

Traditional Home-garden Agro-biodiversity, Agro-ecosystem Services and Management Practices: The Case of Sidama Region in Ethiopia

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Abstract

This study investigated the characteristics of traditional home-garden agro-biodiversity as well as its agro-ecosystem services in diversifying farm household livelihoods and management practices. A total of 373 households were selected from two districts using simple random sampling techniques. Data were collected through questionnaire, key informant interview, direct field observation, free listing and focus group discussion. Results show that households managed different traditional home-garden sizes and diverse plant species delivering wide range of agro-ecosystem services. Most traditional home-gardens were rich in agro-biodiversity and their corresponding agro-ecosystem services. The corporate agro-ecosystem services delivered among others were food and nutritional supplements, income generations, and medicines. Regarding coverage, *Ensete ventricosum*, *Catha edulis* and *Eucalyptus camaldulensis* dominated the majority of home-gardens. The management is essentially a traditional knowledge-based farming system, managed by family members' knowledge and skill. Soil fertility is managed through adding organic fertilizers sourced from agro-biological resources. The status of the agro-biodiversity varied with the degree of traditional knowledge and management practices. The major challenges were unstable market prices, poor access to market places, and diminishing home-garden sizes. In conclusion, traditional home-garden is a diverse agri-food systems with remarkable contribution to farmer livelihood diversification through delivering multitudes of agro-ecosystem services.

1. INTRODUCTION

Traditional home-gardens are one of the most diverse agroforestry systems and make a vital contribution to meet various household needs, especially for smallholder farmers in developing countries. Of course, the uses of home-gardens vary, as some are used for subsistence agriculture and others for commercial production of food crops (Hansen et al., 2022). Many traditional agricultural systems, in particular home gardens and agroforestry, are rich in agricultural biodiversity (Robson and Berkes 2011). Agricultural biodiversity includes all components of biological diversity of relevance to food and agriculture: the variety and variability of plants, animals and micro-organisms at genetic, species and ecosystem level which are necessary to sustain key functions in the agro-ecosystem, its structures and processes (Kazemi et al., 2018).

Agro-biodiversity is essential to the world for the following functions: sustainable production of food and other agricultural products, including providing the building blocks for the evolution or deliberate breeding of useful new crop varieties; biological support to production, for example, soil biota, pollinators and predators; wider ecological services provided by agro-ecosystems, such as landscape protection, soil protection and health, water cycle and quality, and air quality. Home-gardens involve integration of various woody perennials, herbaceous crops and/or livestock on the same unit of land management with the aim of increasing production and income generation (Panda *et al.*, 2018). Traditional home-gardens agro-biodiversity are usually identified as important social and economic units which can play a crucial role in ensuring livelihood as well as food security of rural households and can be considered as an income diversification strategy under risky circumstances (World Bank, 2016). FAO (2015) indicated that

home-gardens productivity declined due to gradual decline of soil fertility which was mainly influenced by various factors in agroforestry home-garden farming systems.

The major reason for practicing agroforestry land use systems is the domestication of soil improving trees for enhancing soil productivity through a combination of selected trees and food crops on the same farm field (Atiso and Fanjana, 2020). The agro-biodiversity practices in traditionally managed home-gardens have potential to connect and integrate with the surrounding landscapes and mediate the livelihood need of people (Singh et al., 2021). Traditional home-gardens display a high level of diversity of agro- biological resources and traditional knowledge-based farming system. Home-gardens are prevalent in the highlands of Ethiopia and accommodate supplementary fruits and vegetables as a principal means of livelihood for households and sites that have been considered as a sign of prestige and pride (Atiso & Fanjana, 2020). In order to maintain the ecological equilibrium, conservation of plant genetic diversity and to meet the home garden products for requirements of the people, scientific information is required (Faraji and Karimi, 2022).

Home-gardens are an important resource for food security in Ethiopia. The major benefits from home-garden agro-biodiversity are source of nutrition and income and help to meet socio-cultural needs. Along with these benefits, they help to reduce environmental pollution and soil erosion and to conserve the agro-biodiversity. For effective extension of home-gardens, three factors namely socio-economic factors, ecological factors and available knowledge and practice of the farmers need to be considered (Terfassa, 2021). In Ethiopia, research and documentation on home-garden agro-biodiversity are very few (Terfassa, 2021, Erenso, and Andemo, 2022, Abebe and Asfaw, 2023). Without a full assessment of the structure, composition and diversity of home-gardens, their relation to indigenous household knowledge and management cannot be fully explained. Apart from that, detailed and empirically inventoried documentation about the agro-ecosystem services and traditional management system of traditional home-garden agro-biodiversity are lacking in Ethiopia. Most of the research works conducted on home-gardens and management are limited only to specific locations. Specifically, their agro-ecological services and challenges have been overlooked by most previous studies. The objective of the current research is to fill a gap in the body of knowledge regarding the agro-biodiversity in traditional home gardens, their agro-ecological services in support of household livelihood diversification, and their traditional management practices in the Sidama Region in Ethiopia.

2. METHODOLOGY

Description of the study area

The Sidama region is one of the Regional States in Ethiopia. It is bordered on the south by the Oromia Region (except for a short stretch in the middle where it shares a border with Gedeo zone), on the West by the Bilate River, which separates it from Wolayta zone, and on the north and east by the Oromia Region. Geographically, it is located at 5⁰45' – 6⁰ 45' N; 38⁰ 15' – 39⁰ E (Fig. 1). Hawassa, which is

located in the northern tip of Sidama, is the regional capital and located at a distance of 273 km south of Addis Ababa, the capital city of Ethiopia.

The Sidama Region covers 6538 km² area with a human population of 3.4 million (CSA, 2011). It is the most densely populated area in southern Ethiopia with average population density of 520 persons per km² (CSA, 2011). It is one of the leading coffee producing Regions in Ethiopia, which contributes greatly to the foreign exchange of the federal government.

Different soil types exist in the Region. The most common types in the Enset-coffee home-gardens are eutric nitosols, pellic vertisols, orthic acrisols, chromic luvisols and eutric fluvisols. The Region constitutes diverse altitudinal zones ranging from 500 to 3500 m.a.s.l. Its topography is generally undulating with massifs, plateaus and plains, with a number of rivers flowing year round. A large portion of the Region receives rainfall for most part of the year having annual rainfall of 1000–1800 mm distributed in 8 to 10 months. It is a high potential area for perennial crops where the enset - coffee agroforestry home-gardens predominate.

The Region has also different types of natural vegetation, including montane evergreen thickets and scrubs, montane dry evergreen forests, montane moist evergreen forests and various types of savanna. In the high potential perennial areas where the home-gardens are dominant, remnant trees of evergreen forests are common. The most important are *Cordia africana*, *Podocarpus falcatus*, *Millettia ferruginea* and *Bersama abyssinica*. In general, combinations of altitude, rainfall and temperature play influential roles in determining the land use practices. Accordingly, of the five major traditional agro-ecological zones identified in Ethiopia, three of them are present in Sidama Region. About 53% of land is occupied by agro-forestry home-garden with coffee and enset, fruits, trees, vegetables, root and tuber crops and pulses (BoFED, 2008).

The three different agro-climatic zones existing in Region manifest different land use systems. These include, dry and hot tropical climate, which lies between 500 and 1500 m.a.s.l., receives an annual rainfall of 400–800 mm, and experience a mean annual temperature of 20–25 °C. The dry and hot tropical climate constitutes 30% of the total area of the Region.

Agriculture is dominated by annual crops such as maize, sorghum and haricot bean; and pastoralism is also an important economic activity. The other is moist to humid, warm subtropical agro-ecological zones, which lies within 1500–2500 m.a.s.l., receives an annual rainfall of 1000–1800 mm, and enjoys a mean annual temperature of 15–20 °C. It constitutes 54% of the total area of Sidama Region. This agro-ecological zone is a high potential perennial cropping area where the *Enset*-coffee-based home-gardens are dominant. Diverse kinds of fruits trees, including mango, avocado, banana, and others dominantly grow in this particular zone. The third is wet and cool temperate agro ecological zone that lies within the elevation of 2500 to 3500 m.a.s.l., receives an annual rainfall of 1200 to 1800 mm, and experiences a mean annual temperature of 10–15 °C. It constitutes 6% of the total area of Sidama Region. Enset is a

dominant crop in this zone; nevertheless, cereals such as barley and wheat as well as vegetables are also widely grown.

Research Design

Both qualitative and quantitative methods were employed for data collection. Questionnaire survey, interview, focus group discussion, and field observation were used for primary data collection. In addition, secondary data from literature and desks were used to substantiate the primary data.

Population, sample size and sampling techniques

Target population

The population for this study comprised households having traditional home-gardens, agriculture development agents, *Kebele*¹ leaders, and focal persons of District (*Woreda*) Agricultural Offices.

Sample size and sampling technique

Two districts were selected using a purposive sampling technique based on the information gained from the Districts Agricultural Office. The total number of households of the two districts was 6353. Out of the 6353 households, a sample size of 376 households was determined (Yemane, 1967). Finally, the sample households were selected through simple random and proportionate sampling techniques (Table 1):

$$n = \frac{N}{1 + Ne^2}, \text{ where } n = \text{sample size (smaller population),}$$

N = the whole population (larger population),

e = Margin error usually 0.05.

Table 1
List of sample households and kebeles with their respective districts

District	Sample <i>Kebele</i>	Sex		Sample household		
		Male	Female	Total	Return rate (99.21%)	Non-return rate (0.79%)
Shabadino	Taramesa	1130	77	1207	71	-
	Howolso	1038	102	1140	67	1
	Morocho Nagasha	790	60	850	48	2
Dale	Debub Mesinkala	761	63	824	49	-
	Semen Mesinkala	1031	73	1104	65	-
	Soyama	1197	31	1228	73	-
Total size		5947	406	6353	373	3

Data gathering instruments

Home-gardens observations

Series of home-garden observations were done systematically with selected key informants and home-garden owners in each site. Guided field walks were carried along with key informants, including *Kebele* administrators, home-garden owners, development agents, and agricultural experts were asked to give their insights regarding indigenous knowledge of local community and discuss the socio-cultural and agro-ecological knowledge of households of traditional home-gardens, management practices and challenges.

Free listing

Free listing was used by asking the key informants to list the local names of all plants growing in their home-gardens and nearby, and the agro-ecological services of each plant species. At the time of listing, the informants were also asked to mention the traditional management practices and associated challenges.

Household questionnaire survey

Questionnaire was delivered to the sample household heads with a return rate of 99.12% (Table 1). The most important issues addressed were related to socio-demographic characteristics of households, plant agro-biodiversity and their local names, agro-ecological services, traditional management practices and associated challenges, and other traditional home-garden related questions.

Focus group discussion

Group discussions were conducted with 30 informants, selected from the six study *Kebeles* (Table 1). These discussants were selected based on years of experience of managing traditional home-gardens, years resided in the study areas, and experiences in working with traditional home-garden owners. The discussants were selected from each home-garden type (small, medium and large). During the discussions, the discussants were allowed to discuss the types of food and non-food crops grown in home-gardens, the agro-ecological services of home-gardens and their associated challenges.

Frequency

Frequency describes the distribution of a species through a stand. Frequencies were determined by calculating the percentage of a household farm in a sample area on which a given species occurs. Frequency classes calculated to estimate the heterogeneity and homogeneity of species by following Lamprecht (1989).

$$\text{Frequency} = \frac{\text{Number of home gardens in which a species occurs}}{\text{Total number of sampled home garden}} \times 100 \quad (1)$$

Relative frequency

Relative frequency is the distribution of one species in a sample relative to the distribution of all species (Lamprecht, 1989).

$$\text{Relative frequency} = \frac{\text{Frequency of a species in a home – garden}}{\text{Total frequency of all species in home – gardens}} \times 100$$

2

Data analysis

Both the qualitative and quantitative data were analyzed. The quantitative data were tallied, summarized, coded and analyzed using Statistical Package for Social Sciences (SPSS) version 20 software. The mean, range, frequency, and percentage of the variables were calculated and interpreted following descriptive statistics methods. The qualitative data were also analyzed through segregating them into theme and subtheme approach and finally used for cross-checking and substantiating the quantitative data.

3. RESULTS AND DISCUSSION

Household characteristics

Table 2 shows that the male-headed households constituted 82.3% while the female-headed households constituted 17.7%. This shows that most of the data were obtained from male-headed households. Regarding the maximum educational level attended by households, the majority (64.1%) attended primary school education. At the same time, a considerable number of households were illiterate

(33.5%). The age of the majority (60.6%) of the households ranged from 29–39 years. Family size varied among households: 1–4 members (17.2%), 5–8 (70.4%) and 9–12 (12.2%) persons per household. The majority of the households (79.08%) had their monthly income exceeding 500 Ethiopian currency (Birr) per month.

Table 2
Demographic characteristics of sample households

No.	Variables	Category	Households (n = 373)	
			Frequency	%
1	Sex	Male	307	82.3
		Female	66	17.7
		Total	373	100
2	Responsibility	Male-headed households	307	82.3
		Female-headed households	66	17.7
		Total	373	100
3	Level of education	Illiterate	125	33.5
		Primary education	239	64.1
		Secondary and above education	9	2.4
		Total	373	100
4	Age	18–28 years	51	13.6
		29–39 years	226	60.5
		40–50 years	67	17.9
		51–61 years	29	7.7
		Total	373	100
5	Family size	1–4	65	17.2
		5–8	262	70.4
		9–12	46	12.2
		Total	373	100
6	Monthly income	Less than 500 Birr	78	20.9
		Greater than 500 Birr	295	79.08
		Total	373	100
7	Residence duration	For the last 20 years	345	92.5
		For the last 10 years	20	5.4
		For less than 10 years	8	2.1
Household livestock holding types				

		Total	373	100
8	Marital status	Single	13	3.5
		Widowed	53	14.2
		Separated	5	1.3
		Divorced	22	5.9
		Married	280	75.1
		Total	373	100
Household livestock holding types				

Livestock provided households with food, income, manure, and traction power. Out of the livestock holding, cattle had the highest number, with horses numbering the least (Fig. 2). The difference in the holding size and preference depended on the service the different livestock provide to households as well as adaptation to existing local agro-ecologies. Livestock manure is used by households to improve the soil fertility in their home-gardens, which in turn serve as a source of fodder for the livestock. Livestock play crucial roles in sustaining home gardens as a source of manure for organic fertilizers, and home gardens greatly contribute to livestock production through providing forage and fodder (Ghimire and Joshi, 2020, Ichinose et al., 2020).

Distribution of traditional home-gardens across study areas

Table 3 presents the distribution of the traditional home-gardens across the study sites. The majority of the households (99.6%) practiced traditional home-gardens. The practice of home-gardening is generally uniform across the study areas.

Table 3
Distribution of traditional home-gardens across the study areas

<i>Site</i>	Household	Frequency	%
<i>Taramesa</i>	71	71	18.8
<i>Howolso</i>	68	68	18.0
<i>Morocho Nagasha</i>	48	50	13.2
<i>Dehub Mesinkala</i>	49	49	13.0
<i>Semen Mesinkala</i>	64	65	17.2
<i>Soyama</i>	73	73	19.4
Total	373	373	99.6

Arrangement of traditional home-gardens

Most traditional home-gardens were completely fenced, placed, and sized in accordance with the location of the house and the size of the street-facing section of the garden. The arrangement of home-garden yards varied among households: front yard, back yard, side yard, front and back yard, front and side yard, back and side yard, and circular gardens (Fig. 3). The dominant arrangement was the back yard type. The backyard gardens is encouraged as a solution to supplementing household food security and income. This finding agrees with findings from previous studies (David & Grobler, 2022, Santos et al., 2022) backyard gardens are practiced by majority of households for their agro-ecological services. Home-gardens had also different shapes; rectangular, square, circular or irregular shape. Studies in many areas also disclosed home-gardens with various kinds of shapes (Gbedomon et al., 2016, Ketsa et al., 2020).

Size of traditional home-gardens

Different sized home-gardens became an essential part of the agri-food production system. Home-garden size ranged from 0.03 to 2.70 hectare with the mean value of 1.36 hectare. About 32.43% of households had small-sized gardens, 45.3% had medium-sized gardens and 22.25% had large-sized home-gardens (Fig. 4). The majority of the households had home-garden size of half hectare to one hectare. The size of home-gardens has been declining per households in recent times. Home-garden size has been declining in the Ethiopian landscape because of socioeconomic changes, lack of technological inputs, and loss of the product diversity provided by the home-garden system (Sahle et al., 2022). Home-gardens consisted of different types of cultivated and non-cultivated plant species. There are similar findings from previous studies supporting this particular result (Vogl-Lukasser & Vogl, 2018, Hong & Zimmerer, 2022).

Growth form of traditional home-garden agro-biodiversity

A total of 129 species were recorded in the traditional home-gardens. There were five life forms: trees, shrubs, herbs, lianas and climbers (Fig. 5). Among the recorded plant species, 34 were herbs, 26 were shrubs, 63 were trees, 5 were climbers and 1 was liana. This shows that trees are predominant life form in home-gardens.

Botanical characteristics of traditional home-garden agro-biodiversity

The agro-biodiversity in traditional home-garden exhibited a wide variety of plants, varying from small herbs to trees. The 129 plant species identified belonged to 106 genera and 61 families. Families like Fabaceae ranked top, followed by Poaceae, Rutaceae and Rosaceae. There are also other families including Euphorbiaceae and Moraceae, Asteraceae, Brassicaceae, Myrtaceae and Solanaceae, and Musaceae and Lamiaceae, and Acanthaceae, Amaranthaceae, Anacardaceae, Apocynaceae, Araceae, Aricaceae, Boraginaceae, Cucurbitaceae, Cupressaceae, Flacourtaceae, Lauraceae, and Verbenaceae.

The traditional home-gardens are located mostly near the residence; contain a high diversity of plants including woody trees to herbs; and occupy a small area; as well as production is mostly supplemental rather than a main source of household consumption and income generation. Fruit trees, vegetables, cereals, pulses, and root and tuber crops are major sources of food and income. They are a unique human-nature interspace that accommodates a diverse spectrum of plant species and provides multiple agro-ecosystem services to households (Singh, 2019, Ivanova et al., 2021, Santos et al., 2022, Hong & Zimmerer, 2022).

Area share of plant species of traditional home-garden agro-biodiversity

Table 4 presents the area coverage of plant species in traditional home-gardens. In accordance, the surveyed home-gardens covered a total area of 362.75 hectares with the mean value of 55.53 per sites. In accordance, *Ensete ventricosum* covered 34.25 hectares, occupying the highest share of the surveyed areas, followed by *Catha edulis* covering 30.84 hectares and *Eucalyptus camaldulensis* covering 29.22 hectares. These results show that most of the home-gardens were dominated by *Ensete ventricosum*, *Catha edulis* and *Eucalyptus camaldulensis*. In general, traditional home-gardens are *Ensete ventricosum* and *Coffea arabica*-based agri-system with supplements of cereal and pulses in which they are well integrated and intercropped with annuals and perennial crops. The top ten plant species are tabulated below (Table 4). This shows that diverse woody species, annuals, and other perennials with diverse agro-ecosystem services dominated individual home-gardens, which varied across the home-garden landscapes (Muhamad et al., 2022, Asfaw & Zewudie, 2021).

Table 4
The top ten largest plants cultivated in home-gardens in hectares (ha)

No	Scientific name	Family name	Area (ha)	%	Freq. (%)	Rel. freq.
1	<i>Ensete ventricosum</i>	Musaceae	34.25	10.27	100	3.18
2	<i>Coffea arabica</i>	Rubiaceae	27.44	8.23	98.9	3.15
3	<i>Catha edulis</i>	Celastraceae	30.84	9.25	76.8	2.44
4	<i>Eucalyptus camaldulensis</i>	Myrtaceae	29.22	8.76	100	3.18
5	<i>Persea americana</i>	Lauraceae	25.37	7.61	90.4	2.88
6	<i>Musa x paradisiaca</i>	Musaceae	17.51	5.25	79.2	2.5
7	<i>Brassica carinata</i>	Brassicaceae	12.85	3.85	98.4	3.13
8	<i>Zea mays</i>	Poaceae	10.48	3.14	74.2	2.36
9	<i>Mangifera indica</i>	Anacardiaceae	8.92	2.67	87.7	2.79
10	<i>Musa accuminata</i>	Musaceae	4.12	1.23	50	1.59

Agro-ecosystem services of traditional home-garden agro-biodiversity

The most important agro-ecosystem services delivered by home-gardens agro-biodiversity were food and nutrient supplement, medicine, multipurpose, shade, ornamental, forage and fodder, firewood and dry fence, among others (Fig. 6). Generally, the integration of livestock and poultry activities into home-gardening contributed to improving the agro-ecological services of agro-biodiversity in home-gardens (Gifawesen et al., 2020, Pushpakumara et al., 2020, Atiso & Fanjana, 2020).

Home-garden agro-biodiversity as food and nutrition supplement

As part of agro-biodiversity, several food crops were cultivated in the home-gardens. The large number of them was mostly available during the main rainy season between June and September. Whereas, the vast majority of fruit and vegetable crops were cultivated throughout the year and provide easy day-to-day access to an assortment of fresh and nutritious foods for the household. Households reflected that including fruits and vegetables in their daily meal improved family health. In addition, fruit and vegetables enhanced their social interaction with neighbors and stimulate social change and development. The products of home-garden agro-biodiversity were mostly collected for household consumption. Food and income fetching crops were the most diversified and abundant in most home-gardens. These results agree with findings from previous studies (Asfaw & Zergaw, 2022, Fernandez & Méndez, 2018). Relatively, resource-poor households often depended more on home-gardens for their food staples than wealthy ones, which used home-garden plants as supplements and secondary staples to food and income generation. Home-gardens offered a cheap source of nutritive foods for poor and marginalized households (Dissanayake, 2020, Rammohan et al., 2019, Nair, 2019).

Home-garden agro-biodiversity as sources of stimulants

The three most important stimulant plant species were *Catha edulis*, *Coffea arabica* and *Rhamnus prinoides*. These plants were limited to a few household home-garden agro-biodiversity whereas abundant in their occurrence. *Catha edulis* is widely cultivated in the home-gardens. The next most commonly used stimulant plant was *Coffea arabica*. Most of the households use coffee as stimulants on a daily basis. In addition to stimulants, coffee is the most widely used multipurpose crop. Coffee is also used during negotiation of conflicts. *Rhamnus* locally named as “Xaddo” is also well known to prepare local beer for holidays and for other several socio-cultural values. It is cited to be one of the major income generating plants. In general, among the three stimulant plants, *Catha edulis* is the most dominant among households as a source of income. The plant parts and methods of use for stimulants are presented below (Table 5). This demonstrates that various stimulants are present in traditional home-gardens, with various plant parts acting as stimulants (Alemu et al., 2019, Kefale, 2020, Woyesa & Kumar, 2022, Dhakad et al., 2022).

Table 5
Home-garden agro-biodiversity as sources of stimulants

Botanical name	Local name	Part used	Method of use
<i>Catha edulis</i>	<i>Khat</i>	Young leaves	Chewing young leaves
<i>Coffea arabica</i>	<i>Bunu</i>	Seed and leaf	As hot beverage
<i>Rhamnus prinoides</i>	<i>Xaddo</i>	Stem and leaf	As hot beverage

Home-garden agro-biodiversity as sources of spices

The agro-biodiversity in traditional home-gardens provided spice as additional ecosystem service. Out of the 129 plant species identified, 7.75% were spice plants. The spices are used for household consumption, income generation or both. This demonstrates the abundance of plants used as spices in home-gardens, which are used for various purposes at a household-level (Babu & Thomas, 2020, Gifawesen et al., 2020, Bistaa et al., 2022).

Home-garden agro-biodiversity as sources of medicines

The management of traditional home-garden agro-biodiversity also embraced cultivation of medicinal plants for treating both human and livestock ailments. Households and traditional healers assume growing medicinal plants in home-gardens like owning a medical doctor at home. In particular, their accessibility and affordability promoted the cultivation of medicinal plants in almost all home-gardens for traditional medicine. The traditional medicines are used as a remedy for human diseases such as emergency illness, bloating, tapeworm, toothache, gastric, diarrhea, wound, tonsillitis, and malaria, among others. This demonstrates that traditional home-gardens provide a variety of medicines for treating a broad range of human and livestock ailments (Abebe & Asfaw, 2023, Elfrida et al., 2020).

Home-garden agro-biodiversity as sources of forage and fodder

Forage plants were found to be important components of traditional home-garden agro-biodiversity management. Out of the total plant species identified, about 18.6% were categorized as forage, which is about one fifth of the total plant species identified. The most widely used forage plants species were *Musa X paradisiaca*, *Pennisetum purpureum*, *Zea mays*, *Musa acuminata*, *Ensete ventricosum*, *Phaseolus vulgaris* and *Eragrostis tef*. Different parts of the plants are used for forage. The most important plant parts used for forage are: only leaf (15 species), leaf and pseudo-stem (3 species), leaf, stem and seed collectively (3 species), and leaf and seed (3 species). They are also used in the form of left over, straw and stubble. This result designates that home-gardens offer a variety of forage and fodder plant species that would enhance their integration with livestock for enhancing family welfare and other home gardens' agro-ecosystem services (Abebe & Asfaw, 2023, Ghimire & Joshi, 2020, Woyesa & Kumar, 2022).

Home-garden agro-biodiversity as sources of ornamentals

Households managed different types of ornamental plants among home-garden agro-biodiversity. These plants are used for the beautification and enhancing the attractiveness and scene of home-gardens. They accounted for 21.7% of the total plant species, which is nearly one fifth of the total plant species. These plant species are classified into 28 genera and 23 families, which is 21.7% of the total plant families identified. Among the 23 families of ornamental plants, *Meliaceae*, *Anacardiaceae*, *Rutaceae* and *Cupressaceae* had the highest number of species. In addition, regarding growth form of the ornamental plant species, their composition varied as follows: tree (71.4%), herb (17.8%), shrub (3.57%) and liana (7.1%). This indicates that the majority of the ornamental plants in traditional home-gardens are trees.

Moreover, the attractive and beautiful parts of the plants were leaf, flowers or influences, forms of vine, bracts, pseudo-stem and the whole parts of the plants. This shows that different parts of plants are used for beautification. The most frequently distributed ornamental plants were *Cupressus lusitanica*, *Mangifera indica*, *Schinus molle*, *Callistemon citrinus*, *Euphorbia dumalis*, *Euphorbia pulcherrima*, *Cymbopogon citratus*, *Jacaranda mimosifolia*, *Strobilanthes dyerianus* and *Tradescantia pallida*. This result unveiled that home-gardens integrate plants species mainly for enhancing the aesthetic benefits as well as for environmental, economic, and social services of household wellbeing (Balasha et al., 2019, Pushpakumara et al., 2020, Patel et al., 2022).

Home-garden agro-biodiversity as sources of shade services

The traditional home-garden agro-biodiversity served as a shade, which in turn is used for multiple purposes like for cultural ceremonies, social meetings, recreational value and shading other plants. They comprised about 25.58% of the total plant species identified in the study area. They were intercropped with other plants and also delivered different agro-ecosystem services. Among the most important families, *Fabaceae* and *Myrtaceae* ranked the highest, pursued by *Rosaceae*, *Anacardiaceae*, *Cupressaceae* and *Meliaceae*. *Fabaceae* and *Myrtaceae* are pre-dominant with the highest number of species. *Cordia africana*, *Persea americana*, *Croton macrostachyus*, *Mangifera indica*, *Erythrina brucei*, *Albiza gummifera* and *Podocarpus falcatus* were among the top plant species providing shade services. They are essentially eco-friendly in living with other neighboring plant species and improving soil fertility. The most important home-garden plants benefiting from the shade service of others are *Coffea arabica*, *Catha edulis*, *Ensete ventricosum* and several other annuals and perennials. There are similar findings from previous studies (Setiani et al., 2022, Abebe & Asfaw, 2023, Erenso & Andemo, 2022).

The majority of the shade plants were trees, composing 96.9%. This means that these trees are also managed for other ecosystem services like construction, furniture, income source, ornamentation, firewood, and food supply, among others. Furthermore, the most frequently distributed plants, in more than 50% of the home-gardens, were *Ensete ventricosum*, *Eucalyptus camaldulensis*, *Cupressus lusitanica*, *Cordia africana*, *Persea americana*, *Coffea arabica*, *Croton macrostachyus*, *Mangifera indica*, *Erythrina brucei*, *Grevillea robusta*, *Albiza gummifera* and *Podocarpus falcatus*.

Home-garden agro-biodiversity as sources of domestic energy services

The home-garden agro-biodiversity provided firewood and charcoal as the major sources of domestic energy supply. Out of the identified plant species, about 26.35% were used for firewood and charcoal. Of these plant species, again about 67.64% were used only for firewood purpose whereas the remaining 32.35% were used for both firewood and charcoal. This means that out of the total plant species identified, one third is used for firewood and charcoal purposes. Apart from that, most of the households depend upon firewood for their domestic energy supply. This heavy reliance on the firewood and charcoal points to lack of alternative energy sources such as biogas technology, solar energy, and electricity. There are similar findings from previous studies (Alemu et al., 2019, Erenso & Andemo, 2022, Humnessa et al., 2022).

Regarding biodiversity of plants providing domestic energy, there were 34 plant species, which were categorized into 21 families and 31 genera. Among these families, *Fabaceae* was the most dominant accounting for 28.57% species, followed by *Rosaceae* and *Myrtaceae*, *Asteraceae*, *Meliaceae*, *Cupressaceae* and *Euphorbiaceae*. Similarly, trees had the highest number of plant species composing 82.35% of plant species in terms of plant growth form, followed by shrubs, herbs and lianas. The most regularly distributed plant species, occupying more than 50% of home-gardens, were *Eucalyptus camaldulensis*, *Cupressus lusitanica*, *Cordia africana*, *Zea mays*, *Croton macrostachyus*, *Coffea arabica*, *Erythrina brucei*, *Grevillea robusta*, *Persea americana*, *Podocarpus falcatus* and *Acacia decurrens*. Likewise, the most commonly used plant species for charcoal were *Acacia abyssinica*, *Acacia seyal*, *Croton macrostachyus*, *Persea americana* and *Balanites aegyptica*. There are similar findings (Abebe & Asfaw, 2023, Tefera et al., 2019, Erenso & Andemo, 2022) that home-garden agro-biodiversity are also versatile sources of domestic energy such as firewood and charcoal besides other agro-ecological services.

Home-garden agro-biodiversity as sources of materials for construction and furniture

Growing plants for constructional and timber production are also integral parts of traditional home-garden management. About 16.27% of the total plant species identified in the study areas were commonly used for construction materials and furniture. Of these plant species, about 12 were used for construction materials and furniture, 7 were used only for construction purpose and 2 were used only for furniture. This shows that the great majority of plant species serve both functions. There are similar research findings from previous studies (Mukhtar, 2019. Abebe and Asfaw, 2023, Alemu et al., 2019, Akter et al., 2022).

From this point of view, *Fabaceae* was the most dominant plant species, accounting for 14.28.6% of the total plant species, followed by *Cupressaceae*, *Myrtaceae* and *Poaceae*. Therefore, ascribing to their ecosystem services, members of *Fabaceae* are the most diverse and well managed plant species. This is because members of *Fabaceae* are nitrogen fixing and are ideal for managing soil fertility and having no negative effect on adjoining plants. They also provide fodder for the livestock. For this reason, farmers cultivate them together with other plants in their home-gardens and receive multiple ecosystem services including construction and timber production. Most members of *Fabaceae* are trees (90.47%). Trees are

predominant sources of materials for constructional and furniture. In this regard, for most plants, stem only is used, followed by stem and branch, and stem and stem sheath. This shows that stem is the most useable parts of most plants for construction and furniture. Moreover, the most frequently distributed plant species were *Ensete ventricosum*, *Eucalyptus camaldulensis*, *Cupressus lusitanica*, *Cordia africana*, *Persea americana*, *Grevillea robusta*, *Croton macrostachyus* and *Podocarpus falcatus*.

Home-garden agro-biodiversity as sources of live fence and dry fence

Garden fencing was one of the important management practices in the study area to take care of home-garden components. Therefore, households used plants as live fences and dry fences, which grow around home-gardens. Out of the total number of plant species identified in the study areas, about 24.03% of them were used for live and dry fencing. Out of which again, 25.8% species were used only for live fences, 45.16% species only for dry fences and 29.03% plant species used for both functions. These plant species were categorized into 17 families and 27 genera. Among these families, *Fabaceae* ranked top, followed by *Euphorbiaceae*, *Poaceae*, *Myrtaceae*, *Asteraceae*, *Rosaceae* and *Cupressaceae*. This result implies that *Fabaceae* is the most dominant family among live and dry fence plant species. Regarding domestications, wild plant species took the first place with the highest number of species, with semi-wild and cultivated plant species ranking second and third. In addition, trees comprised the highest rank, followed by shrubs, herbs and climbers when plant growth form is taken into consideration.

The most common plant species used for live fences were *Cupressus lusitanica*, *Dovyalis abyssinica*, *Euphorbia tirucalli*, *Euphorbia dumalis*, *Euphorbia pulcherrima*, *Euphorbia abyssinica*, *Caesalpinia decapetala*, *Justicia schimperiana*, *Vernonia amygdalina* and *Sesbania sesban*. The plant species that households frequently use for dry fences were *Eucalyptus camldensis*, *Arundinaria alpina*, *Arundo donax*, *Balanites aegyptiaca*, *Sorghum bicolor* and *Zea mays*. Moreover, fences provide the subsidiary benefits to households. Such supplementary values are food (fruits and leaves), medicine, beautification and others. This means that fences are very important to obtain multiple functions. There are similar findings from previous studies (Tefera et al., 2019, Abebe and Asfaw, 2023) that home-gardens also integrate into their landscape diverse plants species serving for live and dry fences.

Home-garden agro-biodiversity as sources of multipurpose plant species

The agro-biodiversity in traditional home-gardens also comprised plant species with multipurpose agro-ecological services. The multipurpose agro-ecological services include food and nutritional supplement, income generation, construction, furniture and equipment, firewood and charcoal, traditional medicine, beautification and scene, fence, shade, socio-cultural service, soil fertility management, forage and fodder, among others. From the 129 total number of plant species identified in the study areas, about 42 of them belonged to 24 families and 39 genera with multiple purposes. The most dominant families were *Poaceae* and *Rutaceae*, followed by *Musaceae*, *Solanaceae* and *Fabaceae*. Likewise, the most dominant plant species delivering multipurpose ecosystem services were *Eucalyptus camaldulensis*, *Coffea arabica* and *Ensete ventricosum*. There are similar findings (Ivanova et al., 2021, Hong & Zimmerer, 2022,

Naigaga et al., 2021, Khanal et al., 2019) that home-gardens contain versatile plants, ranging from herbs to woody trees, with multi-functions for households.

Home-garden agro-biodiversity as sources of income generation

For income generation, the six most marketable home-garden species were *Coffea arabica*, *Catha edulis*, *Ensete ventricosum*, *Allium cepa*, *Brassica oleracea*, and *Percea americana* (Table 6). They provide farmers with better income than the rest of the home-garden products. They also provide to the farmers other agro-ecosystem services.

Compared to men, women profoundly engage in the management of home-gardens. They engage in land preparation, planting, weeding, harvesting, and marketing. Therefore, they are the most beneficiaries from home-gardening. There are plenty of research findings supporting the present result (Atiso & Fanjana, 2020, Gifawesen et al., 2020, Mulia et al., 2022) that one of the primary goal of homegardens managed by households is to increase revenue to better support their families.

Table 6
Most marketable home-garden agro-biodiversity for household income generation

<i>Species</i>	<i>Local name</i>	<i>Rank based on market survey</i>
<i>Coffea arabica</i>	<i>Bunu</i>	1
<i>Catha edulis</i>	<i>Chaate</i>	2
<i>Ensete ventricosum</i>	<i>Weese</i>	3
<i>Allium cepa</i>	<i>Yehabesha key shinkurt</i>	4
<i>Brassica oleracea</i>	<i>Ququmadu shaana</i>	5
<i>Percea americana</i>	<i>Awukaadu</i>	6

Traditional home-gardens as means of agro-biodiversity conservation

The traditional home-gardens served as a valuable repository for preserving and transferring indigenous crops and plant species, knowledge and skills to the future generations. It is an eco-friendly agricultural production system that sponsors huge plant biodiversity conservation. The traditional home-garden agro-biodiversity embraced wide array of plant species with huge genetic diversity. The genetic diversity enables them to provide diverse agro-ecological services such as source of food and nutrient, firewood, medicine, construction materials and income. The traditional home-gardens served as center for in-situ conservation of plant genetic resources.

These multitudes of plants exhibit different life forms and are managed for their various agro-ecological services. The traditional home-garden agro-biodiversity served as *In-Situ* conservation, consisting of a tremendous array of plant diversity, such as wild, cultivated, indigenous, endangered, etc. for their agro-ecological services. Among these plant species were *Juniperus procera*, *Cordia africana*, *Podocarpus*

falcatus, *Croton macrostachyus*, *Acacia abyssinica*, *Olea europaea*, *Rhamnus prinoides*, *Coffea arabica* and several other cereals, vegetables and landraces. There are similar findings (Jiang et al., 2023, Suwardi et al., 2023, Naigaga et al., 2021, Jana & Roy, 2022) that home-gardens, with their plant species diversity and ecosystem services, are hotspots of biodiversity conservation in terms of conservation of plant genetic resources and nearby natural forests.

Home-gardens served as preservation of medicinal plants, which are practically degenerating from their natural setting due to illegal forest clearing. This is the other reason for conserving those trees and shrubs in their home-gardens as shade or fence plants. Therefore, ecosystem approach that combines food production and the provision of other goods and services appear appropriate for sustainable management of agro-biodiversity in traditional home-garden.

Traditional home-garden agro-biodiversity and soil fertility management

Both organic and inorganic fertilizers were applied for soil fertility management of home-garden agro-biodiversity. Households used mostly organic materials of household wastes (kitchen wastes, and ashes) incorporating with crop residues, weeds, and animal wastes for increasing soil fertility. Accordingly, about 75% of the households used organic fertilizers from household wastes, manure and composts for enhancing soil fertility and increasing the yield of home-garden crops (*Eragostis tef*, *Triticum aestivum*, *Hordeum vulgare* and *Zea mays*), root and tuber crops (*Solanum tubersum*, *Ipomoea batatas* and *Colocasia esculenta*), pulses (*Phaseolus vulgaris* and *Vicia faba*) and sometimes for growing seedlings of *Eucalyptus camaldulensis*. About 15% of the households used mixes of inorganic and organic fertilizer and 10% used only inorganic fertilizers such as urea and DAP. Similarly, the key informants affirmed that the majority of households used organic fertilizers for managing soil fertility and increasing the yields of home-garden plants.

Other traditional methods of managing soil fertility and increasing yields are intercropping legumes plants with other crops, which have ability to fix nitrogen. Specially, members of Fabaceae family like *Acaccia species*, *Albiza gummifera*, *Sesbania sesban*, etc. are well known to maintain and restore soil fertility. Crop rotation, engaging pulses, cereals and vegetables, is also practiced for maintaining and restoring soil fertility and increasing yields. Households also practice a mixture of annual and perennial herbs and woody perennials as agro-forestry for improving soil fertility of their home-gardens for increasing yields, and diversifying food sources. In addition to fodder plants, plant materials, such as twigs, leaves, straw, stubble, stover, are used as fodder for the livestock and livestock manure is incorporated into the compost, hence reducing the need for chemical fertilizer. There is a similar report from a previous study in Ethiopia (Gifawesen et al., 2020, Fujii et al., 2023, Sahle et al., 2022, Suwardi et al., 2023) that the plant species themselves have a major impact on soil fertility, both directly and indirectly, by producing organic materials that break down and enrich the soil.

Challenges to the management of traditional home-garden agro-biodiversity

Table 7 shows the ten major factors that affect home-garden agro-biodiversity in the study area. The three most remarkable challenges to the sustainable management of home-garden agro-biodiversity were climate change, home-garden size, disease and pest and seed quality. Plant species most vulnerable to climate change impacts were largely annuals including *Triticum aestivum*, and *Zea mays* as well as vegetables, and pulses. Perennial crops such *Ensete ventricosum*, *Coffea arabica*, *Persea americana*, *Musa x paradisiaca*, *Musa acuminata*, and *Mangifera indica* are mainly affected by the degenerating home-garden size, pest and diseases, lack of quality of seeds and seedlings, landraces, etc. Relatively, perennials crops are less vulnerable to climate variables, such as rainfall variability, drought, dry spells flood runoff, etc. As a result, for instance, the area share of *Ensete ventricosum* has considerably been shrinking in recent times due to the impacts of combinations of these factors. Tesfaye Abebe (2005) reported a declining area share of crops due to similar factors.

About 30.29 % of the households and 30\% of the key informants reported that flood run-off affected home-garden agro-biodiversity directly and indirectly (Table 7). It affects soil fertility, seed germination and seedling growth. In addition, lack of agricultural inputs like good quality seeds, seedlings and fertilizers were challenges to the managements of traditional home-garden agro-biodiversity. Lack of transportation facilities and poor road infrastructure to market places also challenged home-garden management through making market information gaps among the households. On the other hand, theft and robbery attempts of crops and instability in market prices of fruits, coffee, *Khat* and vegetables are additional challenges. Besides, wild animals are also challenges to home-garden management, for instance, *Echidna* feeds on *Ipomoea batatas* and young *Ensete ventricosum* corms; apes and porcupines feed on seeds and fruits of *Zea mays* and birds feed on seeds and fruits of *Zea mays* and *Sorghum bicolor*.

Table 7
Challenges to the management of traditional home-garden agro-biodiversity

Challenge	Household(n = 373)	%	Rank	Key informant(n = 30)	%	Rank
1. Unstable prices of fruits, vegetables and other crops	149	39.94	1	11	36.6	1
2. Illegal trading and lack of access to market places	39	10.45	5	15	50	4
3. Lack of transportation and infrastructure facilities	127	34.04	3	12	40	5
4. Diminishing home-garden size	11	2.9	2	10	33.3	2
5. Theft attempts	18	4.82	7	8	26.6	8
6. Disease and pests	148	39.67	4	17	56.6	3
7. Climate change, e.g. frost, drought, rainfall	231	61.93	6	26	86.6	6
8. Flood run off	113	30.29	8	9	30	7

The top five factors affecting home-garden agro-biodiversity management were home-garden size; disease and pest; illegal trading and lack of access to market places, transportation and infrastructure facilities; and unstable price of fruits, vegetables and other crops that eventually caused fluctuations in household income. Generally, poor economic background related to buying good quality seeds, and seedlings; declining landraces; diseases and pests; inadequate support from extension services; poor market value chain; shortage of traction power; and poor management of wild animals were the major bottlenecks to managing home-garden agro-biodiversity. Therefore, trainings, incentives for tree plantings and seedling distribution, pest and disease management, marketing, etc. need attention by all stakeholders. There are similar findings from previous studies in Ethiopia (Asfaw & Zergaw, 2022, Mehari & Abera, 2019, Setiani et al., 2022, Bistaa et al., 2022) that similar challenges predominantly constrained the sustainable management of traditional home-garden agro-biodiversity and similar recommendations such as promoting researches on home-gardens agro-biodiversity and agro-ecological services, creating awareness of stakeholders, scaling-up of appropriate home-garden components, provide quality seeds and seedlings, and reinforce policies and strategies that encourage farmers and key stakeholders to make home-gardens an alternative to improve their welfares.

4. CONCLUSIONS AND RECOMMENDATIONS

The traditional home-garden agro-biodiversity is an integral component of local agri-food – agroforestry system in rural settings, which provides multiple agro-ecological services. These broad ranges of agro-ecological services ascribe to the wide-ranging array of plant species. The home-garden agro-

biodiversity embraces plants used as vegetables, fruits, herbs, trees, pulses, tubers, roots, shades, bio-fertilizers, medicines, aromatics, ornamental and spices as well as livestock and poultry that can serve as a supplementary source of food and manure for soil fertility management. The most important agro-ecological services delivered by the home-garden agro-biodiversity among others include food and nutritional supplements, income generation, domestic energy supply (firewood and charcoal), forage and fodder, medicine, shade, and beautification. It holds endogenous solutions for multiple issues related to improving livelihoods of smallholder farmers and agricultural development. It is therefore widely used as a remedy to improve their welfare including alleviation of food insecurity and malnutrition. They also contain other wide range of plant species, including landraces, rare or threatened species, and medicinal plants. They are ideal sites for *in situ* conservation of agro-biodiversity and genetic materials. The traditional home-garden agro-biodiversity practice could therefore be one option to address the problems of deforestation and related resource degradations.

Although the management of home-garden agro-biodiversity is a time-tested local strategy that is widely adopted and practiced by local communities for multiple benefits, there are numerous limitations. The key constraints are declining home-garden size; lack of access to suitable and sufficient land to establish new home-gardens; lack of access to credit services; limited marketing opportunities; access to markets and hence excessive post-harvest losses; limited access to agricultural inputs such as seeds and planting materials; damages due to insect pests, diseases, flood run-offs, wild animals, and theft; weak extension and advisory services; inadequate research and development on traditional home-garden agro-biodiversity and their agro-ecosystem services; and lack of adequate information on nutritional benefits of home-garden agro-biodiversity.

Recognizing the potential of home-gardens for enhancing agro-biodiversity, agro-ecosystem services and improving livelihoods of smallholder farmers, governmental, non-governmental, and international organizations should 1) provide support and build farmers' capacity to enhance sustainable management of agro-biodiversity in traditional home-gardens, 2) promote their agro-ecosystem services and 3) scale up such home-garden practices for their wider applications. In addition, traditional home-garden agro-biodiversity's perspectives of food and nutrition, access to new technologies, extension and advisory services, economic and non-economic benefits, women empowerment, and long-term sustainability need further research. Therefore, though traditional home-gardening is a proven eco-friendly agri – food – forestry system having multiple agro-ecosystem services, there is yet a need for more research and empirical data to appraise their roles in assessing their economic and non-economic values and their impacts on food security, nutrition, and economic growth as well as agro-ecosystem functioning and services.

Declarations

Competing interests

Authors declare no conflicts of interests

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Author Contribution

All authors participate in problem identification, data collection, data analysis and write of the manuscript

Availability of data and material

All the data used for this study are already included in the manuscript itself.

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Footnotes

1. Kebele is lowest administrative unit in Ethiopia

Figures

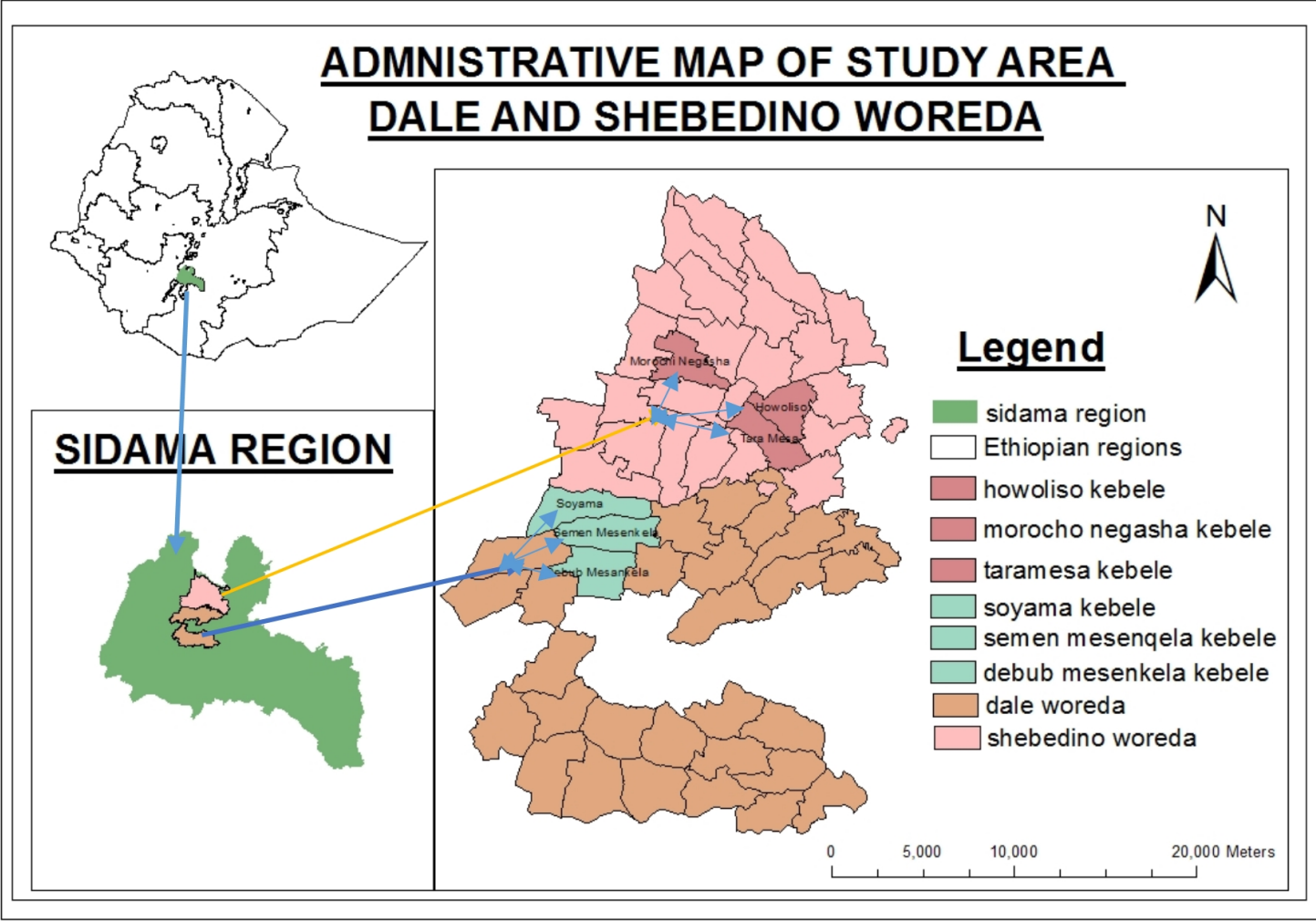


Figure 1

Map of the study area

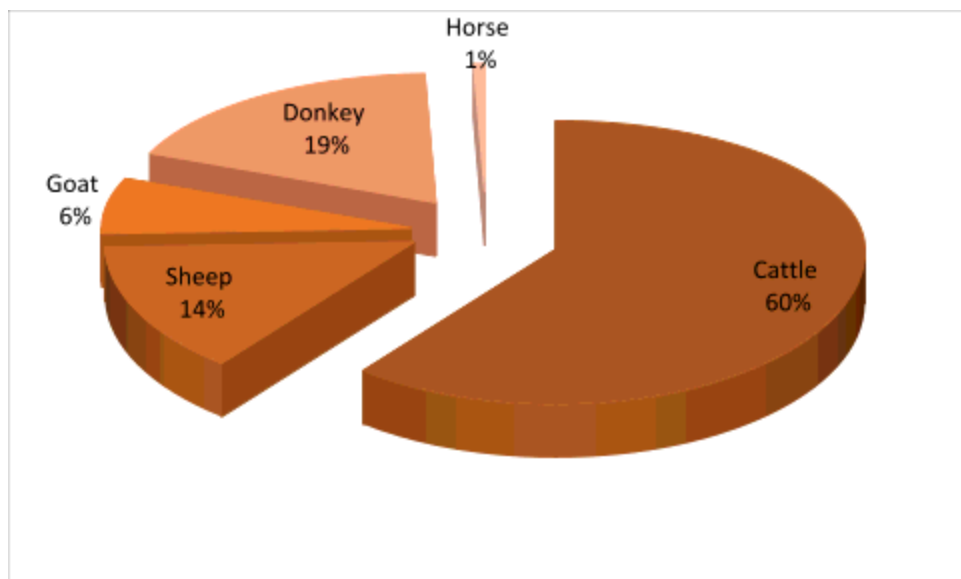


Figure 2

Household livestock holding size (%)

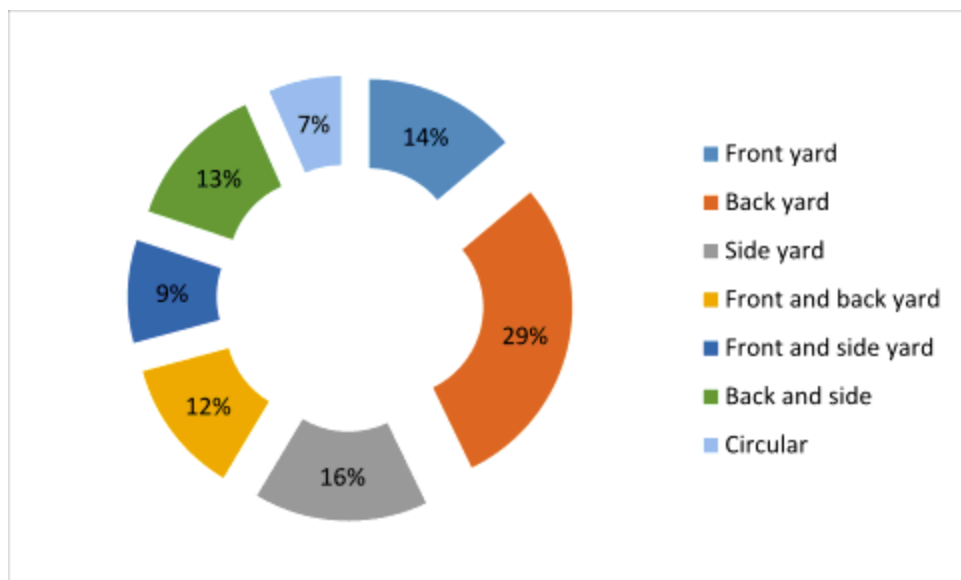


Figure 3

Arrangement of traditional home-garden yards

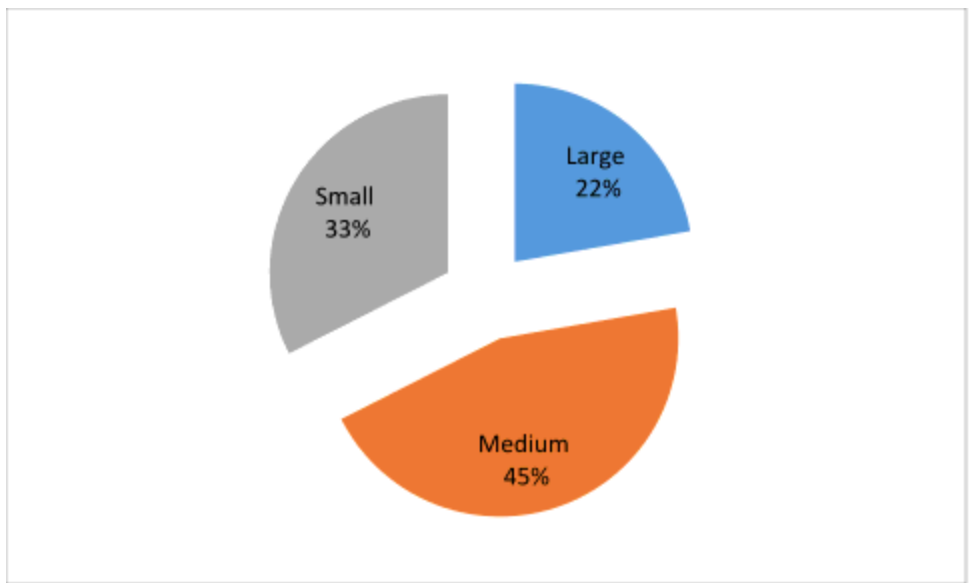


Figure 4

Size of traditional home-gardens and their distribution frequency (%)

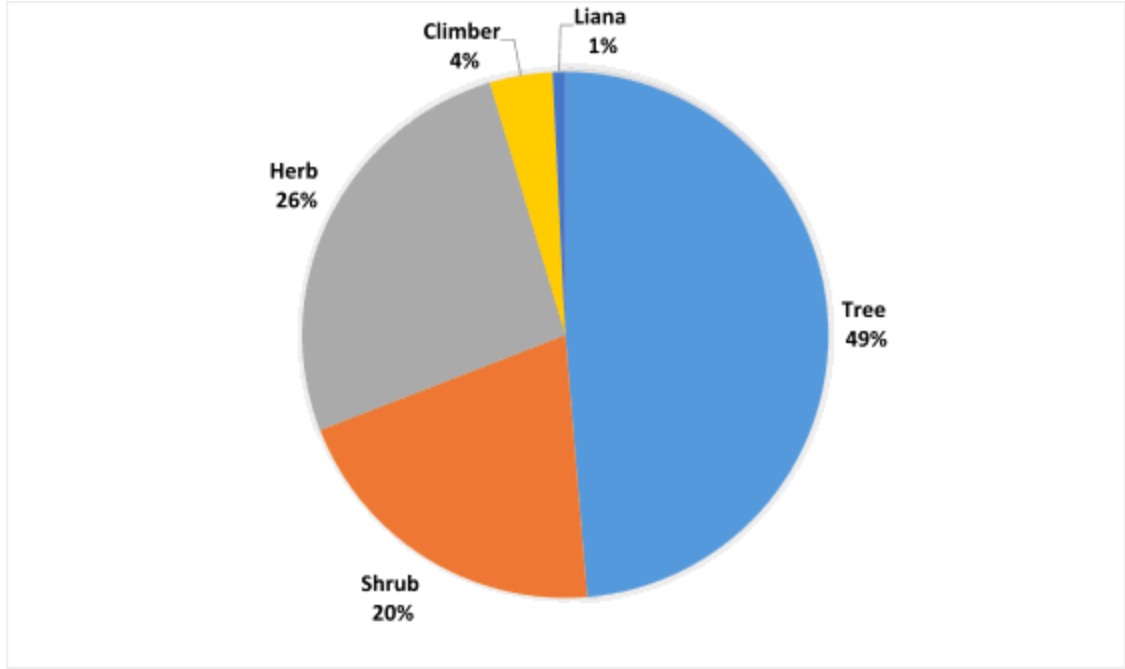


Figure 5

Growth form of plant species in home-gardens

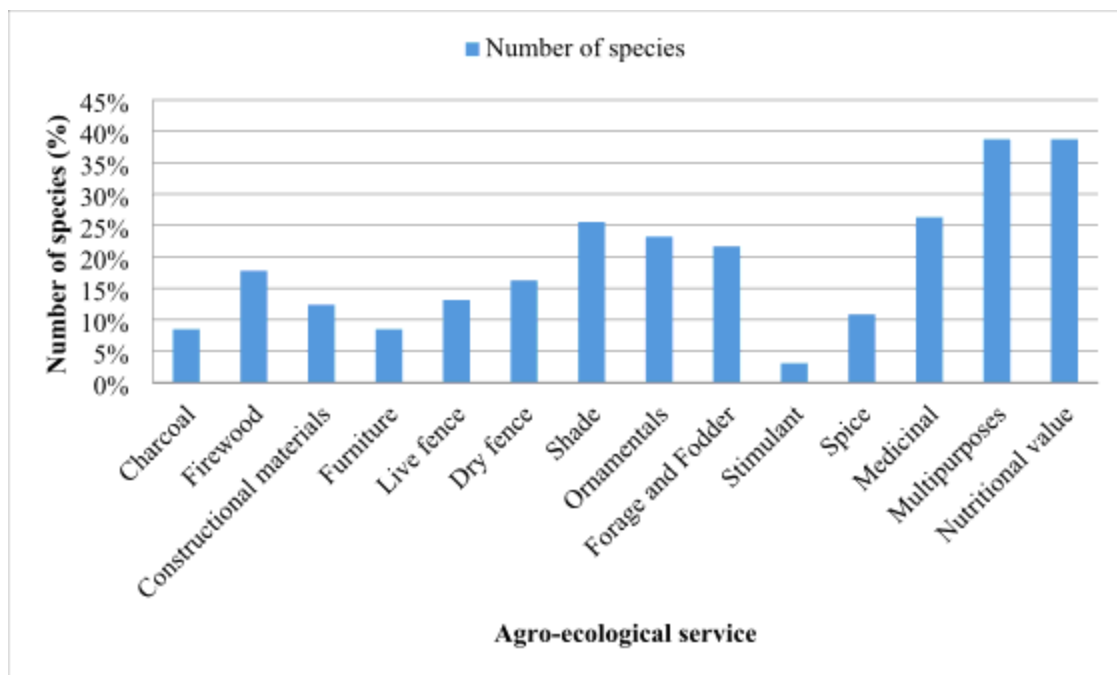


Figure 6

Agro-ecosystem services of traditional home-garden agro-biodiversity