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Contribution of Homegarden Agroforestry to Household Income Generation and Woody Plant Species Diversity in Lay Armachiho District, Northern Ethiopia

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Abstract

Homegarden agroforestry (HGAF) is a complex, multifunctional, and sustainable land use system that integrates various farming components to provide economic, social, and environmental services. This study aims to assess the role of HGAF in household income generation and woody plant species diversity in the Lay Armacho district of Northern Ethiopia. Multistage sampling techniques were employed for household sampling, using both quantitative and qualitative approaches for data collection. Quantitative data were gathered from a sample of 315 farmers through structured and semi-structured questionnaires. Qualitative data were collected via focus group discussions (FGDs) and key informant interviews (KIIs). The quantitative data were analyzed using descriptive statistics and one-way analysis of variance (ANOVA). For assessing plant species diversity, each homegarden was divided into one or more 10 x 10 m plots based on size, and a plot was randomly selected for analysis. The results indicate a highly significant difference in annual income generation between HGAF adopters and non-adopters, with adopters generating an average of 24,276.85 $\pm$ 20,059.60 Ethiopian Birr, compared to 11,379.96 $\pm$ 5,873.46 Birr for non-adopters. In terms of woody plant species diversity, HGAF in the study area exhibited a diversified and evenly distributed array of species, comprising a total of 52 woody plant species belonging to 30 families. Thus, practicing homegarden agroforestry holds significant value for both income generation and woody plant species diversity in the study area. To fully realize these benefits, it is recommended that all farmers in the region adopt homegarden agroforestry practices.

Keywords/Phrases: Homegarden agroforestry, Household income, Woody Plant species diversity, Ethiopia

1 Introduction

Homegarden agroforestry (HGAF) is a complex, multifunctional, and sustainable land use system practiced around residences that integrates multiple farming components (Nzilano, 2013; Weerahewa *et al*., 2012). It serves as a small-scale food production and storage system operated by and for household members, mimicking a natural multilayered ecosystem (Mitchell & Hanstad, 2004; Mohri *et al*., 2013). Unlike monocropping agricultural systems, HGAF is characterized by a highly diversified range of cultivated plant species, a multi-storied vegetation structure, a high rate of nutrient cycling, and the maintenance of in situ soil fertility (Kang & Akinnifesi, 2000).

Despite its importance, HGAF is often overlooked as a source of food security and income generation worldwide (Nzilano, 2013). While primarily utilized to provide supplemental food and cash, HGAF can also serve as a habitat for diverse plant species and help conserve natural forests by alleviating pressure on local ecosystems. It provides food, timber, fuel wood, fodder, and medicinal plants (Kumar, 2015). Consequently, it holds significant value for household income generation (Atiso & Fanjana, 2020; Guuroh *et al*., 2012), food security (Sharma *et al*., 2022), medicinal uses (Kumar & Tiwari, 2017), ornamental purposes, and other non-food livelihood needs of the poor (Maroyi, 2009; Regassa, 2016).

Despite these benefits, research on the contribution of HGAF to household income and woody species diversity remains limited in certain regions of Ethiopia (Beyene *et al*., 2018; Mekonnen *et al*., 2014), including the current study area (LAWAO, 2022). Therefore, this study aims to investigate the role of homegarden agroforestry in household income generation and woody plant species diversity in the study area.

2 Materials and Methods

2.1 Description of the Study Area

The study was conducted in the Lay Armachiho district, located approximately 771 km from Addis Ababa and 23 km from Gondar town. Lay Armachiho is one of the woredas in the Amhara regional state, within the Central Gondar zone. It is situated between latitudes 12*o*33’0"N and 12*o*54’0"N and longitudes 37*o*15’0"E and 37*o*31’30"E (Figure 1).

Agroecologically, the district is classified as Kola, Woyna Dega, and Dega, receiving an average rainfall of 1,300 to 1,500 mm. The minimum and maximum annual average temperatures are 18°C and 27*o*C, respectively. The topography of the study area features hills, plains, mountains, and valleys, with an average elevation ranging from 1,600 to 2,700 meters above sea level. The predominant land use types in the area include cultivated (arable) land, agroforestry, grazing, and forest cover (LAWAO, 2022). The study focused on three kebeles: Addisgie, Jiha, and Shumara Lomye.

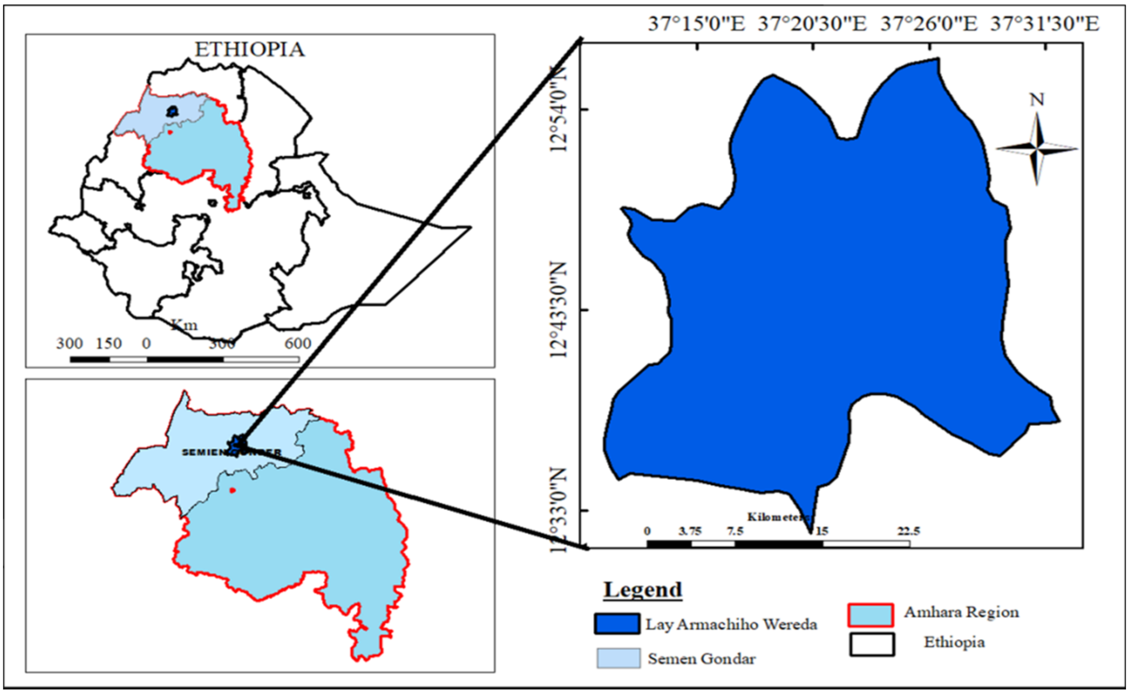

Figure 1. Map of the study area

2.2 Research Methods

2.2.1 Household Sampling Technique and Sample Size Determination

Multistage sampling techniques were employed in this study. First, the woreda was purposefully selected due to the widespread presence of homegarden agroforestry practices in the area. Next, three kebeles were randomly chosen. Finally, the sample size of households from each kebele was determined using a combination of stratified and random sampling methods, applying a proportional formula to account for the heterogeneous nature of homegarden agroforestry practices.

Stratification was based on whether farmers were practicing homegarden agroforestry or not. Using this approach, the sample size was calculated using Yamane's (1997) formula:

$$n = \frac{N}{1+N(e)^2}$$

Where:
N = the total population
n = the required sample size
e = the precision level which is $\pm$ 5%

Based on this sampling method, 315 households were selected from a total of 1,502 households across the three kebeles. Proportional representation was established for each kebele, resulting in the selection of 118 respondents from Shumara Lomye, 104 from Jiha, and 93 from Addisgie. The proportionality for each kebele was determined using Yamane's (1997) formula:

$$n_i = \frac{N_i x n}{N}$$

Where:
N_i = Total population of each kebele
n_i= required sample size for each kebele

Key informants (KIs) were selected using the snowball method (Bernard, 2017). Initially, five farmers were randomly asked to provide the names of six KIs each. From the thirty candidate KIs mentioned, the top five were selected from each kebele, resulting in a total of 15 KIs for the entire study. Additionally, in each kebele, a focus group was formed consisting of 8 to 10 participants, taking into account socioeconomic factors such as age, education, and gender (Kumar, 2018).

2.2.2 Estimation of Woody Plant Species Diversity

Homegardens were randomly selected from each kebele, focusing on households that extensively practice homegarden agroforestry. All woody plant species were recorded from the three kebeles where agroforestry is practiced. In total, 34 homegardens were selected-12 from Shumara Lomye, 13 from Jiha, and 9 from Addisgie-based on the proportionate number of households practicing homegarden agroforestry.

To assess woody species diversity, each homegarden was divided into several 10 x 10 m plots, from which a plot was randomly selected for analysis (Negash, 2013). Within each selected plot, the diameters at breast height (DBH, 1.3 m) for trees and diameters at stump height (d40 cm) for shrubs were measured. Species identification and data collection were conducted with the help of knowledgeable local elders, agricultural experts, and researchers. For any unidentified species, photographs were taken and specimens preserved for further identification at the national herbarium. Woody species nomenclature was based on "Useful Trees and Shrubs of Ethiopia" (Bekele, 2007) and "Flora of Ethiopia and Eritrea" (Edwards *et al.*, 2000) as references.

2.3 2.2.3 Data Type and Sources

Both primary and secondary data were utilized in this study. Primary data were collected through structured and semi-structured questionnaires, along with field inventories. Secondary data were obtained from woreda and kebele administrations, as well as from published and unpublished documents.

2.2.4 Method of Data Analysis

The data collected through the household survey was analyzed using both qualitative and quantitative methods. Prior to analysis, the quantitative data were coded and entered a computer for processing using MS Excel and SPSS (Statistical Package for Social Sciences, version 25). Descriptive statistics were employed to analyze the data from the sampled households. The qualitative data were narrated and summarized accordingly.

A one-way analysis of variance (ANOVA) and independent t-test were used to compare the income generation contributions of homegardens between adopters and non-adopters of homegarden agroforestry (HGAF) at a significance level of $P<0.05$. To assess woody plant species diversity in homegarden agroforestry, the Shannon diversity index (H'), Simpson diversity index (D), and species evenness (E) indices were utilized.

3 Results and Discussions

3.1 Contribution of Homegarden Agroforestry to Household Income Generation

Homegarden agroforestry has a significant effect on annual household income generation, as indicated in Table 1. The mean annual income (± standard deviation) for homegarden adopters was 24,276.85 ± 20,059.60 Ethiopian Birr, compared to 11,379.96 ± 5,873.46 Ethiopian Birr for non-adopters.

Table 1. Average annual income of adopters and non-adopters in Ethiopian Birr

Practice	N	Mean ± Std. Deviation	P
Adopters	196	24276.85 ± 20059.60	0.00
Non-adopters	119	11379.96 ± 5873.46	

Significant level P<0.05

There is a highly significant difference in annual income generation between homegarden adopters and non-adopters. As indicated in Table 1, the mean annual income for adopters was 24,276.85 ± 20,059.60 Ethiopian Birr, compared to 11,379.96 ± 5,873.46 Ethiopian Birr for non-adopters. This result demonstrates that homegarden agroforestry adopters have a greater average annual income than their non-adopter counterparts. This disparity arises because homegarden agroforestry contributes to household income in various ways due to its diverse range of products.

Evidence from the household survey, key informants, and group discussions indicates that households practicing homegarden agroforestry can generate income both directly and indirectly.

In terms of direct income generation, households can increase their income by selling verities of fruits like Mangifera indica, Musa spp., Citrus aurantifolia, Citrus sinensis, Persea americana, Psidium guajava, Carica papaya, and Citrus reticulata; and Vegetables such as Brassica oleracea, Lactuca sativa, Brassica carinata, Allium cepa L., Solanum lycopersicum, and Allium sativum. In addition to fruits and vegetables, they obtain a variety of incomes from cash crops like Coffea arabica L., Rhamnus prinoides, and Catha edulis; and also from animals and their products, poultry and its products, honey, food crops, and other tree products.

For indirect income generation, homegardens provide shelter for chickens, protecting them from predators such as eagles. These chickens can either be sold at local markets or consumed at the household level, contributing to increased household income. Additionally, homegarden agroforestry reduces expenditures on food, fuelwood, fodder, construction materials, and medicine, further enhancing household income.

These findings align with previous studies conducted by Nzilano (2013) in Mbeya rural district, Tanzania, and Atiso & Fanjana (2020) in Boloso Bombe District, Southern Ethiopia. Both studies indicated that homegarden agroforestry significantly contributes to household income generation in rural communities, deriving income from diverse products. The income generated from homegarden sales significantly improves families' financial status (Mitchell & Hanstad, 2004).

Another study by Guuroh *et al.* (2012) in Bieha district, southern Burkina Faso, found that 70% of households relied solely on homegardens and farms for food and cash income. These households increased their income levels by selling animals, fruits, vegetables, fuelwood, medicine, timber, and fodder.

Income from homegarden agroforestry, derived from various components, is illustrated in Figure 2 below. Specifically, 6.44% of income came from food crops, 31.12% from fruits, 3.28% from vegetables, 0.05% from spices, 0.81% from fuelwood, 40.35% from cash crops, 1.09% from tree products, 7.27% from poultry and its products, 6.48% from animals and their products, 2.08% from honey, and 1.03% from other sources.

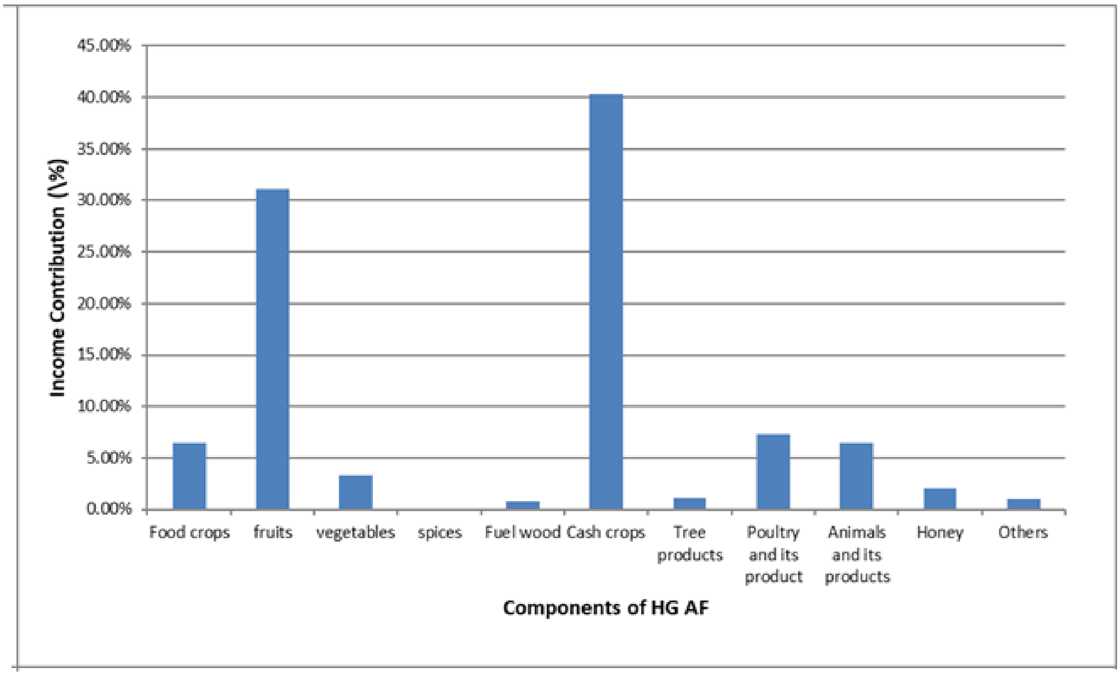

Figure 2. Contribution of Each Component in Homegarden Agroforestry to Income Generation

The main sources of income from homegarden agroforestry in the study area were cash crops (40.35%) and fruits (31.12%), followed by poultry (7.27%) (Fig. 2). This indicates that homegarden agroforestry in the study area is primarily composed of cash crops and fruits.

These findings are consistent with those of Jemal *et al.* (2018) and Hamore & Lemage (2019), which emphasize the vital role of cash crops and fruit trees in generating household income. Mathewos *et al.* (2018) also reported similar results. Additionally, a study by Tang (2011) in Burkina Faso noted that households derive income from various components within homegarden agroforestry, including fruits, vegetables, fuelwood, fodder, medicine, and timber. According to Tang's findings, fruits were the most common source of income for households within homegardens.

3.2 Woody Plant Species Diversity of Homegarden Agroforestry

In the present study, a total of 52 woody plant species belonging to 30 families were identified in the study area (Figure 3). Among these species, 65.4% were trees, 23.1% were shrubs, and 11.5% were classified as other types of trees. This result aligns with previous findings by Tefera *et al.* (2016), who recorded 52 woody plant species in homegarden agroforestry in the Dilla Zuria District of southern Ethiopia. It is also comparable to the findings of Birhane *et al.* (2020) and Molla & Kewessa (2015), who identified 49 and 55 woody species, respectively, belonging to 31 families in Hawassa Zuria District in the Sidama Zone and in Dellomenna District in southeastern Ethiopia.

The highest number of species in the study area was represented by the Fabaceae family, which accounted for 11.5% of the species, followed by the Moraceae and Rutaceae families, each comprising 9.6%. The Myrtaceae family ranked third, contributing 5.8% of the species. The families Anacardiaceae, Bignoniaceae, Celastraceae, Combretaceae, Euphorbiaceae, Meliaceae, and Rosaceae represented 3.8% of the species each, while the remaining families accounted for 1.9% of the species, as shown in Figure 3. Detailed information is provided in Appendix 1.

Similar results were reported by Barbhuiya *et al.* (2016) in the Eastern Himalayan Region of Mizoram, Northeast India, where the Fabaceae family was dominant, followed by the Rutaceae family. Shukla *et al.* (2017) also reported comparable findings.

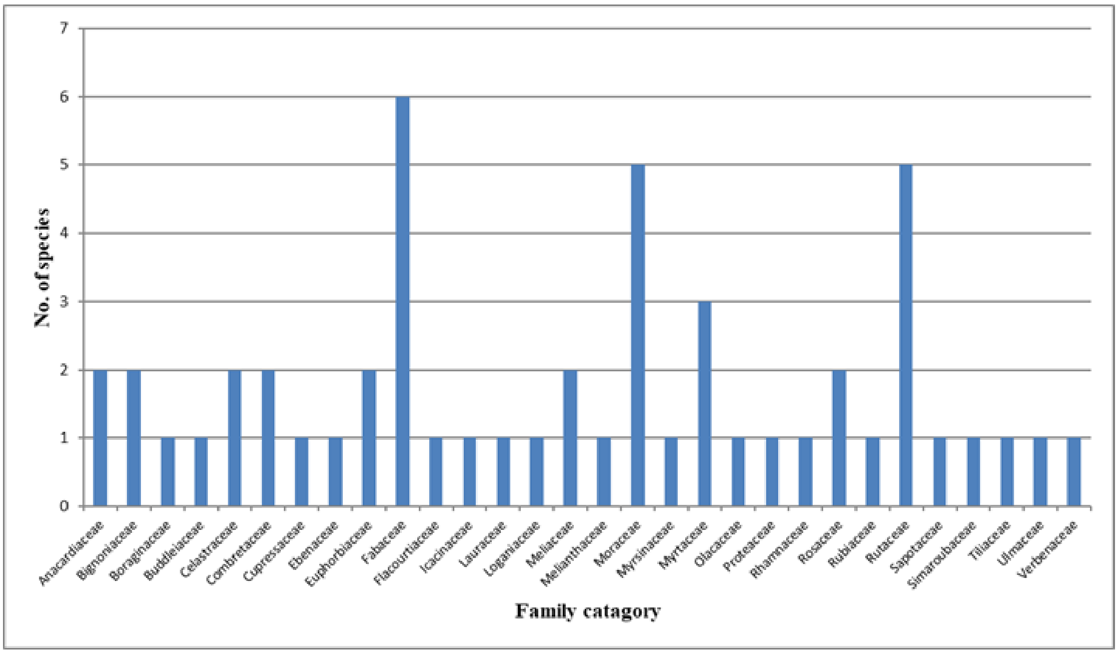

Figure 3. Families with No. of species contained in the study area

In order to get better picture on extent of woody plant species diversity in the study area several diversity indices were employed including Shannon diversity (H'), Simpson's diversity (D), Evenness (H'/H_{max}) and Richness as indicated in Table 2.

Table 2. Woody species diversity indices (Mean ±SD) of homegarden

Richness	Shannon diversity (H')	Simpson's diversity (D)	Evenness (E=H'/H_{max})	Individual
10 ± 1.71	1.92 ± 0.22	0.81 ± 0.06	0.74 ± 0.10	27 ± 11.96

The Shannon diversity index (H'= 1.92 ± 0.22) and evenness (0.74 ± 0.10) indicate a diverse and evenly distributed richness of woody plant species (S = 10 ± 1.71) in the study area. According to Kent (2012) and Magurran (2004), the Shannon diversity index typically lies between 1.5 and 3.5, although exceptional cases can exceed 4.5. The species evenness ranges from 0 to 1.

This result is comparable to the findings of Yismaw and Tadesse (2018), who studied three agroecological zones in this area. They reported an average Shannon diversity index (H' = 1.79 ± 0.09), Simpson's diversity index (D = 0.73 ± 0.04), and evenness (E = 0.74 ± 0.05). However, the present study demonstrates higher species richness (S = 10 ± 1.71) compared to their previous finding (S = 5 ± 0.55). The increased species richness in this study may be attributed to gradual species restoration due to improved management practices over the six years since the prior research.

Another comparable study was conducted by Birhane *et al.* (2020) in Hawassa Zuria District in the Sidama Zone, Southern Ethiopia, which reported woody species diversity indices of Shannon diversity index (H' = 1.87), Simpson's index (D = 0.77), and evenness (E = 0.81). However, the Shannon diversity index (H') in the present study is lower than that reported by Mengitu & Fitamo (2015) in Dilla Zuriya Woreda, Gedeo Zone, SNNPRS, Ethiopia, where they found H' = 3.42. This discrepancy may be due to the fact that SNNPRS, particularly the Gedeo Zone, is well known for its homegarden agroforestry practices, whereas such practices are less extensive in the northern parts of Ethiopia.

4 Conclusion

In general, practicing homegarden agroforestry significantly contributes to income generation for households, both directly and indirectly. There is a highly significant difference in annual income between homegarden agroforestry adopters and non-adopters. Homegarden adopters generate income from a variety of sources, including food crops, fruits, vegetables, fuelwood, cash crops, tree products, poultry and its products, animal products, and honey. Among these, fruits and cash crops were the primary contributors to income generation in the study area. Homegarden agroforestry also plays a major role in enhancing woody plant species diversity. The study area exhibited a diverse and evenly distributed range of woody plant species, with the Fabaceae, Moraceae, and Rutaceae families being the most dominant.

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Appendices

Plant's local name, scientific name, and their family, habit and total abundance in the study area

St. No.	Scientific Name	Local Name	Family	Habit	Abundance
1.	*Acacia seyal*	Girar (nech girar)	Fabaceae	Tree	2
2.	*Albizia gummifera*	Kachona	Fabaceae	Tree	5
3.	*Anogeissus leiocarpus*	kikira	Combretaceae	Tree	11
4.	*Apodytes dimidiata*	donga	Icacinaceae	Tree	12
5.	*Azadirachta indica*	Neem	Meliaceae	Tree	1
6.	*Bersama abyssinica*	Azamir	Melianthaceae	Tree	6
7.	*Brucea antidysenterica*	waginos	Simaroubaceae	Shrub/tree	3
8.	*Buddleia polystachya*	anfar	Loganiaceae	shrub/tree	1
9.	*Calpurnia aurea*	Zigta	Fabaceae	Shrub/tree	2
10.	*Casimiroa edulis*	Yetlian kok	Rutaceae	Tree	18
11.	*Catha edulis*	Chat	Celastraceae	Shrub	33
12.	*Celtis africana*	Quaniquana	Ulmaceae	Tree	2
13.	*Citrus aurantifolia*	lomi	Rutaceae	Shrub	34
14.	*Citrus medica*	Tiringo	Rutaceae	Shrub	1
15.	*Citrus reticulata*	Menderin	Rutaceae	Shrub	3
16.	*Citrus sinensis*	Birtukan	Rutaceae	Shrub	46
17.	*Coffea arabica*	Buna	Rubiaceae	Shrub	210
18.	*Cordia africana*	Wanza	Boraginaceae	Tree	58
19.	*Croton macrostachyus*	Bisana	Euphorbiaceae	Tree	15
20.	*Diospyros mespiliformis*	serkin	Ebenaceae	Tree	7
21.	*Dovyalis abyssinica*	koshem	Flacourtiaceae	Shrub	2
22.	*Ekebergia capensis (E. rueppeliana)*	Lol	Meliaceae	Tree	3
23.	*Erythrina abyssinica*	kuara	Fabaceae	Tree	5
24.	*Eucalyptus camaldulensis*	bahrzaf	Myrtaceae	Tree	1
25.	*Ficus congesta*	godn shola	Moraceae	Tree	3
26.	*Ficus sur (F. capensis)*	banbuleda	Moraceae	Tree	3
27.	*Ficus sycomorus*	Shola	Moraceae	Tree	10
28.	*Ficus thonningii Blume*	Enst chibaha	Moraceae	Tree	7
29.	*Ficus vasta*	warka	Moraceae	Tree	7
30.	*Grevillea robusta*	Grevila	Proteaceae	Tree	12
31.	*Grewia ferruginea*	Lenkoata	Tiliaceae	Tree	1
32.	*Jacaranda mimosifolia*	Yetawla zaf	Bignoniaceae	Tree	1
33.	*Juniperus procera*	Yehabesha- tid	Cupressaceae	Tree	3
34.	*Maesa lanceolata*	Kilabo	Myrsinaceae	Shrub/tree	3
35.	*Malus domestica*	aple	Rosaceae	Shrub	7
36.	*Mangifera indica*	mango	Anacardiaceae	Tree	107
37.	*Maytenus arbutifolia*	atat	Celastraceae	Shrub	9
38.	*Millettia ferruginea*	birbira	Fabaceae	Tree	16

St. No.	Scientific Name	Local Name	Family	Habit	total Abundance
39.	*Mimusops kummel*	Ishe	Sapotaceae	Tree	4
40.	*Nuxia congesta*	atquaro	Buddleiaceae	Tree	4
41.	*Olea africana*	Weira	Olacaceae	Tree	5
42.	*Persea americana*	Avocado	Lauraceae	Tree	20
43.	*Premna schimperi*	chocho	Verbenaceae	Shrub	1
44.	*Prunus persica*	Yehabesh Kock	Rosaceae	tree/shrub	4
45.	*Psidium guajava*	Zeituna	Myrtaceae	Shrub	6
46.	*Rhamnus prinoides*	gesho	Rhamnaceae	Shrub	135
47.	*Rhus vulgaris*	kimo	Anacardiaceae	Tree	5
48.	*Sapium ellipticum*	ahoma	Euphorbiaceae	Tree	3
49.	*Sesbania sesban*	meno zaf	Fabaceae	Shrub/tree	1
50.	*Stereospermum kunthianum*	zana	Bignoniaceae	Tree	2
51.	*Syzygium guineense*	Dokma	Myrtaceae	Tree	58
52.	*Terminalia avicennioides*	wonbela	Combretaceae	Tree	1
Total					919