Research article

Homegarden and coffee agroforestry systems plant species diversity and composition in Yayu Biosphere Reserve, southwest Ethiopia

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A R T I C L E   I N F O

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A B S T R A C T

Agroforestry systems are among the promising land use systems that enable to address both the development and livelihood issues of the community all over the world. In southwestern Ethiopia, homegarden and coffee agroforestry systems are widely used farming systems. Despite the fact that the systems are widely used and important, there are little studies on the subject. Therefore, the objective of this study was to assess homegarden and coffee agroforestry systems plant diversity and composition in Yayu Biosphere Reserve. To achieve the study's goal, data was collected through forest inventories and household surveys. A total of 101 plant species from 49 families were identified, with 74 from homegardens (37 families) and 57 from coffee agroforestry systems (34 families). In terms of dominating plants in agroforestry systems, home gardens are dominated by herbaceous plants, accounting for 51 percent, whereas coffee agroforestry systems in the study region are dominated by trees, accounting for 72 percent. About 38 percent of household gardens and 77 percent of coffee agroforestry are made up of indigenous plant species. According to the findings, both agroforestry systems at the research site have a great diversity of plant species. As a result, the systems may be able to provide a wide range of services to farmers. Farmers, professionals, and legislators must collaborate to improve the systems' components, composition, and arrangements in order to maximize and protect the systems' multiple benefits.

1. Introduction

Agroforestry systems are common land use systems among smallholder farmers in southwest Ethiopia. Agroforestry is believed to enhance agricultural sustainability due to the intimate association between the multitude of crops, trees and livestock, which provide various ecological and economic benefits (Shapiro and Frank, 2016). In line with reducing household vulnerability to food insecurity shocks, agroforestry plays a major role (Kebebew and Urgessa, 2011). Various studies realized that, agroforestry systems compared to other alternative systems are higher to assist farmers to spread risks and their cumulative benefits.

Understanding of agroforestry systems has the potential to generate useful empirical evidence about the performance and interaction of their subsystems (Figueroa, 2014). ICRAF classification of agroforestry is broadly on the basis of structural, functional, ecological and socioeconomic (Nair, 1993). Homegarden and coffee agroforestry systems are recognized worldwide as a sustainable intensive land use system. Homegardens as land use systems around a homestead are characterized by the intensive use of multispecies agro-ecosystems on the same plot of land managed in integration (Shapiro and Frank, 2016). Toledo and Moguel, 2012, as cited in Pinard et al. (2014), stated that coffee agroforestry systems are systems that exhibit a continuum of structural and biological diversity with wide range of species-rich complex agroforests. According to Valencia et al. (2014), conservation practitioners and policy makers seeking coffee agroforestry as a conservation strategy should consider how such agroforestry systems differ in species diversity and composition of the native forests to promote greater resource conservation.

Homegarden and coffee agroforestry systems of South Western Ethiopia are one such stable agro-ecosystem and these systems have contributed to improvements in food security, regional and national economies and environmental resilience (Kebebew et al., 2011). According to Gole (2003), homegardens are recommended for complementary conservation approaches to enhance the conservation and use of coffee genetic resources for Yayu forest.

Despite the contribution of agroforestry, only few studies have been undertaken on the systems and less attention has been given to their benefits (Kebebew and Urgessa, 2011). Agroforestry knowledge gaps yet not addressed so far are greater than the actual body of knowledge in context and local aspects (Mbow et al., 2014). The dynamic nature of the
system that uses multiple principles needs a research plan that extends through time (Shapiro and Frank, 2016). According to the recommendation forwarded by Mbow et al. (2014) research efforts on these important cropping systems needs to intensifying by addressing tree species under a given site conditions, and tree-crop-site combinations that are characterized by their interactions. An integrated approach that takes into account the different sub-components of the farming system and their interactions is needed to identify and test context-specific improvements that can be implemented and tested at on-farm sites to foster practical knowledge (Timler et al., 2014). Although Southwest Ethiopia is a potential area for agroforestry, its potentials and limitations for high productivity, economic return and ecological services are not yet fully studied. Therefore, this agroforestry practice in the region needs research and development to realize its full economic and ecological potentials (Worku, 2013). Understanding all aspects of agroforestry systems to connect all possible beneficial collaborations and try to develop sustainable closed-loop farming systems is most important (Figueroa, 2014).

This study aimed to describe homegarden and coffee agroforestry systems based on the diversity and composition of plants. The study has a vital role to contribute for understanding and improving agroforestry systems, because those systems in the area are important to be addressed from the perspectives of livelihood support and conservation of biodiversity as well as diversification of agriculture. More specifically, the main objective of this study was to assess plant diversity and composition of homegarden and coffee agroforestry systems in Yayu Biosphere Reserve.

2. Materials and methods

2.1. Description of the study area

Yayu Biosphere Reserve is situated in the Southwestern part of Oromia National Regional State and located about 560 km west of Addis Ababa. The study was conducted in Yayu and Hurumu district in the

Biosphere Reserve Illu Abba Bora zone Oromia National Regional State, Southwest of Ethiopia (Figure 1).

The geographical location of Yayu Biosphere Reserve is between 8° 0' 42" N to 8° 44' 23" N and 35° 20' 31" E to 36° 18' 20"E, which is the location of a potential Ethiopian forest. The altitudinal range of Yayu Biosphere reserve is found from 1,200 to 2,000 m. a.s.l as stated by Gole et al. (2008). The total area of the Yayu Coffee Forest Biosphere Reserve is 167,021 ha. UNESCO was registered the Biosphere Reserve by the year 2010. The mean annual temperature is about 20 °C. According to Gole et al. (2008) the mean annual rainfall is 2,100 mm per year. The mean annual temperature is about 20 °C. There is some variation in temperature throughout the year, with the hottest months in February to April (29 °C) and the coldest months during July to September (12 °C). The study area is consists Dega 11.35%, Woynadega 56.78% and Kolla 31.87% with the total area of 133241.08 ha.

2.2. Methods

2.2.1. Study site selection

The study sites Kebeles (Peasant Associations) and Districts were selected purposefully. Four kebeles from two districts Wabo and Bondo Magela from Yayu, and Wangegne and Gaba from Hurumu district were selected for this study. Yayu Coffee Forest Biosphere Reserve and districts were selected based of the forest resource potential and the interaction of the community with the existing forest resource found in the transition zone of the biosphere reserve. The selection of the study sites Kebeles was on the basis of the wide practice of the agroforestry system and accessibility to conduct the study following Linger (2014) and Feyssa et al. (2015).

2.2.2. Sampling techniques

To decide the study approach and techniques to be used for the main study as well as to have an overview of the study area a preliminary
assessments was carried. General practice of agroforestry systems were addressed through conducting Focus Group Discussions (FGD) in respective sites. In addition to this, questionnaire tools were tested during the preliminary assessment and accordingly improved for the final study. Farmers who practice homegarden and coffee agroforestry systems were identified and included in the sampling frame of this study which was the entire population for the study.

Thirty-two households, 16 households from each district, were selected by a systematic sampling technique in order to constitute 32 interviewees following procedures of a previous study of Meylan et al. (2013). The plots for vegetation assessment were taken from the respective household farms those selected for household interview followed by Meylan et al. (2013). This plot selection method enables to avoid the mismatch between interviewed household and the assessment of agroforestry system. A total of 64 plots, 32 homegarden and 32 coffee agroforestry plots, were used for the inventory.

### 2.2.3. Data collection methods

The primary data were collected through FGD, direct observation, household survey and field inventory. Owners of the farms, elders and local botanist were used to identify the local vernacular name of plant species in Afan Oromo (AO). As has been used by many previous studies, to identify the scientific names and families of plant species different published volumes of Flora of Ethiopia and Eritrea, and Azene Bekele were used (Edwards, 1995; Phillips, 1995; Edwards et al., 2000; Bekele-tesemma, 2007).

### 2.2.4. Data analysis

The household interview data were analyzed by using IBM (SPSS version 20) software. Inventory data were organized by using Microsoft Excel 2016. To analyze diversity of species and species evenness, a Shannon index of diversity, which takes into account both richness and evenness, were used.

Shannon’s index: \[ H = - \sum \left( \frac{n_i}{N} \ln \left( \frac{n_i}{N} \right) \right) = - \sum P \ln P_i \]

Where \( n_i \) refers to number of individuals of each species (the \( i \)th species) and

\[ N = \text{natural log of the number for the site.} \]

Evenness: \[ E = \frac{H}{\ln S} \]

Where \( H \) is Shannon’s diversity index, \( S \) is total number of species in the site, and \( \ln \) is the natural log of the number Magurran, A.E. (1988) as cited in Abebe (2013).

To compute similarity and dissimilarity of species composition in the sample within the systems Sorensen’s similarity index were applied. Sorensen’s Index: \[ S_s = \frac{2a}{a+b+c} \]

Where: \( a \) refers joint occurrences number of species in sample A and sample B

\( b \) stands for number of species in sample B but not in sample A

\( c \) represents number of species in sample A but not in sample B.

Spearman Correlation, percentages and indexes were analyzed. The analyzed results were reported in frequencies, or as percentages, by using figures and tables.

### 2.3. Ethical approval

The research work was approved by Jimma University College of Agriculture and Veterinary Medicine Research and Ethical Review Board (RERB). Ethical consent was through verbal and all respondents were informed as well as their willingness was confirmed orally.

### 3. Results and discussion

#### 3.1. Characteristics of households, homegarden and coffee agroforestry

The most common family size was six persons per household, which accounted for around 31% of the sample households, with an average of five. The research areas sampled households’ educational status ranges from illiteracy to completion of high school. At the first (grades 1–4) and second (grades 5–8) cycles, 16 percent and 50 percent of households were educated, respectively, and around 25% of them were illiterate. The remaining 9% of households have at least a secondary school education. As shown in the graph, the average total landholding size of the studied households was 1.84 ha, with a range of 0.5–4.5 ha. About 25% of all families have a total land holding of less than one hectare. Total land holding size has a strong positive correlation with homegarden and coffee agroforestry area.

The average size of a homegarden in the research area is 0.103 ha, with a range of 0.03–0.25 ha. This is smaller than the 0.15 ha average homegarden size reported by Kebebew et al. (2011) for homegardens around Jimma, Ethiopia. About 56% of homegarden area was 0.11 ha and 83% of the homegardens area was less than the average homegarden size of the study area. Homegardens of the study area are characterized by small and uniform land size.

This is because of most of the land owners got the garden during resettlement program. With this program the land size for homestead was 0.1 ha (25 \( \times \) 40 m\(^2\)). The land size of homegarden has a direct relationship with income farmers get from homegarden. The coffee agroforestry land size of sampled households of the study area ranges between 0.38 and 3 ha. The average coffee agroforestry land size of the overall mean is 0.93 ha.

The age of homegardens ranges between 8 and 42 years with overall mean of 24 years. Some of the households were resident in the area from the beginning of their live; some were old immigrant and the rest were new immigrant to the area; due to such reason, the area changed through time depending on the settlement of the householders. Homegardens of Yayu Coffee Forest Biosphere Reserve about 81% and 19% converted from cultivated/farm land and coffee farm respectively. About 90% of the respondents said that the management responsibilities of homegarden mainly accomplished by females. The remaining 10% responded that they share equal responsibilities. Except some labor intensive works that covered by males most activities including harvesting and sale of products from homegarden covered by females.

The average age of coffee agroforestry system of the study area was about 26 years with range of 15–42 years. This result is greater than the average age of coffee agroforestry 11.6 years reported from the La Sepultura Biosphere Reserve (SBR) of Mexico with range 2–40 years (Valencia et al., 2014). From the sample coffee agroforestry systems 69% were originally natural forest and 31% converted from farm land. About the management responsibilities of coffee agroforestry all of the respondents confirmed that mainly males take the responsibilities. Females have a great role in coffee harvesting time. According to the responses of respondents, females also take share during coffee seedling plantation time in coffee agroforestry. Again this also confirmed by the group discussion.

#### 3.2. Composition and diversity of plant species agroforestry system

Analyses of the plant species composition in the homegarden agroforestry system indicates two dominant plants Coffea arabica (Buna) and Persea Americana (Avocado) occurred equally in 96.9 % of the homegardens, followed by Brassica carinata (Raufuu) 87.5%, Ruta chalepensis (Tendamada) 84.4%, Phaseolus vulgaris (Dafeye) and Ensete ventricosum (Kochoo/Warkee), both occurred in 81.3% of the homegardens (Table 1). The most common plant species in the coffee agroforestry system was Coffea arabica (Buna) that occurs in all farms (100%) (Table 1). Members
of FGD and owners of the farms provided evidence that the plant species in the coffee agroforestry were selected on priority status, based on the suitability of trees for shade as well as construction and other benefits they provide. Among the identified plant species in the homegarden and coffee agroforestry, 28 plant species were recorded in common in both homegarden and coffee agroforestry systems of the study area. The Sørensen’s similarity index showed that the two agroforestry systems share 42.75% of plant species in common.

### 3.2.1. Plant species diversity in agroforestry system

A total of 101 plant species were identified in both homegarden and coffee agroforestry systems of the study area, belonging to 49 families. The commonly represented families were Fabaceae which contains 10 species, followed by Euphorbiaceae and Rutaceae that contain 7 and 6 plant species, respectively. The reason that Fabaceae is the most dominant in the system is due to the fact most vegetables, spices and medicinal plants belong to this family, which is found in the study site. This result is supported by Regassa (2016) who reported that Fabaceae was the family with the highest number of species followed by Euphorbiaceae. Twenty-eight of the families each contain only one plant species; among those identified are Acanthaceae, Annonaceae, Apiaceae.

The total number of plant species recorded from the sample homegardens were 74, which belong to 37 families, with an average of 14 plant species per homegarden. This result is in line with Mengistu and Fitamo (2015) who reported 75 plant species in the homegardens of Dilla zuriya district of Gedeo Zone. Moreover, the results are comparable with previous finding of Sidama homegarden agroforestry by Abebe (2013), who found 78 plant species with an average of 16 per farm; and also with Mekonnen et al. (2014) who reported 69 plant species in homegardens of Amhara region. Minimum and maximum plant species richness per homegarden were recorded as 8 and 22, respectively; which is higher than the range of plant species (between 4 and 13) reported in previous findings by Kebebew et al. (2011) from the homegardens around Jimma. The most species rich families in the homegarden were Fabaceae with six species, which is supported by a previous study in the homegarden of Holeta (Amberber et al., 2014) followed by Euphorbiaceae, Poaceae, Rutaceae and Solanaceae families, each containing five plant species.

The overall result of the Shannon’s diversity index and Evenness index of homegardens with coffee in the research area were $H' = 2.45$ and $E = 0.61$, respectively. The changes of the indexes due to coffee are also indicated in Table 2. The reason for increasing diversity and evenness without coffee were due to the domination of coffee stands in the system. The share of coffee in number of individuals in the homegardens of the study area was about 29% (see Table 3).

From the coffee agroforestry system of the study area, a total of 57 plant species belonging to 34 families were identified. The result of current study is in agreement with Pinard et al. (2014), who reported that 59 tree species that belonged to 30 plant families were identified in coffee agroforestry systems of Central Kenya. Fabaceae is the most species-rich family in the coffee agroforestry system, which contains nine plant species followed by Euphorbiaceae family, containing six plant species, and Moraceae and Rutaceae families each containing three plant species. Least plant species numbers were recorded in 22 families that contain only one plant species and seven families each consisted of two plant species. Plant species richness per plot was ranges between six and fifteen with an average of nine plant species.

Evenness and Diversity of Shannon’s index of plant species with coffee were computed as $E = 0.11$ and $H' = 0.43$, respectively. The diversity indexes computed for sites without coffee were $H' = 2.75$ and $E = 0.71$ (Table 2). This indicated that the number of coffee individuals in the agroforestry systems of the study area is much higher than that of other plant species. Coffee covered 93% of plant individual stands in the coffee agroforestry system. The results provide a lesson on how an individual species affects the diversity of a given plant community. The Sørensen’s similarity index showed that the two agroforestry systems share 42.75%

### Table 1. Socioeconomic characteristics of sampled household.

| Household Characteristics | Study Sites | | | | |
|---------------------------|-------------|-------------|-------------|-------------|-------------|
|                           | Yayu        | Hurumu      | Total       | | |
| Age                       | Min         | Max         | Min         | Max         | Mean        |
|                           | 36          | 75          | 30          | 66          | 48.38       |
| Education                 | 0           | 10          | 0           | 12          | 5.06        |
| Family size               | 2           | 9           | 1           | 7           | 5.38        |
| Total land size (in ha)   | 0.5         | 4           | 0.03        | 0.15        | 0.093       |
| HG land size (in ha)      | 0.38        | 3           | 0.38        | 3           | 0.38        |
| CAF age                   | 8           | 42          | 12          | 35          | 24.69       |
| HG age                    | 18          | 42          | 15          | 35          | 24.88       |
| CAF age                   | 18          | 42          | 15          | 35          | 24.88       |

CAF = Coffee Agroforestry, HG = Homegarden

### Table 2. Top 10 plant species in frequency across homegarden and coffee agroforestry.

| No. | Scientific Name | Percentage (%) | Scientific Name | Percentage (%) |
|-----|-----------------|----------------|-----------------|----------------|
| 1   | Persia americana| 96.9           | Coffea arabica  | 100            |
| 2   | Coffea arabica  | 96.9           | Albisia gummifera| 78.1          |
| 3   | Brassica carinata| 87.5           | Albertia grandibracteata| 68.8    |
| 4   | Ruta chalapensis| 84.4           | Acacia lahai    | 65.6           |
| 5   | Phaseolus vulgaris| 81.3           | Cordia africana| 56.3           |
| 6   | Ensete ventricosum| 81.3           | Croton macrostachys| 43.8      |
| 7   | Zea mays        | 71.9           | Sapium ellipticum| 37.5       |
| 8   | Euphorbia tirucalli| 71.9           | Bridelia micrantha| 31.3       |
| 9   | Mangifera indica| 71.9           | Vernonia amygdalina| 28.1      |
| 10  | Musa paradisiaca| 65.6           | Euphorbia tirucalli| 28.1     |

### Table 3. Plant species diversity ($H'$) and evenness ($E$) of homegarden and coffee agroforestry.

| Study sites | Shannon indexes | Homegarden AF | Coffee AF | | |
|-------------|-----------------|---------------|-----------|---------------|-----------|
|              | With coffee     | Without coffee | With coffee | Without coffee |
| Yayu        | $H' = 2.259$   | $2.314$       | $0.402$   | $0.402$       |
|             | $E = 0.584$    | $0.601$       | $0.106$   | $0.374$       |
| Hurumu      | $H' = 2.553$   | $2.793$       | $0.437$   | $2.444$       |
|             | $E = 0.64$     | $0.703$       | $0.116$   | $0.654$       |
| Total (Over all) | $H' = 2.454$   | $2.613$       | $0.431$   | $2.75$        |
|             | $E = 0.607$    | $0.649$       | $0.111$   | $0.714$       |
of plant species in common. The number of plant species that belong to the homegarden agroforestry system is 46 out of 74; whereas, 29 out of 57 are found only in the coffee agroforestry system. Those plant species found only in coffee agroforestry are the species that preferred for coffee shade and required wider space; that is why farmers not need to cultivate in their homegarden. This indicated that there is a high probability that the two systems share some species in common.

### 3.2.2. Growth habit and origin of plant species

Plant species in the research site identified through this study belong to three growth habits: tree, shrub and herbs. In the homegarden agroforestry system, most species were herbaceous; which is about 51.35% of the identified species. This is due to farmers’ preference for herbaceous crops especially vegetables for home consumption and market purposes. This result is in line with Amberber et al. (2014) who reported that herbaceous plants contributed more in the homegardens of Holeta. Trees and shrubs contributed in the homegardens of Yayu Biosphere Reserve by 33.78% and 14.87%, respectively. The result reported by Regassa (2016) showed that herbs were the most numerous species in the homegardens of Hawassa followed by shrubs 27.13% and trees 24.8%. Whereas, in the coffee agroforestry system most of the species belonged to trees (71.93%); followed by shrubs which accounted for 22.81%. The domination of trees in the coffee agroforestry system is due to the formation of the system that had been modified from a natural forest for coffee production and shade demand for coffee plant cultivation.

The two agroforestry systems, homegarden and coffee agroforestry, consists both native and exotic plant species. Homegarden agroforestry of the Yayu Biosphere Reserve is consists 46 (62.2%) exotic plant species out of 74 plants that were identified through this study. Only 28 (37.8%) of plant species are native to Ethiopia. The domination of exotic plant species in the homegarden agroforestry is due to fruit and vegetables, which have a great contribution in species richness; and farmers used the exotic species more for a food source. This result is in line with Regassa (2016) who reported that plant species in the homegardens of Hawassa consist of 32.17% plants are native to Ethiopia, and 62.02% of the identified plants are exotic species. The results of our study are also in agreement with Senbeta et al. (2013) reported that, trends in frequency of use are in favor of exotic and economically important species. This result is slightly different from the previous finding in the South-east Ethiopia homegarden agroforestry practice, where farmers manage both exotic (46.7%) and native trees/shrubs species (53.3%) reported by Mengistu and Asfaw (2016). Coffee agroforestry systems of the study area reported here consist of about 43 (76.8%) indigenous plant species and only 24 (23.2%) exotics. This is due to the fact that the coffee agroforestry of the study area was modified from a natural forest for coffee production. So, the remnant of trees and shrubs in the coffee agroforestry including coffee itself are indigenous species. This study is in line with the finding that reported nearly all species are native in a coffee forest of Ethiopia (Senbeta et al., 2013). The result also is in line with Pinard et al. (2014) who reported that indigenous species represented 63% of the richness in coffee agroforestry.

### 3.3. Functional characteristics of plant species

Based on their function among identified plant species, fruit plants had a maximum share in the study homegardens by 19% (14 species) (Figure 2). This result is in line with Kebebew and Urgessa (2011), who reported that homegardens were mainly dominated by fruit trees, which provide subsistence and cash to the household; and also Amberber et al. (2014) who reported the homegarden plant species composition of Holeta included 19 species (17%) that were fruit and 15 species (13%) that were vegetables. The next most important category was construction/fuel wood which covered 15% and followed by vegetables that covered 11% of the species in the homegardens. Farmers introduced fruit and vegetables because of their importance for food and market. Growers of fruit and vegetable are more benefited by providing food items for their families and able to generate a better income from them.

Plant species identified in the coffee agroforestry were categorized under seven functional groups based on the actual uses of the respondents. Plant species grouped under construction and fuel wood use contributed 30% to the coffee agroforestry system. The result is in line with the finding of Senbeta et al. (2013), who reported that the greater proportions of the recorded species were used for timber, firewood, construction, farm tools and production of charcoal. Shade trees contributed 18%, followed by fruits at 10%. There were plant species in the study coffee agroforestry which have multiple functions for farmers; and such plants have a share of 25% in the coffee farms.

#### 3.4. Relationship between agroforestry system characteristics

Spearman correlation results showed that there is a positive significant correlation of total land holding size with homegarden land size and age of homegarden at p < 0.05 and p < 0.01 level of significance, respectively. Homegarden size showed a positive significant correlation with homegarden age and annual income from homegarden both at p < 0.01 level of significance.

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**Figure 2.** Functional groups of plant species in the homegardens of the study area.
The land size of coffee agroforestry system in the study area has a high positive correlation with the total land holding size of the households at p < 0.01 level of significance. This indicated that for households with a large total land size, there is a high probability that such land owners leave more land for coffee production than those of farmers who have less total land.

Annual income from the coffee agroforestry system in the study area ranges from 2,000 to 30,000 ETH birr per annum. The results indicated that the average coffee agroforestry income per annum is about 8,987.5 birr. The homegarden agroforestry annual income ranges between 200 to 1,167 birr.

Annual income from coffee agroforestry system in the study site has a strong positive correlation with the coffee agroforestry land size at p < 0.01 level of significance. This also is further realized by the report of respondents in the FGD who reported that the income from coffee production mainly depends on the size of coffee land that they have. About 78% of respondents realized that land shortage is a major factor that affects coffee production.

4. Conclusions and recommendations

4.1. Conclusions

Homegarden and coffee agroforestry systems are widely practiced in Yayu Biosphere Reserve. Homegarden agroforestry systems were practiced around homesteads in the transition (utilization) zone. Coffee agroforestry systems are found in two zones; i.e., buffer zone and transition zone. Homegarden and coffee agroforestry systems of the study area are characterized by high plant species composition. The diverse plant species have served the community in the area by providing a variety of benefits for small-holder farmers. The homegarden and coffee agroforestry have high contribution for livelihood of the community in the study area. Even though agroforestry systems in the study area as a sustainable land use system provides multiple benefits for land owners, due to various factors the systems do not serve the owners with its full potential as the study revealed the potential of agroforestry is yet underutilized. The systems need an integrated effort to maximize the contribution of the systems to the livelihood of smallholder farmers while they utilize the resources in a sustainable manner.

4.2. Recommendations

Based on the findings of this study the following recommendations are presented.

➢ Homegarden and coffee agroforestry systems provide multiple benefits for the farmers and play an important role for the sustainable management of the Biosphere Reserve. Thus, these systems need more attention to address the aims of conservation of biological diversity and improvement of the livelihood of the community.

➢ Considering their importance of sustainable land use system and sources of multiple benefits, homegarden and coffee agroforestry systems of Yayu need to intensify more at the smallholder farmer level.

➢ The composition of homegarden plant species in Yayu Biosphere Reserve is dominated by exotic plant species, thus indigenous plant species need attention.

➢ Coffee agroforestry practice of the study area highly influencing the plant diversity within it, thus attention is needed by concerned individuals to keep the multispecies farming system that provides greater diversity of native plant species of this system.

➢ Further study is needed to identify a prototype of homegarden and coffee agroforestry systems at a large scale to propose for more specific management options.

Declarations

Author contribution statement

Getinet Seid: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Zerihun Kebebew: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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Appendix 1. Identified plant species with their growth habit and origin in the study agroforestry systems.

| No. | Local name (Afan Oromo) | Scientific name | Family name | Growth Habit | Origin |
|-----|------------------------|----------------|-------------|--------------|-------|
| 1   | Girar                  | Acacia abyssinica Hochst. | Fabaceae | Tree         | I     |
| 2   | Sondi                  | Acacia lahai | Fabaceae | Tree         | I     |
| 3   | Lafto                  | Acacia sieberiana | Fabaceae | Tree         | I     |
| 4   | Alele                  | Albizia grandibracteata | Fabaceae | Tree         | I     |
| 5   | Ambabessa/Muka-arba    | Albizia gummifera Gmel. | Fabaceae | Tree         | I     |
| 6   | Kulubi adi             | Allium sativum | Amarillidae | Herb         | E     |
| 7   | Shunkurta dima         | Allium cepa. L. (A.ascalonicum. L.) | Amarillidae | Herb         | E     |
| 8   | Ananasi                | Ananas comosus | Bromeliaceae | Herb         | E     |
| 9   | Gishta                 | Annona senegalensis Pers. | Annonaceae | Tree         | I     |

(continued on next page)
| No. | Local name (Afan Oromo) | Scientific name | Family name | Growth Habit | Origin |
|-----|------------------------|-----------------|-------------|--------------|--------|
| 10  | Wendebiyo              | Apodytes dimidiate | Icacinaceae | Tree         | I      |
| 11  | Kodo (ariti)           | Artemisia afr. Jacc. | Asteraceae | Herb         | I      |
| 12  | Byby                   | Asadricha indica | Meliaceae   | Tree         | E      |
| 13  | Lodchisa               | Bersama abysinica (subsp. abysinica) | Melanthiaceae | Tree         | I      |
| 14  | Keysiri                | Beta vulgaris (L.) Moq. | Chenopodiaceae | Herb         | E      |
| 15  | Raafuu (Denkele)       | Brassica carinatis A.Br. | Brassicaceae | Herb         | I      |
| 16  | Abraangoo              | Brassica oleraceae L. var. acephala | Brassicaceae | Herb         | I      |
| 17  | Riga-arba              | Bridelia microcarpa (Hochst.) Baill. | Euphorbiaceae | Tree         | I      |
| 18  | Harangama              | Capparis tomentosa | Capparidaceae | Tree         | I      |
| 19  | Berbere                | Capsicum frutescens L. | Solanaceae | Herb         | E      |
| 20  | Mitmita                | Capsicum microcarpum | Solanaceae | Herb         | E      |
| 21  | Papaya                 | Carica papaya L. | Caricaceae | Tree         | E      |
| 22  | Sufii                  | Carthamus tinctorius | Asteraceae | Herb         | E      |
| 23  | Kazmir                 | Caesalpinia edulis | Rhamnaceae | Tree         | E      |
| 24  | Shewshewe              | Cautaria cunninghamiana | Casuarinaceae | Tree         | E      |
| 25  | Chati                  | Catha edulis (Vahl) Forsk. ex Endl. | Celastraceae | Shrub        | I      |
| 26  | Vetiver                | Chrysopogon staminoides L. | Poaceae | Herb         | E      |
| 27  | Lomi                   | Citrus aurantifolia (Christm.) Swingle | Rutaceae | Shrub        | E      |
| 28  | Tiringo                | Citrus medica L. | Rutaceae   | Shrub         | E      |
| 29  | Burtukana              | Citrus sinensis L. | Rutaceae   | Shrub         | E      |
| 30  | Umlaya                 | Clausena anisata | Rutaceae   | Shrub         | I      |
| 31  | Buna                   | Coffea arabica L. | Rubiaceae  | Shrub         | I      |
| 32  | Godere                 | Colocasia antiquorum (L.) Schott. | Araceae | Herb         | E      |
| 33  | Wodessa                | Cordia africana Lam. | Boraginaceae | Tree         | I      |
| 34  | Mekenisia/Dogoma       | Croton macrostachyus Del. | Euphorbiaceae | Tree         | I      |
| 35  | Buke                   | Cucurbeta pepo | Cucurbitaceae | Herb         | E      |
| 36  | Gatira ferenji         | Cupressus lusitanica Mill. | Cupressaceae | Tree         | E      |
| 37  | Erdi                   | Curcuma longa L. | Zingiberaceae | Herb         | E      |
| 38  | Merge Uruga            | Cymbopogon ciratus (DC) Stapf. | Poaceae | Herb         | E      |
| 39  | Karota                 | Daucus carota L. var. sativa. | Apiaceae | Herb         | E      |
| 40  | Loko                   | Disopyros abysinica (Hornr.) F. White | Ebenaceae | Tree         | I      |
| 41  | Serte                  | Dracaena steudneri Engl. | Dracaenaceae | Tree         | I      |
| 42  | Qarabicho              | Echinops kebericho Meuffin | Asteraceae | Herb         | I      |
| 43  | Ulaga                  | Ehretia cymosa | Boraginaceae | Tree         | I      |
| 44  | Ogioyo                 | Eletraria cardamomum | Zingiberaceae | Herb         | E      |
| 45  | Kocho/Werke            | Ensete ventricosum Welw. | Musaceae | Herb         | I      |
| 46  | Ambelta/Hambalta       | Entada abysinica | Fabaceae   | Tree         | I      |
| 47  | Wolensu                | Erythrina brucei | Fabaceae   | Tree         | I      |
| 48  | Bargamo                | Eucalyptus camaldulensis Dohnh. | Myrtaceae | Tree         | E      |
| 49  | Adamsi/Kalkual         | Euphorbia abysinica Gmel. | Euphorbiaceae | Tree         | I      |
| 50  | Ahabo dima             | Euphorbia cotinifolia L. | Euphorbiaceae | Shrub         | E      |
| 51  | Cheda/Anno             | Euphorbia tirucalli L. | Euphorbiaceae | Tree         | I      |
| 52  | Harbu/Ogda             | Ficus sur (F. capensis) | Moraceae | Tree         | I      |
| 53  | Akaku                  | Ficus sycomorus | Moraceae   | Tree         | I      |
| 54  | Jirbi                  | Gossypium barbadense | Malvaceae | Herb         | E      |
| 55  | Gravila                | Grevillea robusta | Proteaceae  | Tree         | E      |
| 56  | Lanquita/Bururi        | Grewia ferruginea | Tiliaceae  | Shrub         | I      |
| 57  | Dame/Mitatisha         | Ipomoea batatus (L.) Lam. | Convolvulaceae | Herb         | E      |
| 58  | Gatira                 | Juniperus procera | Cupressaceae | Tree         | I      |
| 59  | Dumuga                 | Justicia schimperiana (Adhatoda schimperiana) | Acanthaceae | Shrub         | I      |
| 60  | Timatimi               | Lycopersicum esculentum Mill. | Solanaceae | Herb         | E      |
| 61  | Abayi                  | Maesa lanceolata | Myrsinaceae | Shrub         | I      |
| 62  | Applii                 | Malus sylvestris | Rosaceae   | Tree         | E      |
| 63  | Mango                  | Mangifera indica L. | Anacardiaceae | Tree         | E      |
| 64  | Buri                   | Manihot esculenta Crantz. | Euphorbiaceae | Shrub         | E      |
| 65  | Butugi                 | Manilkara butugi | Sapotaceae | Tree         | I      |
| 66  | Sotellu                | Millettia ferruginea | Fabaceae | Tree         | I      |
| 67  | Denbi/Kilku            | Mimusops kummel | Sapotaceae | Tree         | I      |
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