ± 0.62	9.25^{b} ± 0.81

Single different letters on mean values indicate significant difference at $P < 0.05$ between the four study villages.

Table 4. Mean abundance of woody species in homegarden agroforestry belonging to three wealth classes at four villages, Jabithenan district, Ethiopia.

Village	Abundance		
	Rich	Medium	Poor
Waza	32.63^{a} ± 3.21	31.49^{a} ± 5.20	30.85^{a} ± 1.75
Debohela	24.87^{a} ± 3.15	13.87^{ab} ± 3.28	10.13^{b} ± 3.21
Atahagne	49.75^{a} ± 5.43	32.62^{ab} ± 3.34	22.12^{b} ± 4.58
Tikurwuha	46.62^{a} ± 4.93	28.69b ± 3.87	21.62^{b} ± 3.10

Single different letters on mean values indicate significant difference at $P < 0.05$ between wealth classes with in a village in a row.

homegarden species of the study villages can be grouped into four life forms; herbs, shrubs, trees and climbers (Figure 1).

Plant species richness, abundance and frequency

Farmers in the study villages retain various tree components based on spaces available and their compatibility with agricultural crops and household objectives. Table 1 and 2 shows plant species richness at four villages. The highest and lowest number of species (woody and herbaceous) was recorded at Atahagne and Debohela village, respectively. Extent of species richness at village level was in order of: Atahagne > Tikurwuha and Waza > Debohela.

The abundance of woody species in the villages was variable. Except at Waza village, there was significant difference in species richness and abundance between wealth classes (rich households are different from the other) of the same village in the study site (Tables 3 and 4).

Species abundance is a function of either household preference or best fit to the given ecology/climate. In this study, the top abundant recorded species are presented in Table 5 and the village level in Appendix 7.

The frequency occurrence of each species across the study sites is presented in Figures 2 and 3. Of the total species recorded at Mankusa Abdegoma KA; *Coffea arabica* (94%), *Cordia africana* (81%), *Sesbania sesban* (80%), *Persea americana* (60%) and *Citrus sinensis* (50%) were the top five frequently appeared woody species (Appendix 3). Among herbaceous species *Musa paradisiacal* (85%), *Brassica integrifolia* (59%) and *Saccharum oficinarum* (38%) were top frequently appeared ones (Appendix 4).

In Jiga Yelmdar KA, *C. arabica* (96%), *C. africana* (94%), *S. sesban* (75%), *M. indica* (60%) and *P. americana* (56%) were the five most frequently recorded woody species (Appendix 5). In this KA *B. integrifolia* (84%), *M. paradisiacal* (75%), *Daucus carota* (64%) were the top frequent herbaceous species (Appendix 6). The overall frequency across all sites/villages shows that *C. arabica*, *C. africana* and *S. sesban* were the three most frequently recorded species (Figure 4).

Diversity Indices

In order to get a better picture of plant species diversity, various diversity indices (ecological models) were calculated for each village and wealth category within the village. For woody and herbaceous species, the highest values of diversity indices were recorded at Atahagne village (Tables 6 and 7). Diversity indices showed a variation among wealth categories in each village (Table 8).

Table 5. Top five most abundant woody and herbaceous species in homegarden agroforestry at two kebeles, Jabithenan district, Ethiopia.

Kebele	Top five abundant species in decreasing order	
	Woody	Herbaceous
Jiga Y.	*Coffea arabica, Rhamnus prinoides, Sesbania sesban, Catha edulis, Cordia africana*	*Brassica integrifolia* , *Capsicum frutescens* , *Brassica oleracea, Musa paradisiaca, Daucus carota*
Mankusa A.	*Coffea arabica, Rhamnus prinoides, Persea americana, Citrus reticulate, Catha edulis*	*Musa paradisiacal, Brassica integrifolia, Lycopersicon esculentum , Capsicum frutescens, Brassica oleracea*

Table 6. Overall Shannon, evenness and Simpson indices of woody species in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Shannon index	Evenness	Simpson index
Waza	2.26	0.65	0.79
Debohela	2.31	0.66	0.83
Atahagne	2.43	0.73	0.82
Tikurwuha	2.38	0.70	0.80

Table 7. Overall Shannon, evenness and Simpson indices of herbaceous species in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Villages	Shannon index	Evenness	Simpson index
Waza	2.50	0.86	0.89
Debohela	2.28	0.84	0.85
Atahagne	2.55	0.90	0.90
Tikurwuha	2.30	0.83	0.87

Table 8. Mean per plot of Shannon, evenness and Simpson indices of woody species belonging to three wealth categories in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Indices	Wealth	Village			
		Waza	Debohela	Atahagne	Tikurwuha
Shannon	Rich	1.50^{a}± 0.07	1.35^{a}± 0.09	1.26^{a}± 0.09	1.01^{a}± 0.09
	Medium	1.22^{ab}± 0.07	1.40^{a} ±0.08	1.47^{a}± 0.08	1.59^{b} ±0.07
	Poor	0.98^{b} ±0.10	1.36^{a}± 0.07	1.88^{b}± 0.08	1.92^{c} ±0.07
Overall mean		1.23±0.08	1.37±0.08	1.54±0.09	1.50±0.08
Evenness	Rich	0.78^{a} ±0.02	0.77^{a}± 0.03	0.61^{a}± 0.03	0.59^{a}± 0.05
	Medium	0.62^{b}± 0.05	0.75^{a}± 0.04	0.70^{b} ±0.04	0.74^{b} ±0.04
	Poor	0.48^{c}± 0.05	0.71^{a} ±0.07	0.87^{c}± 0.02	0.88^{c}± 0.02
Overall mean		0.63±0.04	0.74±0.05	0.73±0.03	0.74±0.04
Simpson	Rich	0.70^{a}± 0.03	0.68^{a}± 0.04	0.57^{a} ±0.04	0.48^{a}± 0.05
	Medium	0.55^{ab}± 0.07	0.60^{a} ±0.07	0.65^{a} ±0.04	0.67^{b}± 0.04
	Poor	0.46^{b} ±0.05	0.63^{a}± 0.04	0.79^{b} ±0.02	0.81^{c}± 0.02
Overall mean		0.57±0.06	0.64±0.06	0.67±0.03	0.65±0.03

Single different letters on mean values indicate significant difference at ($P < 0.05$) between wealth classes with in a village in a column.

Table 9. Importance value index of the top five woody species with their rank (in bracket) at four villages, Jabithenan district, Ethiopia.

Species	Village			
	Waza	Debohela	Atahagne	Tikurwuha
Cordia africana	31.48(2nd)	38.18(2nd)	38.28(2nd)	55.11(1st)
Coffea arabica	53.69(1st)	49.51(1st)	49.95(1st)	51.82(2nd)
Sesbania sesban	20.96(4th)	20.73(5th)	16.77(4th)	29.33(3rd)
Albizia gummifera	23.39(3rd)	25.53(3rd)	-	17.74(4th)
Persea americana	15.54(5th)	-	16.10(5th)	15.45(5th)
Mangifera indica	-	-	17.92(3rd)	-
Acacia abyssinica	-	21.16(4th)	-	-

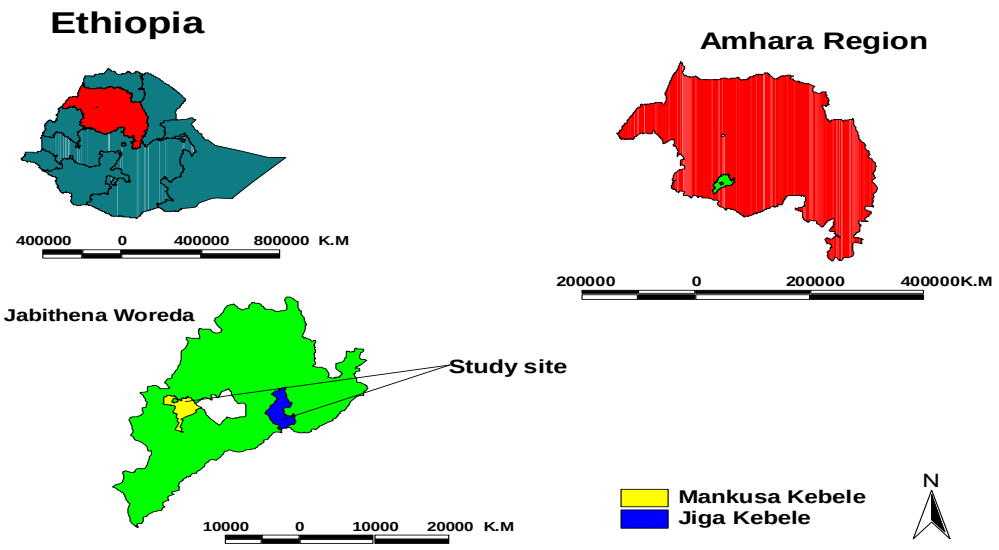

Figure 1. Location of study sites at Mankusa Abdegoma and Jiga Yelmdar Kebele, Jabithenan district, Ethiopia.

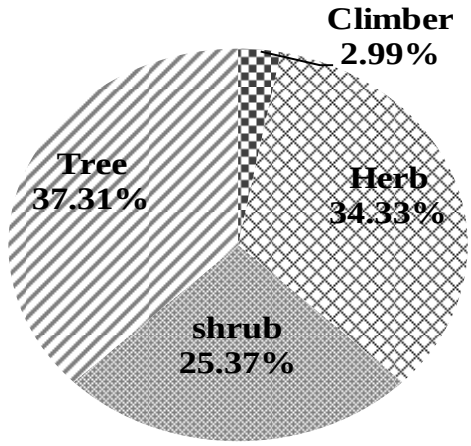

Figure 2. Proportion of life forms among homegarden plant species at four villages, Jabithenan district, Ethiopia.

Importance value index

To evaluate ecological and other benefit of each woody species recorded in the study site, their importance value index (IVI) was calculated and presented in Table 9; mainly for the top five while Appendix 7 shows the overall value for all species.

DISCUSSION

Most plant species found in the studied homegarden were frequently cited in other work, such as *Prunus persica*, *Dodonaea viscose*, *Zea mays*, *Curcurpita pepo* (Larato, 2011), *Citrus* species and *Psidium guajav* (Wezel and Bender, 2003); *Schnius molle* (Molebatsi et al., 2010); *Rhamnus prinoides*, *Otostegia integrifolia*, *Chata edulis, Brassica integrifolia, Lycopersicon esculant,*

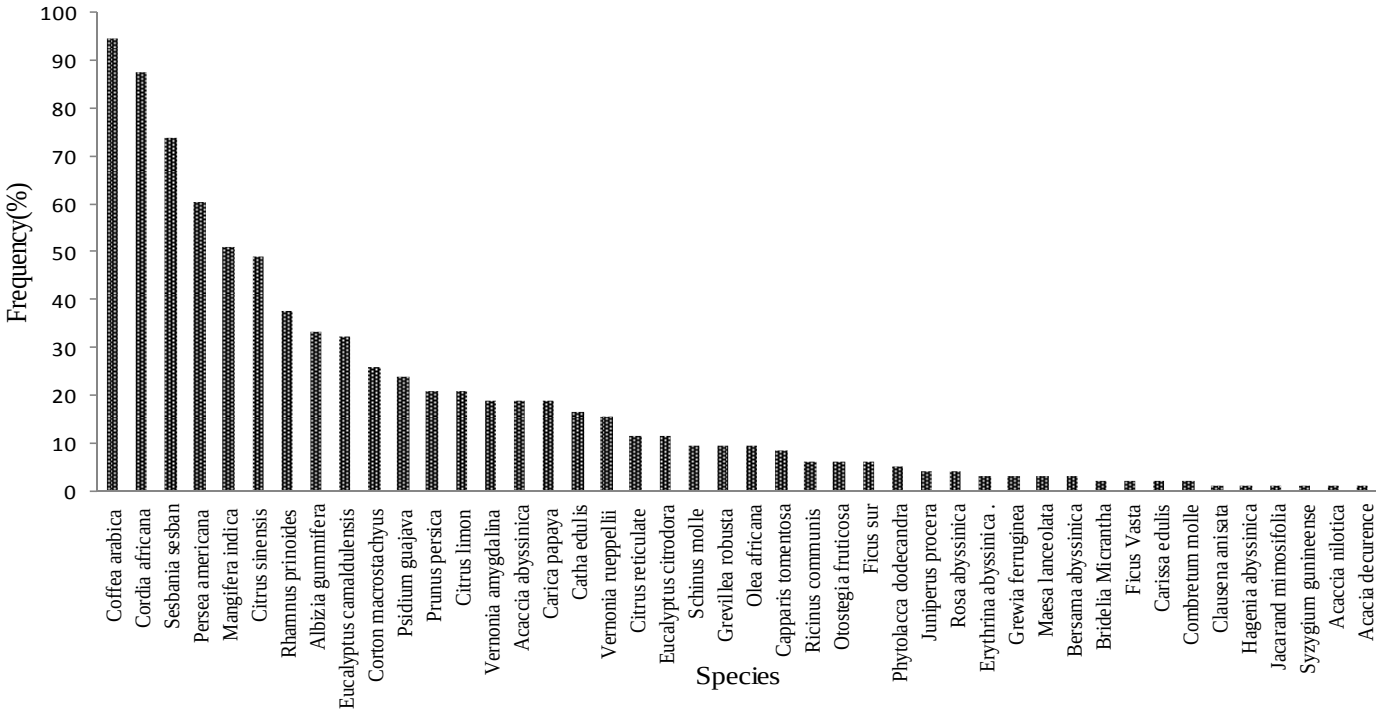

Figure 3. Overall frequent occurrence of woody species in homegarden agroforestry across four villages, Jabithenan district, Ethiopia.

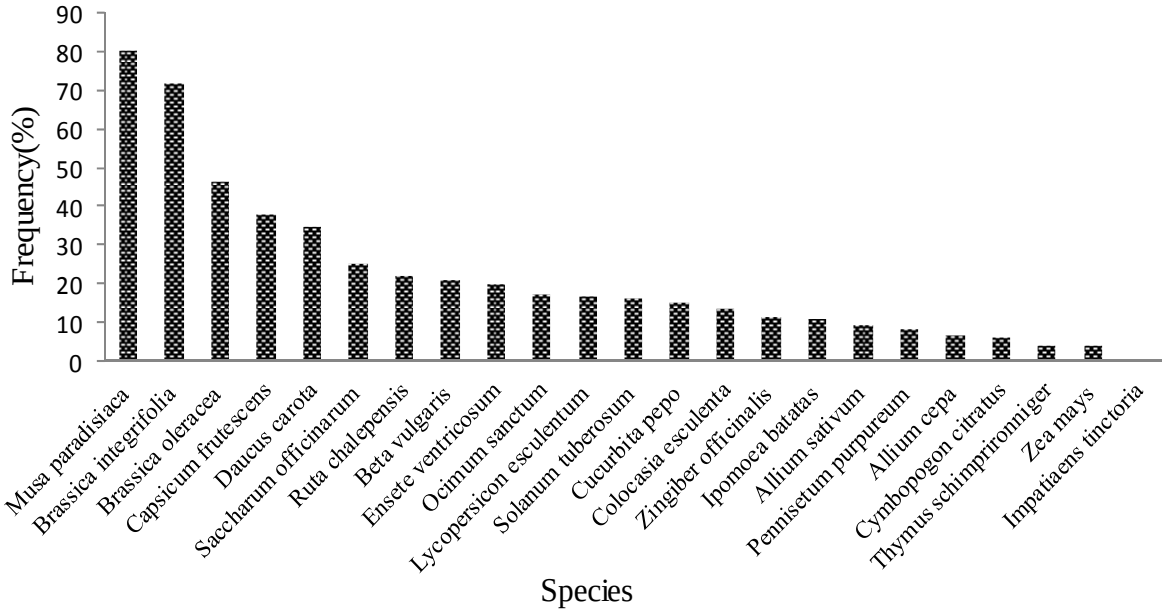

Figure 4. Overall frequency occurrence of herbaceous species in homegarden agroforestry across four villages, Jabithenan district, Ethiopia.

Allium cepa (Abebe et al., 2010). Wider global distribution of species shows their higher socio-economic and environmental role.

The 48 studied homegardens were composed of a total of 69 species. A study done in Sri Lanka, out of 106 homegarden, 289 plant species were recorded (Sandya et al., 2009); 84 plant species (n=420) from Nigeria (Udofia et al., 2012) and 32 plant species (n=81) from semiarid environment of central Sudan (Gebaur, 2005). Even in the study homegarden, there was a significant difference ($P < 0.05$) of plant species richness between two KA and more particularly the mean number of

species (species richness) per homegarden varied within a village.

The mean number of species (averaged across villages) per homegarden in this study (7) is lower than (11.0) that reported by Zemede and Ayele (1995) from 111 sample homegarden in Ethiopia and higher than the mean number of species (3.94) reported from Hintalo wajerat homegarden of Tigray (Hinsa, 2012). In general, the difference in species richness from place to place could be attributed to income difference, altitude, personal preference of species, soil type and homegarden size. Even in Debohela village, rich farmers had significantly higher number of species than poor farmers. This is may be due to the fact that farmers that experience income constraint tends to focus on few selected species which generate money to satisfy immediate needs, which is in line with research in homegarden of Arsi negele, Ethiopia (Motuma et al., 2008). In contrast, in Jiga Yelmdar Kebele; rich farmers had significantly lower number of species richness than poor households. This is may be due to the fact that richer household prefer to purchase species that are not much valued than poor farmers.

Jiga Yelmdar KA has higher species diversity than Mankusa Abdegoma kebeles in a plot base. This may be due to the higher species richness which leads to the higher species diversity In Jiga Yelmdar. This possible explanation was also forwarded to sidama homegarden (Abebe, 2005). The Shannon diversity index of the study area in village base was higher than that of the research done in northern Ethiopia of Tigray (H'=1.6 to 1.8) (Muruts, 2012); but the mean Shannon index was lower than homegarden of Meghalaya (2.37) (Tynsong and Tiwari, 2010). Mean Shannon indices vary widely in tropical homegardens and ranged from 0.93 to 3.00 (Tynsong and Tiwari, 2010).

In the study site, *C. arabica* and *Rhamnus prinoides* are the two most abundant species due to their higher socio-economic and social roles. *C. arabica* is the major source of cash income, whereas *R. prinoides* is primarily used to prepare local beer called ''Tela'' and is also another source of cash income. So, the studied homegarden is dominated by cash generating plant species instead of supplementary food crop.

The frequent occurrence of plant species was estimated to understand the extent of species distribution in each homegarden. *C. arabica, C. africana* and *S. sesban* were the top three most frequently appearing species. Farmers preferred the species due to their higher socio-economic and service benefit than the rest recorded species.

The importance of each individual woody species was estimated (importance value index). Accordingly, *C. arabica* scores the first and *C. africana* follows. This finding is also in line with the reports of Tynsong and Tiwari (2010) which shows that species with multiple uses showed higher IVI value.

Conclusion

High plant diversity was found in the studied homegardens. Homegarden agroforestry can also act as a refuge for threatened species like *C. africana* in Ethiopia. Vegetable crop (*Brassica integrifolia*), cash crop (*Coffea arabica*), fruit crop (*Persea americana, Musa paradisiaca*), timber tree (*Cordia africana*) and fodder tree (*Sesbania sesban*) are important species that were recorded.

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