ASSESSMENT OF TREE SPECIES DIVERSITY PATTERNS AND SOCIOECONOMIC USES ON AGRICULTURAL LANDSCAPES A CASE OF WESTERN OROMIA, ETHIOPIA

M.Sc. Thesis

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ASSESSMENT OF TREE SPECIES DIVERSITY PATTERNS AND SOCIOECONOMIC USES ON AGRICULTURAL LANDSCAPES A CASE OF WESTERN OROMIA, ETHIOPIA

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(Forest and Nature Conservation)

By

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SCHOOL OF GRADUATE STUDIES

As thesis research advisors we hereby certify that we have read and evaluated the thesis prepared under our direction by Dawit Samuel Teshome, entitled 'ASSESSMENT OF TREE SPECIES DIVERSITY PATTERNS AND SOCIOECONOMIC USES ON AGRICULTURAL LANDSCAPES A CASE WESTERN OROMIA, ETHIOPIA and recommend that it be accepted as fulfilling the thesis requirement.

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DEDICATION

I dedicate this piece of work to my wife, Senait Dejene and my daughter, Meklit Dawit, for all their contribution

STATEMENT OF AUTHOR

First, I declare that this thesis is my own work and that all sources of materials used for writing it have been duly acknowledged. This thesis has been submitted to Jimma University, College of Agriculture and Veterinary Medicine in partial fulfillment of the requirements for the Degree of Master of Science and is deposited at the library of the University to be made available to borrowers under the rules and regulations of the library. I declare that I have not submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The Author, Dawit Samuel Teshome, was born in West Shewa Zone, Gindeberet District on April 18, 1984. He attended his elementary education Mukadima elementary school from 1990-1995, Secondary high school at Gindeberet secondary high school from 1996-2002 and higher education at the former Debub University Wondo Genet College of Forestry and Natural Resources (WGCF-NR) now Hawassa University Wondo Genet College of Forestry and Natural Resources (WGCF-NR). He graduated with Degree of Bachelor of Science in Farm forestry in 2006. And then, he was employed by Oromia Agricultural Office in Ejere District Agricultural and Rural Development Office, West Shewa Zone and has worked as Soil and Water Conservation Expert from November 2006 to April 2008 and also as Forestry Expert from May 2008 up to December 2008. Later on he was by employed Oromia Agricultural Research Institute, Bako Agricultural Research Center Forestry/Agro-forestry research team as position of Assistant Researcher-I up to October 2012. He has been working there until he joined Jimma University, College of Agriculture and Veterinary Medicine in October 2012 to pursue a study program to the Degree of Master in Natural Resource Management (Specialized Forest and Nature Conservation).

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ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
CSA	Central Statistics Authority
^{0}C	Degree Celsius
DBH	Diameter at Breast Height
GPS	Global Positioning System
ha	Hectare
HHs	Households
ICRAF	The World Agroforestry Centre (International Centre for Research in Agroforestry)
IVI	Importance value Index
Km	Kilometre
LSD	Least Significance Difference
mm	Millimeters
m	meters
PA	Peasant Association
PAs	Peasant Associations
SPSS	Statistical Package for Social Science

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ASSESSMENT OF TREE SPECIES DIVERSITY PATTERNS AND SOCIOECONOMIC USES ON AGRICULTURAL LANDSCAPES A CASE WESTERN OROMIA, ETHIOPIA

ABSTRACT

Deforestation is one of the prominent problems in developing countries. Forest destruction, land degradation and loss of biodiversity are major environmental problems in Ethiopia. A study was conducted to assess study was to characterize on-farm tree diversity, their patterns and socioeconomic uses in the study area. Four sites representing drier and moist agroecology in the sub-humid agroecology were selected. A total of 100 households, 25 from each sites, were randomly selected and assess tree and shrub species diversity and understand their socioeconomic importance. Data on tree species diversity in the homestead, crop fields and grazing/pasture land use system were collected from 100, 18 and 11 households, respectively. The result showed that a total of 82 tree species were recorded from crop fields, homegardens and grazing/pasture land use system in the study sites. The total number of tree species in the homegardens, crop fields and grazing land was 67, 52 and 29 respectively. The Shannon diversity index in the entire land use system varied from 2.11 at Uke Badiya to 2.28 at Ongobo Bakanisa, and species evenness of the entire land use system varied from 0.565 at Oda Haro to 0.593 at Ongobo Bakanisa. The Shannon diversity index in the homestead land use system varied from 1.80 at Wayu Kumba to 2.13 at Oda Haro, and species evenness of the homestead land use system varied from 0.519 at Wayu Kumba to 0.596 at Oda Haro. The Shannon diversity index in the crop fields use system varied from 1.06 at at Oda Haro to 2.44 at Ongobo Bakanisa, and species evenness of the crop fields land use system varied from 0.450 at Wayu Kumba to 0.879 at Ongobo Bakanisa. The Shannon diversity index in the grazing land use system varied from 1.53 at Ongobo Bakanisa to 1.82 at Oda Haro, and species evenness of the grazing land use system varied from 0.487 at Ongobo Bakanisa to 0.709 at Oda Haro. The density of woody species recoreded in entire land use system varied from 133 at Oda Haro to 476 at Wayu Kumba. Structurally, Eucalyptus camaldulensis was the most important tree species among the common species to the three land use system in the study sites. Homestead size area influenced the species diversity, and coversly wealth status did not influence it. From the total surveyed of tree species abundance in the study sites 85.6% estabilished through plantation and 18.4% established through natural regenerated (retention). The purposes of tree retaining/planting were 38% for live fence, 30% for firewood, 13% for income, 13% for fodder, 4% for timber and 2% for fruit production. Generally, the study showed that agricultural landscapes harbour high diversity of trees and shrubs, to which farmers attach various values to the different utilities acrued from the system.

Key words: tree species diversity, wealth status, homestead, crop field, grazing land, species richness, species eveness.

1. INTRODUCTION

1.1. Background and Justification

Deforestation is one of the prominent problems in developing countries. Agricultural expansion, declining farm land productivity, demand for forest products and investments in the forested areas are some of the major underlying factors exacerbating the problem. Ethiopia's forest cover has now 11% (FAO, 2010); however; the rate of deforestation is still remaining high. For instance, the average annual deforestation rate is estimated at 141,000 ha (FAO, 2010). The destruction of natural forests leads to the loss of biodiversity that important ecosystem function.

Population growth combined with the demand for natural resources are increasingly threatening the sustainable management and use of natural resources. This is the case in many parts of the tropics, where a great proportion of natural forests and the associated biodiversity are either modified into other land uses (Toby *et al,* 2009).

Forest destruction, land degradation and loss of biodiversity are major environmental problems in Ethiopia. The country's population depends heavily on wood and other non-timber forest products (Million, 2001; Alemayehu and Hager, 2009). This high dependence is because of the poor infrastructural development in the country to provide alternative sources of energy, construction materials and other needed wood products. Altogether, population increment, land shortage, diminishing forest area and high dependence on wood resources facilitate the implementation of small-scale tree and shrub growing among the rural community in Ethiopia which makes up around 85% of the country's population (Regassa, 2006)

Even if agricultural expansion is thought to be one of the reasons for the loss of biological diversity, there are variations among agricultural landscapes in their attributes that affect biodiversity (Harvey and Harber, 1999). For example, monocropping agricultural practices

are likely to have low species diversity while some traditional agricultural systems common to the tropics include a remarkable diversity of plant species. The latter when compared to highly simplified systems such as monocultures, appear to be better buffered against perturbations such as drought or pest epidemic (Power and Flecker, 2001).

Woody species cover in agricultural landscapes for both conservation and production goals, it is important to understand the existing patterns of tree cover, how farmers manage the trees within their farms, and the roles that trees play with in production systems. Furthermore, understanding of the roles of trees on farms and diversification of the farm in terms of species richness, as well as evenness through increase in number of trees of rare species, or through replacement of more common species are the best options for preventing degradation of agroforest ecosystems on farms (Kindt *et al.,* 2005).

On-farm trees can be found in agricultural landscapes in various forms of spatial and temporal arrangements for different purposes. One of the features of on-farm tree management is that the biological characteristics of trees are often taken in to account to determine where it should be grown (Tesfaye, 2005).

Inventory of woody species diversity is essential for sustainable development (Chenje *et al.*, 1998; Shumba, 2001). The lack of it has resulted in weak monitoring that has led to vegetation fragmentation (Timberlake *et al.*, 1993). This has ultimately led to a reduced variety of trees species which lead to negative impacts on socio economic development due to reduced varieties in goods and serviced derived from the ecosystems.

Hence, it is vital to assess what woody plants are grown/ maintained on which niche, for what purpose and at what stocking level. By such an assessment the role of farmers and the extent of their contribution to the conservation of the plant genetic resources in farming landscapes could be quantified.

The outcomes of the study was provided information on type of tree species, their relative abundance and distribution on agricultural landscape and would ultimately help in achieving the sustainable management of the tree resources on the agricultural landscape. It also helps to understand the purpose of growing/maintaining the various tree and shrub species on agricultural landscapes. Moreover, the outcome could serve as an input for future ecological studies in the area.

1.2. Objectives

1.2.1. General Objective

The general objective of the study was to characterize on-farm tree diversity, their patterns and socioeconomic uses in the study area.

1.2.2. Specific Objectives

- To assess trees and shrubs diversity on agricultural landscapes in the study area;
- To identify mode of regeneration and niches of tree species on agricultural landscape in the study area;
- To identify and document the purpose of maintaining trees and shrubs on agricultural landscape in the study area

Research Questions

What is the composition and diversity of tree species that exist in agricultural landscape?
Where is the place of tree on farm?
How are trees on the agricultural landscapes regenerated?
What are the purposes of tree species growing/maintaining in the different agricultural landscapes?

2. LITERATURE REVIEW

2.1. Agriculture and Biodiversity

Land use changes mainly from natural forest to agriculture have been the major causes of species losses in the tropics over the last few centuries. Agriculture, which has been described as the "engine of economic growth" because of its powerful role in facilitating and stimulating growth of other sectors of the economy (Mellor *et al*., 1987), started as a subsistence activity 8000 years ago. The early subsistence systems are generally considered to have been sustainable because of their diverse nature. But large scale, capital-intensive, modern agriculture has traded innate sustainability for chemical and other inputs and is characterized by deforestation and decrease in the overall numbers of associated wild plants and animals to favour the growth of the planted crop.

Land use in Africa has been characterized by a significant amount of land degradation and conversion (Barbier, 2000). Many African farming households respond to declining land productivity by abandoning existing degraded cropland and moving to new lands for cultivation. Even if rural households choose to stay on degraded land, its declining productivity will be unable to support growing populations. Thus, households will be forced to abandon existing agricultural areas in search of new land and this process will repeat itself.

Therefore, one of the main reasons for the destruction of natural forests is the expansion of agriculture which has transformed landscapes into mosaics of managed and unmanaged ecosystems, resulting in habitat loss and fragmentation for many species of flora and fauna. However, agricultural landscapes vary substantially in the attributes that affect biodiversity (Harvey and Harber, 1999).

Modern commercial agriculture is mostly dominated by monoculture, and has a reduced plant diversity which influences the composition and abundance of the associated biota, such as wildlife, pollinators, insect pests and their natural enemies, soil invertebrates, and

microorganisms (Matson *et al*., 1997). In agroecosystems, populations with low species diversity (monocultures) have sometimes been associated with higher levels of damage from pests (Power and Kareiva, 1990). A decline in diversity creates losses of species which in turn may have a number of undesirable consequences. Some of these consequences are changes in food webs and losses of ecosystem functions (Bengtsson, 1998). Yields of monocultures are also more susceptible to environmental vagaries.

Traditional cropping systems common to the tropics include remarkable diversity of plant species than conventional, commercial cropping systems, although they seldom approach the diversity of surrounding natural systems. Compared to mono-cropping system, species in such systems are not selected exclusively for high productivity and the species diversity of this system is often high (Harvey and Harber, 1999). These traditional systems of high woody species diversity also tend to have higher faunal diversity. The traditional systems are more similar to undisturbed ecosystems and appear to be better buffered against perturbations such as drought or pest epidemic.

2.1.1. Conceptualizations of on-farm trees pattern and management

In order to manage tree cover in agricultural landscapes for both conservation and production goals, it is important to understand the existing patterns of tree cover, how farmers manage the trees within their farms, and the roles that trees play with in production systems. Furthermore, understanding of the roles of trees on farms and diversification of the farm in terms of species richness, as well as evenness through increase in number of trees of rare species, or through replacement of more common species are the best options for preventing degradation of agroforest ecosystems on farms (Kindt *et al.*, 2005).

On-farm trees can be found in agricultural landscapes in various forms of spatial and temporal arrangements for different purposes. One of the features of on-farm tree management is that the biological characteristics of trees are often taken in to account to determine where it should be grown (Tesfaye, 2005). For instance, trees that contribute positively to agricultural crops are grown dispersed in crop fields while trees that compete with crops are planted

separately in block arrangements. Trees are planted on farms in different niches (Nair, 1993). Depending on the type of ecological settings, trees will be arranged in different patterns. For example, (Arnold and Dewees, 1995) have identified different patterns of planted trees on farmlands as**:** Trees planted on non-arable or fallow land, trees grown in homestead areas, tree growing along boundaries, intercropping on arable land and mono cropping on arable lands.

2.1.2. Diversity in homegardens

When managed mixed gardens of trees, shrubs and herbaceous species are located close to the house, they are known as homegardens (Power and Flecker, 2001). These systems provide food, firewood, medicines, ornamental plants and construction materials to the household (Nair, 1993). They also provide fodder for domestic animals. Homegardening is an age old practice in various parts of the world and play important economic as well as cultural roles in rural societies. A homegarden is an ensemble of deliberately chosen species of plants of human utility combined so as to mimic a natural climax system. It is characterized by relative stability, self-sustainability and ability to maintain productivity. Jose and Shanmugaratnam (1993), described homegardens of Kerala as human ecosystems which can be regarded as analogues of natural tropical forest ecosystems.

Homegarden systems are intensively managed and exhibit high taxonomic and structural diversity. Species richness in these systems ranges from relatively modest levels to very high diversity. A study on the structure of homegardens in Guatemala (Gillespie *et al.*, 1993) suggested that, farmers used existing native forest species as the basic farming of their homegarden structure, which are useful for fruit, medicine, or shade. The cultivation of homegardens, have been emphasized as an example of sustainable agroforestry management systems that has been practiced for perhaps hundreds of years with no apparent loss of vigour or detrimental effects to the environment (Soemarwoto, 1997). Farmers value the trees grown in their homegardens not only as a source of cash income and subsistence, but also for improving habitat quality, conservation of soil and water resources, and they also appreciate the aesthetic value of the homegarden (Jose and Shanmugaratnam, 1993). As forest like

ecosystems, homegardens may therefore be very important as a low input productive unit that stabilizes the sloping land, the hydrological balance as well as the nutritional supply. Homegardens are producing an increasingly important supply of food in many countries as population pressure reduces the amount of land available to each household for food crops. They support the cultivation of multipurpose trees and shrubs, often in association with annual and perennial agricultural crops and livestock, within the household compound.

Homegardening in Ethiopia may be as old as agriculture; the latter is estimated to have started at about 7000 years ago (Ehert, 1979; cited in Zemede Asfaw and Ayele Nigatu, 1995). Commonly, multiple perennial and annual crops are grown in homegardens with certain spatial or temporal arrangement. For instance, Tesfaye Abebe (2005) reported about 120 tree and shrub species from the homegardens in southern Ethiopia. The mixing of different crops allows diversification of niche and some of the crop combinations complement each other.

Fences of gardens are usually reinforced with live plants, which also give some useful products for the family. Big trees are usually left in the open space in the vicinity of the house for their multipurpose use. Farmers usually use such trees for shade and as facility for social gatherings of the villagers demonstrating the special regard given to trees in the traditional rural life (Zemede Asfaw and Ayele Nigatu, 1995).

2.1.3. Woody species in crop fields

In the tropics, conservationists have focused their attention on the protection of natural forests and woodlands, and until recently (Schelas and Greenberg, 1996) have not given much attention to the widely dispersed on-farm woody species. These patches are often critical components of a farmers' environment being a source of products and environmental services of importance to the farmers' livelihood and welfare. Recently, it has been recognized that the part played by the woody species in these landscapes play an important role in maintaining biological diversity (Schelas and Greenberg, 1996; Nikiema, 2005).

The integration of woody species into crop fields, has been proposed as one way of diversifying agro-ecosystems in a way that is beneficial to the environment and can maintain and perhaps enhance biodiversity (Sanchez *et al*., 1997). They could provide replenishment of soil fertility and could also provide marketable forest products. The relevant services of woody species are those that increase the crop yields (nitrogen fixation, increased soil organic matter content, nutrient cycling, soil conservation, etc.), create environmental resilience (niche diversification, food-web complexity, reduced greenhouse emissions through carbon sequestration, etc.).

Remnant woody species in crop fields may play an important role in conserving biodiversity within agricultural systems because they provide habitats and resources that are otherwise absent from agricultural landscapes (Harvey and Haber, 1999). They also serve as critical nesting, feeding, and roosting sites for a variety of bird and bat species. They also provide transient habitats for many migratory birds. The presence of woody species in crop fields also favours the survival of native forest plants. In addition, on-farm trees often serve as a source of propagules for forest regeneration both because they produce seed locally, and because the birds that visit their canopies regurgitate or defecate seeds of forest plants while perched in the trees. As a result, the seed rain beneath on-farm trees is significantly higher than in open areas (Harvey and Haber, 1999). The woody species also contribute to the enrichment of faunal biodiversity in the agricultural landscapes.

The presence on-farms trees of diverse tree species that serve different socio-economic and ecological functions could contribute to the sustainability of agricultural systems (Tesfaye, 2005). At the same time, the diversification of on-farm trees provides biological assets for maximizing on-farm resources, thus lowering the cost of production. Trees on-farms, in the form of agroforestry, are uniquely suited to provide eco-agricultural solutions that successfully combine the objectives of increased food security and conservation gains, especially by promoting the greater use of native tree species (Atta-Krah *et al.,* 2004). Diversifying the composition of on-farm tree species also enhances the stability and productivity of agro-ecosystems (Kindt and Coe, 2005) and combines the objectives of

attaining gains in food security and in conservation of biodiversity (Atta-Krah *et al.*, 2004; Garrity, 2004).

2.1.4. Contribution of on-farm trees to different demands of farmers needs

Planted fruit trees appear everywhere at an early stage in agricultural settlement. As natural tree stocks diminish, the amount and range of tree planting by farmers generally increase (Arnold and Dewees, 1995). However, tree management decisions by farmers reflect much more than diminishing stocks of naturally occurring tree stocks. Tree planting may be explained as one or more of four categories of farmers' response to change (Scherr, 1995; Arnold and Dewees, 1995), which are designed: to maintain supplies of tree products as production from off-farm tree stocks declines due to deforestation or loss of access; to meet growing demands for tree products as populations grow, as new uses for tree outputs emerge, or as external markets develop; to help maintain agricultural productivity in the face of declining soil quality or increasing damage from exposure to sun, wind or water run-off; to contribute to risk reduction and risk management in the face of needs to secure rights of land tenure and use, to even out peaks and troughs in seasonal flows of produce and income, and in seasonal demands on labour, or to provide a reserve of biomass products and capital available for use as a buffer in times of stress or emergency.

Tree resources on farms thus serve well-defined purposes: production of fruit or fodder, shelter from the wind, restoration of soil nutrients, boundary demarcation, etc. The patterns of tree stocks and tree cover that emerge on farm lands are therefore quite different from those found in natural forests. Thus, while tree growing by farmers may be in part a response to the depletion of tree stocks from deforestation, and can create additional supplies of wood and other forest products, it does not recreate forests.

2.1.5. Rationale for retaining woody species in agricultural landscapes

The selective retention of woody species in agricultural landscapes is a traditional agroforestry practice in the smallholder sector of much of Africa (Ingram, 1990; Boffa *et al.,* 2000). Several indigenous tree species are protected and managed by farmers on crop fields and homegardens as a part of a traditional approach to land use in the tropics. The trees serve as a source of wood, food, fodder and medicine for the farmers. They also provide ecological services including soil fertility and microclimate amelioration. In addition to direct domestic use of the tree products, they are a source of cash for many poor people. Most farmers value trees more for their traditional roles such as the provision of fruit, fodder, wood, shade, meeting places, and medicines than for their soil ameliorative role (Campbell *et al.,* 1991).

Fruits from trees were valued as supplements to the subsistence diet in the household. Trees produce wood for fuel and also produce litter that through decomposition increases organic matter status of the soil. They also create shade which has costs in terms of reduced crop production, and benefits in terms of places to rest and eat, and places to leave babies whilst working in the field (Musa *et al.,* 2000). Therefore the retention of woody species in agricultural landscapes is likely to be due to the market and non-market values of trees rather than soil amelioration effects. A more generally relevant and important advantage of retaining diverse woody species is the so-called `insurance hypothesis', which suggests that high diversity leads to more reliable ecosystem functions over time when environmental conditions vary (Naeem, 1998), e.g. because of climate change.

Species composition and tree densities of woody species in agricultural landscapes are the results of local natural characteristics as well as human influences. A host of biological, socioeconomic and policy factors influence farmer management of tree densities in agricultural landscapes (Boffa, 1999). Among those, an interaction pattern between selected woody species and associated crops is a likely one. They also relate directly to recommendations of optimal woody species densities in fields to farmers by development and extension services (Boffa, 1999). The presence and future of the woody species in agricultural landscapes ultimately depends on the farmers who own and manage the land and the principal

value of woody species in agricultural landscapes lies in their utility for resource poor farmers (Gardon *et al.,* 2003).

Conservation initiatives that reduce these use values, such as the prohibition of felling, might cost the farmer without providing a good return for the conservationist. Indeed that return might be negative if benefits to farmers are curtailed to the point at which they cease to permit or encourage natural regeneration within their agricultural landscapes (Gardon *et al.,* 2003).

2.2. Factors Affecting Diversity of Woody Species in Agricultural Landscapes

Physical and socio-economic factors influence farm level woody species diversity (Zebene Asfaw and Hulten, 2003; Kindt *et al*., 2004; Tesfaye Abebe, 2005). Altitude and temperature are important ecological factors influencing the diversity of woody species. Spatially, the tropics have more diverse woody vegetation (Krebs, 1985) and areas with moist and warm climatic conditions host a greater variety of woody species.

Moreover, socioeconomic factors such as farm size, wealth status of the household, proximity to natural forest, access to market, and availability of labour also determine the diversity of woody species. For example, study in Western Kenya by Kindt *et al*. (2004) indicated low species richness of fruit, medicine and construction trees for wealthier households as they prefer to purchase these products rather than producing on their own farms.

The same study also indicated lower abundances of construction and timber trees in the villages closest to natural forest. Kindt *et al*. (2004) also indicated that woody species diversity increases with increasing farm size. Similar results were also reported by Zebene Asfaw and Hulten (2003) and Tesfaye Abebe (2005) from southern Ethiopia. Less species diversity was reported for households with more access to local markets as compared to farmers with less access to market in the highlands of Sidama (Zebene Asfaw and Hulten, 2003). On the other hand, Tesfaye Abebe (2005) found a non-significant relationship between woody species richness and distance to market.

2.3. Woody Species Diversity in Agricultural Landscapes and Food Security

Woody species in the agricultural landscapes provide basic food products and traditional medicines as well as a variety of other products including fodder, spices, gums, resins, fuel-wood, construction wood and wood for making farm implements for a large number of people, in sub-Saharan Africa (Zewuge Teklehaimanot, 2004). Increasing the quality, number and diversity of woody species in agricultural landscapes that provide a wide range of benefits enhance its capacity to fulfill its ultimate potential as a way to alleviate poverty (Cooper *et al*., 1996).

It has been estimated that a large amount of land survive under traditional agriculture as raised fields, terraces, swidden fallows, polycultures, and agroforests including homegardens and other agroforestry systems (Altieri, 1995) and while these seldom have the potential to produce marketable surpluses, they do make major contribution to food security. It has been suggested by Heywood (1999) that traditional cropping systems are said to provide as much as 20% of the world's food supply.

These contributions of traditional agriculture like agroforestry, which mainly integrates woody species with crops, come in three major forms: (a) the environmental protection role of trees and forests that enhance water and soil conservation to maintain high levels of productivity; (b) the direct food commodity contributions which can supplement normal farm yields or serve as substitute products in the event of crop failures due to floods, droughts or insect infestation; and (c) the socioeconomic contributions of woody species in agricultural landscapes to food security (Becker, 1986).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

Location

The study was conducted at West Shewa and East Wollega zones of Western Oromia. West Shewa zone is one of the zones in Oromia Regional State, and it is found between 8^0 17" north to 9^0 60" north latitude and 37^0 17" east to 38^0 45'east longitude. The Zone is adjacent to, East Wollega and Horo Guduru Zones in the West and North West, Jimma zone in South West, South West Shewa zone in South East and North Shewa zone in the South East.

East Wollega zone is one of the zones in Oromia Regional State, and it is found between 9°31'9.41" north latitude and 36°45'27.44" east longitudes. The zone is one of the zones in the central Oromia region of Ethiopia. Nekemte town is the zonal capital. East Wollega is bounded on the southwest by Illubabor, on the west by the Didessa River which separates it from East Wollega, on the northwest and north by the Benishangul-Gumuz Region, on the northeast by Horo Gudru Wollega Zone, on the east by West Shewa, and on the southeast by the Gibe River which separates it from Jimma. The highest point in this zone is Mount Garochan 3,276 m (http://en.wikipedia.org/wiki/MisraqWelega_Zone).

An agroforestry research project by the name "Trees for Food Security Project" is being conducted in East Wollega and West Shewa Zones of Oromia Regional State. The specific sites of the project Wayu Kumba in Jimma Arjo, Uke Badiya in Guto Gida and Ongobo Bakanisa in Gobu Seyo Woredas of East Wollega and Oda Haro in Bako Tibe Woreda of West Shewa, the present study was conducted in all the four project sites. Wayu Kumba is located 65 km south of Nekemte town; Ukee Badiya 35 km north of Nekemte; Ongobo Bakanisa 70 km east of Nekemte and 12 km west of Bako town and Oda Haro 98 km East of Nekemte, 16 km East of Bako. The districts and the peasant associations (PAs) study was conducted illustrated below in (Figure 1) and (Figure 2) respectively.

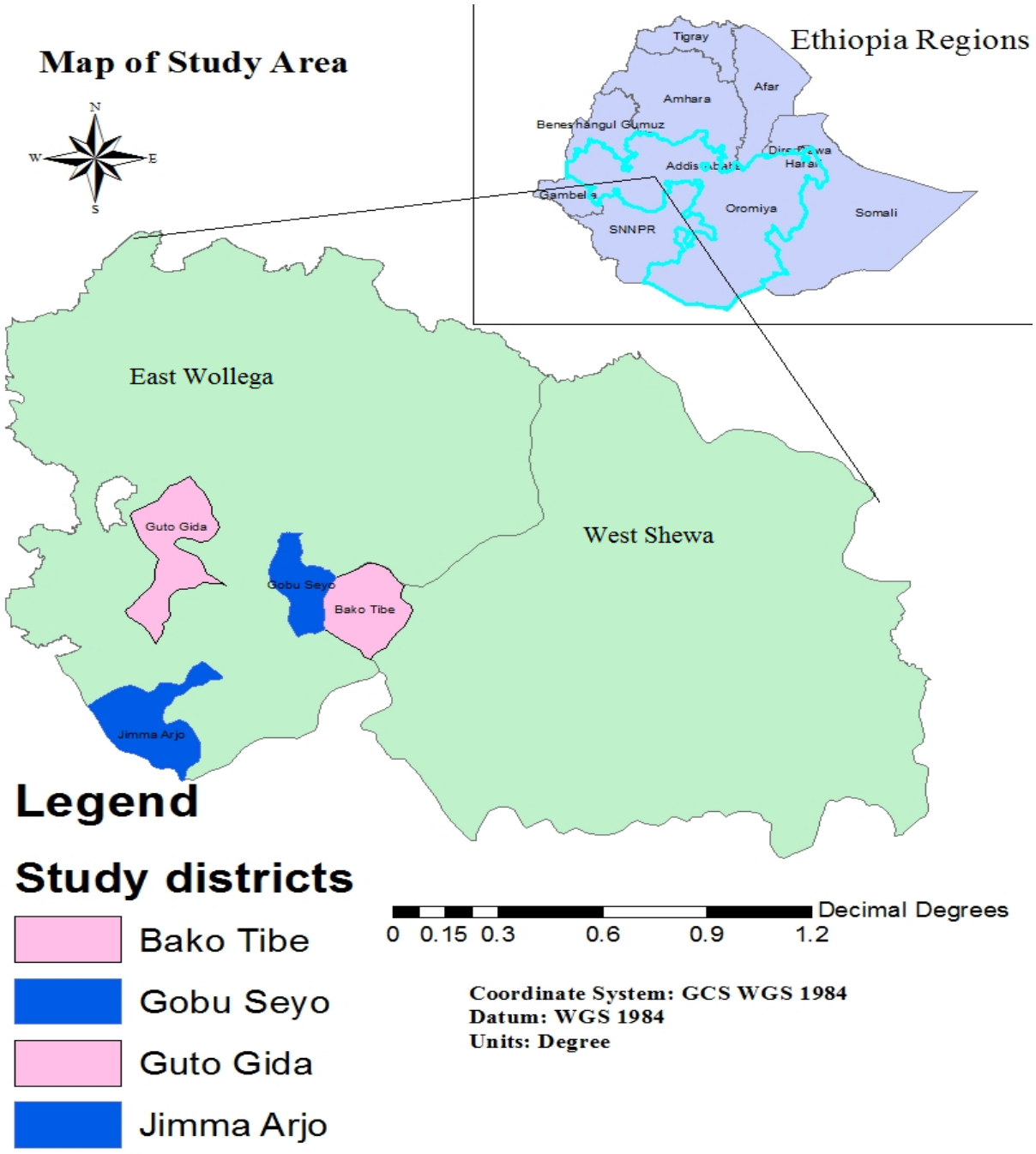


Figure 1. Location of the districts of the study areas

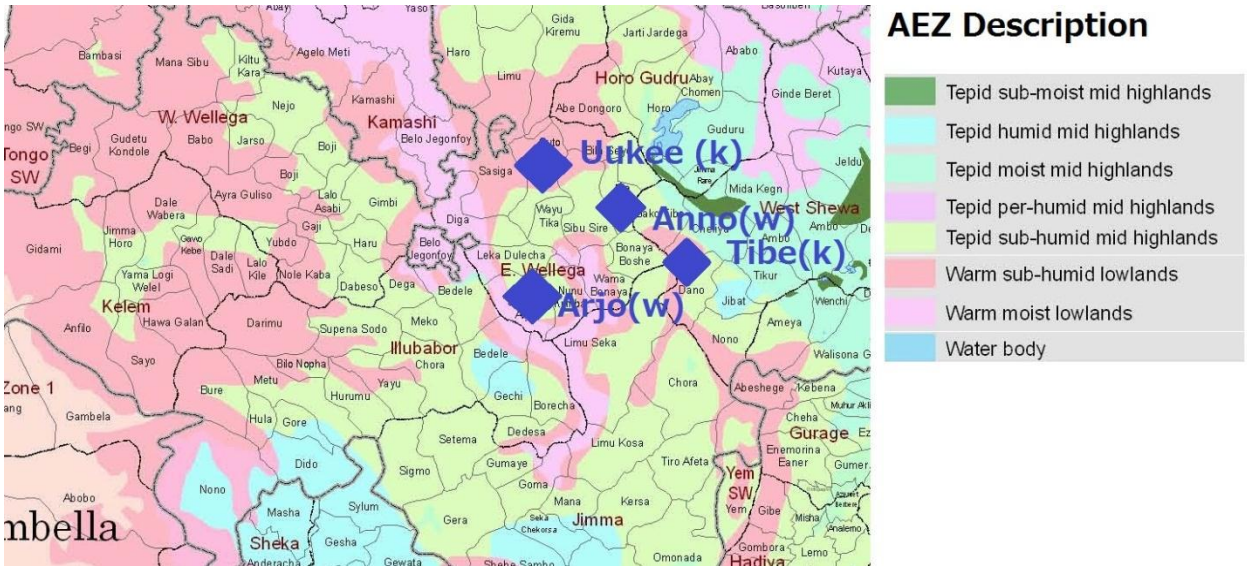


Figure 2. Location of the study PAs with agro-ecological description.

Demography

Based on figures published by the Central Statistical Agency in 2007, the total population study area of each districts are illustrated (Table 1).

Table 1.Total population of the study districts area

Districts Name	Rural		Urban		Total		
	Male	Female	Male	Female	Male	Female	Total
Jimma Arjo	37,935	39,981	5,118	5,245	43,053	45,226	88,279
Guto Gida	47,109	45,438	0	0	47,109	45,438	92,547
Gobu Seyo	18,660	19,017	2,316	2,435	20,976	21,452	42,428
Bako Tibe	49,506	51,203	11,760	11,089	61,266	62292	123,558

Sources: - (CSA, 2007).

Climate

Depending on the topography, agro-ecologies vary, but many of administrative zones in western Oromia are dominantly sub-humid: kola-warm lowland (orange in legend) and Weinadega-tepid mid highlands (greenish yellow in legend) (Figure 2). Some areas with gorges of rivers have more warm moist lowland climates, while toward higher altitudes tepid humid/moist climates are prevalent. The study districts Jimma Arjo, Guto Gida, Gobu Seyo and Bako Tibe the annual rainfall follows unimodal regime characterized by one distinct rainfall peak (August- September), while the driest season is November to February. The mean annual temperature ranges between 15 ^{0}C to 20 ^{0}C, greater than 15 ^{0}C, 15 ^{0}C to 20 ^{0}C and 14.1 ^{0}C to 28.3 ^{0}C, and where as the mean annual rainfall is between 1400 to 2000 mm, 1600 to 2000 mm, mean annual rainfall may reach to 2000 mm, average annual rainfall of 1,320 mm at Jimma Arjo, Guto Gida, Gobu Seyo and Bako Tibe districts respectively (http://www.oromiyaa.com/english/).

Topography and soil types

The physical features of the west parts of Oromia state have rugged landscapes and terrains of mountains, hills and valleys. The soils type of Jimma Arjo district Dystric Nitosols and Orthic Acrisols. Dystric Nitosols, which have good agricultural potential, covers most part of the district. On the other hand orthic acrisols, which occurred mostly on sloping terrain and have less agricultural potential, occupy the areas along the Didesa river valley bordering west wollega zone. The soil type of Guto Gida district dominant by sandy, clay Loam, clay Soil, Loam and silty. The soil type of Gobu Seyo Clay loam and loam soil is exceedingly dominating the district, which has a good quality of agricultural potentialities. The coverage of Clay loam soil in hectares is 27,002 and of these hectares 14,889.4 hectares is suitability for agriculture. Loam soil also covers 6750.6 hectares and it is totally suitable for agriculture. The soil type of Bako Tibe Rendzinas, Haplic and Luvic phaeozems (4.0%), chromic and Orthic Luvisols (14.9%), Dystric Nitosols (60.2%), and Chromic and Pellic Vertisols (20.9%) are the major soil types found in the district (http://www.oromiyaa.com/english/)

Land-use patterns and vegetation

Livelihood of the majority of the inhabitants in the study area is agricultural practices. The dominant crops are more or less similar *Zea mays* (maize) predominant, *Sorghum bicolor* (sorghum), *Eragrostis tef* (teff) and *Guizotia abyssinica* (Niger seed).

The forest coverage and vegetation of Jimma Arjo district the potential forest area of this district is in the low lands around the upper and lower valley of Didesa (Lalo Bobio) that had been under study for the reservation of wild lives. In the high land areas there are different patches of natural and plantation forests like Jemo, (8 ha), Laro (5 ha), Koye (95 ha), Garjaja (94 ha) with different tree species. The dominant tree species are *Croton macrostachyus*, *Acacia abyssinica*, *Eucalyptus species* and *Cordia africana* (http://www.oromiyaa.com/english/).

In Guto Gida district previously the district was highly covered with dense forests and savanna grasses and the high lands even around the capital town "Nekemte" there are remnants or big mother trees which show the presence of forests in the past which is now denuded and left the area barren without any regret. The dominant tree species are few *Acacia abyssinica*, *Cordia africana*, *Ficus species* however, *Grevillea robusta* looks doing well in town. Some indigenous fruits; potential *Mangifera indica.* Today plantation and natural forests of the district like Komto and some others are under sever condition, which needs close control in order to save for future ecological balance for the surrounding. These forests are also the home of different wild animals including very attractive seasonal birds, which are not found in areas where there is no forest. Deforestation is highly practiced by the local farmers through which they gain an income by selling charcoal, firewood and different lumbering materials. The greatest portion of fuel wood consumption of the capital town is obtained from this district, in which the major area in the district where fuel wood possibly comes at large to the town is expected from these forests. The natural vegetation pointed above occupies 3430.67 ha of land in the district, in which 1036.67 ha is natural forest and 2394 ha is plantation (man-made) forest (http://www.oromiyaa.com/english/).

In Gobu Seyo district has a better vegetation cover than the other neighboring districts. There are different patches of forests along the river sides. There was a forest area assumed to be under forest on some areas having a total area of about 1746 ha, but not demarcated as assumed. The dominant tree and fruit tree in the area are *Ficus vasta* on farm, eucalypt on boundaries, *Acacia abyssinica*, in a section of the village with irrigation, *Coffea arabica* and *Carica papaya*. However, there is a very serious deforestation especially along the river and it's surrounding where there had been a jangle forest before a decade. Different wildlife those had been surviving in the district for a long period of time has migrated to different neighboring areas; such wildlife was Lion, tiger, Buffalo, and other different wild animals (http://www.oromiyaa.com/english/).

In Bako Tibe district, high forest, woodland, riverine vegetation, shrubs and bushes, savanna and plantation forests are available. The dominating native tree species include: *Cordia africana, Acacia tortilis, Acacia abyssinica, Ficus vasta, Ficus sur, Ficus sycamourus, Ficus thonningi, Croton macrostachys, Stereospurmum kunthianum, Combretum molle, Albizia gummifera, Syzygium guineense, Pterolobium stellatum, Vernonia amdyglana, Deinbolla kilimandshorica* and *Sapium ellipticum*. These are the remnants of the past forest left scattered over the landscape. The natural forests were devastated due to land clearing for agriculture and over-exploitation of tree resources for fuel, construction and for destroying habitats of wildlife, such as pigs, monkeys, baboons, porcupines, etc., which would otherwise seriously damage their food crops.

In addition to the indigenous species, there are also many introduced trees showing good performance in the area. The major species are: *Spathodia nilotica, Eucalyptus camaldulensis, Jacaranda mimosifolia, Mangifera indica, Cupressus lustanica, Casuarina equisetifolia, Acacia mearnsii, Calliandra calothyrsus, Grevillea robusta* and *Melia azedarach*. *Leucaena leucocephala* and *Sesbania sesban* are also important in the area. In the absence of game reserves, vervet monkey, baboon, warthog, hippopotamus, leopard, duiker, colobus monkey, bush buck, spotted hyena and civet cat are found dispersedly in the district.

3.2. Methods of Data Collection

3.2.1. Types and sources of Data

Both primary and secondary data were used for the study. Primary data was collected on number of farm plots, tree species name, sources of tree species, mode of regeneration and niches of tree species, purpose of maintain trees and shrubs on agricultural landscape, GPS position of the farm plot, height of the trees and diameter at breast height (dbh) and secondary data was collected on land holding size of each selected farmers from each Agricultural and Rural Development Office of the districts.

3.2.1.1. Sampling design

Tree for Food security Project has identified the households for the project activities. The project follows stratified sampling design. First the zone was divided into different agroeocology and four districts were selected purposively. The districts were further stratified into Peasant Association (PA) and again four peasant associations were selected from the districts purposively. Finally, 351 households (HHs) were selected randomly for socioeconomic baseline survey. This study is nested on the socioeconomic study and selected twenty five households randomly from each Peasant Association (PA) to assess tree and shrub species (Table 2).

Table 2. Number of households selected for tree diversity study

Districts Name	Peasant Associations	HH size	HH surveyed for socioeconomic baselines	HH whose homesteads /homegardns surveyed	HH in which a complete inventory conducted
Jimma Arjo	Wayu Kumba	739	77	25	5
Bako Tibe	Oda Haro	719	75	25	5
Gobu Seyo	Ongobo Bakanisa	1005	104	25	5
Guto Gida	Uke Badiya	907	95	25	5
Total		3370	351	100	20

The socioeconomic baseline data has classified the HHs in the study area into three wealth farmer's house earth=1, cement=2; wall material of the farmer's house: earth/mud=1, wood/bamboo/iron sheet=2 and roof material of the farmer's house: grass=1, iron sheet/asbestos=2 so sum up and divided by three (3), and the farmers gate, 3=poor, 4=medium and 5=rich. Among the total households living in the study site, 6 % was categorized as a rich, 49 % as a medium and 45 % as a poor (Table 3).

Table 3. Wealth class distribution of the HHs in the study areas

Districts Name	Peasant Associations	Poor	Medium	Rich	Total
Jimma Arjo	Wayu Kumba	11	13	1	25
Bako Tibe	Oda Haro	14	10	1	25
Gobu Seyo	Ongobo Bakanisa	8	14	3	25
Guto Gida	Uke Badiya	12	12	1	25
Total percentage		45	49	6	100

3.2.2. Data collection

3.2.2.1. Woody species inventory

In order to estimate the abundance of tree species in homestead/ homegarden, crop field and grazing land to identify in selected household farm plot then, complete tree and shrubs inventory was conducted on agricultural landscape owned by the selected households Agricultural landscape tree and shrubs in this study refers all tree and shrubs species that retained and/or planted on homestead/homegarden, crop fields and grazing land of the selected households.

To determine abundance (number of individual) of each tree species occurring on farms was listed and counted with the owner of complete survey. At the same time the niche where individual species is growing was identified and the interviewed in the presence researcher and enumerators.

In addition, the land use types in which the woody plants are grown were specified: small-scale woodlot, boundary planting, homestead and on-farm. According to FAO (2004), tree is defined as a woody perennial plant, with a single main stem or in case of coppice several stems, and has a more or less definite crown. And a shrub is woody perennial plants, often without a definite crown, and generally with heights between 0.5 m and 5 m. However; the interest of the research to assess all trees and shrubs existing in each land use type, the species of the encountered trees and shrubs were identified, number of stems were counted and the diameter at breast height (>2 cm DBH) and height (>2 m height) of each of them were measured following (Abate Ayalew *et al.*, 2006).

Plant identification was carried out both in the field and in the herbarium. Voucher specimens were collected for all plant species not identified in the field. The plant specimens were properly pressed, dried, transported and deposited at the National Herbarium, Addis Ababa University, Ethiopia for subsequent identification. Nomenclature of species were followed the publications of the Flora of Ethiopia and Eritrea (Azene, 2007).

3.2.2.2. Socio-economic survey

Data was also collected on the socio-economic characteristics of the farm including family size, age, educational status, sex and socio-economic uses of tree species, a semi-structured questionnaire was used to interview household respondents. All the 100 HHs where tree inventory was conducted were interviewed on issues such as tree species available on agricultural landscape, sources of tree species, uses of tree species and perception, regeneration and niches of tree species on agricultural landscape and benefit of tree species the over all perception of the local community on the future sustainable uses of tree species on agricultural landscapes in the area.

3.2.3. Data Analysis

3.2.3.1. Vegetation Data analysis

The woody plants diversity was estimated by using species richness, Shannon diversity index and evenness index. Based on the collected ecological data the population status tree and shrubs species in particular and all tree and shrubs in general were examined by computing the abundance, frequency, dominance, importance value (IV), by constructing population structure. Heterogeneity of the tree, shrubs and study sites were also determined using Shannon-Weiner diversity and Evenness indices. Comparisons were also made between the vegetation of the four study PA. Descriptive statistics were employed to summarise the socio-economic information. Details of the analyses methods used are presented below.

Generally, the composition of the agricultural landscape was analyzed as a proportion in percentage of the various species encountered in relation to the total. Thus, the percentage contribution of the study species in various measurable entities compared to the associated species were analzed as follows.

Measurement of Diversity

The woody species diversity on crop fields, homegardens and different location were estimated using Shannon and Simpson diversity indices. Species richness and species eveness were computed. Species richness is the total number of species in the community, and it is the oldest and simplest concept of species diversity (Krebs, 1999).

The Shannon-Wiener function (commonly referred as Shannon diversity index) is the most widely used type of diversity index (Kent and Coker, 1992). Two components of diversity are combined in the Shannon diversity index: (1) the number of species and (2) equitability or evenness of allotment of individuals among the species (Krebs, 1985).

The Shannon diversity index is calculated as:

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

Where;

H' = Shannon diversity index,

Pi = proportion of individuals found in the i^{th} species.

In this case, using the BiodiversityR software within the R 3.00 environment (Kindt and Coe, 2005) was used to run the analyses. Diversity and Species accumulation curves were determined using an exact method for calculating the average number of accumulated species when sites and individual species are accumulated in a random pattern.

Values of the index (H') usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (Kent and Coker, 1992)**.** Usually, Shannon diversity index place most weight on the rare species in the sample (Krebs, 1999). It is also moderately sensitive to sample sizes (Magurran, 1988).

Shannon's index also takes into account the evenness of abundance of species. The ratio of observed Shannon index to maximum diversity (Hmax = ln S) can be taken as a measure of evenness (E) (Krebs, 1985; Maguran, 1988; Kent and Coker, 1992).

Evenness: - This is a new concept attempting to quantify the unique representation of a given species against a hypothetical community in which all species are equally common, such that when all species have equal abundance in the community, were calculated following Kent and Coker (1992). In this case, using the BiodiversityR software within the R 3.00 environment (Kindt and Coe, 2005) was used to run the analyses and evenness ordering was done by computing Rènyi diversity profiles at 1000 permutations and determining the species richness.

$$\text{Equitability (Evenness)} J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{s} piln\ pi}{\ln S}$$

Where, E = Shannon-Wiener Evenness Index

H' = Shannon-Wiener diversity Index

H'max = lnS= natural logarithm of the total number of species (S) in each site.

The higher the value of E, the more even the species is in their distribution within the sample (Kent and Coker, 1992)

Measurements of similarity

Similarity indices measure the degree to which the species composition of quadrats or samples matches is alike. Many measures exist for the assessment of similarity or dissimilarity between vegetation samples or quadrats.

Some are qualitative and based on presence/absence data, while others are quantitative and was worked on abundance data. Of the large choice available, the Sorensen similarity coefficient is applied to qualitative data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample (Kent and Coker, 1992). The Sorensen coefficient of similarity (Ss) is given by the formula:

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

Where, Ss = Sorensen similarity coefficient

a = number of species common to both communities

b = number of species in recorded in the first community

c = number of species in recorded in the second community

The coefficient is multiplied by 100 to give a percentage.

Structural analysis

Dominance

It refers to the degree of coverage of a species as an expression of the space it occupied in a given area. Usually, dominance is expressed interms of basal area of the species (Kent and Coker, 1992), and two set of dominace were calculated in this case: absolute dominance (the sum of basal areas of the individuals in m^2/ha), and relative dominace, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species.

Basal area

One of the structural parameters considered was the basal area. It is the cross-sectional area of tree stems at breast height. It measures the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in agricultural landscapes. Basal area was calculated for each woody species having a DBH > 2 cm.

It was calculated as:

$$BA = \frac{\pi(DBH)^2}{4}$$

Where, BA = basal area (m^2), DBH= diameter at breast height; $\pi = 3.14$

Abundance: Two sets of abundance value were calculated in this study. These were (i) average abundance per quadrats, calculated as the sum of the number of stems of a species from farm plot divided by the total number farm plot, (ii) Relative abundance, calculated as the percenetage of the abundance of each species divided by the total stem number of all species ha^{-1}.

Density

The density of woody species is one of the most important structural parameters to be considered during data analysis. Density was calculated by summing up all stems across all area and converting into hectare basis.

$$\text{Density} = \frac{\text{Total number of individual}}{\text{Sampled area in hectar (ha)}} * 100$$

Frequeny: Two sets of frequencey were computed following Kent and Coker (1992). Absolute frequency, which is the number of farm plot in which the species recorded and relative frequencey of a species, computed as the ratio of the absolute frequency of the species to the sum total of the frequency of all species.

Importance Value Index (IVI)

The IVI of a species is used to express the relative ecological significance and/or dominance of each study species in the agricultural landscapes which was calculated from the sum of relative dominance/basal area (%), relative density (%) and relative frequency (%) (Kent and Coker, 1992)

$$\text{Relative density (RD)} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} * 100$$

$$\text{Relative dominance (RDO)} = \frac{\text{Dominance of a species}}{\text{Total Dominance of all species}} * 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} * 100$$

The vegetation data gathered from the field was analyzed by Microsoft Excel and Biodiversity-R software (Kindt and Coe, 2005).

3.2.3.2. Socio-economic Data analysis

The data collected through the questionnaire interviews were analyzed using SPSS 16.0 Statistical Software and EXCEL. The content of the interviews of individual respondents was summerised and discussed using descriptive statistics such as percentages and tables.

4. RESULTS AND DISCUSSION

4.1. Woody Species Diversity in Entire Land Use System

4.1.1. Woody species abundance, richness and diversity

A total of 82 woody species belonging to 37 families were recorded across the site. From a total of 13,307 individuals (4608 at Wayu Kumba PA, 2829 at Oda Haro PA, 3455 at Ongobo Bakanisa PA and 2415 at Uke Badiya PA) counted 85.1% of them belonged to only 10 of the species. The result indicated that the area dominated by small number of woody species in entire land use system in the study area.

Most of the dominant species are indigenous, although the most dominant species, *Vernonia amygdalina*, is an indigenous species and accounted the accumulated 25.6% of the total woody species recoreded in the study area.

Table 4. The ten most abundant species and their relative proportions in the entire land use of the study sites

Species	Rank	Abundance	Density/ha	% total number	Accumulated %
Vernonia amygdalina	1	3402	57.02	25.6	25.6
Eucalyptus camaldulensis	2	2791	46.78	21.0	46.5
Justicia schimperiana	3	1081	18.12	8.1	54.7
Calpurnia aurea	4	996	16.69	7.5	62.1
Jatropha curcas	5	722	12.10	5.4	67.6
Sesbania sesban	6	647	10.84	4.9	72.4
Ricinus communis	7	593	9.94	4.5	76.9
Cordia africana	8	381	6.39	2.9	79.8
Croton macrostachyus	9	381	6.39	2.9	82.6
Vernonia auriculifera	10	336	5.63	2.5	85.1
Others (72 species)		1977	33.1	14.9	100

From total number of woody species recorded (species richness) at entire land use system of the study sites Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 41, 44, 47 and 38 respectively (Figure 3).

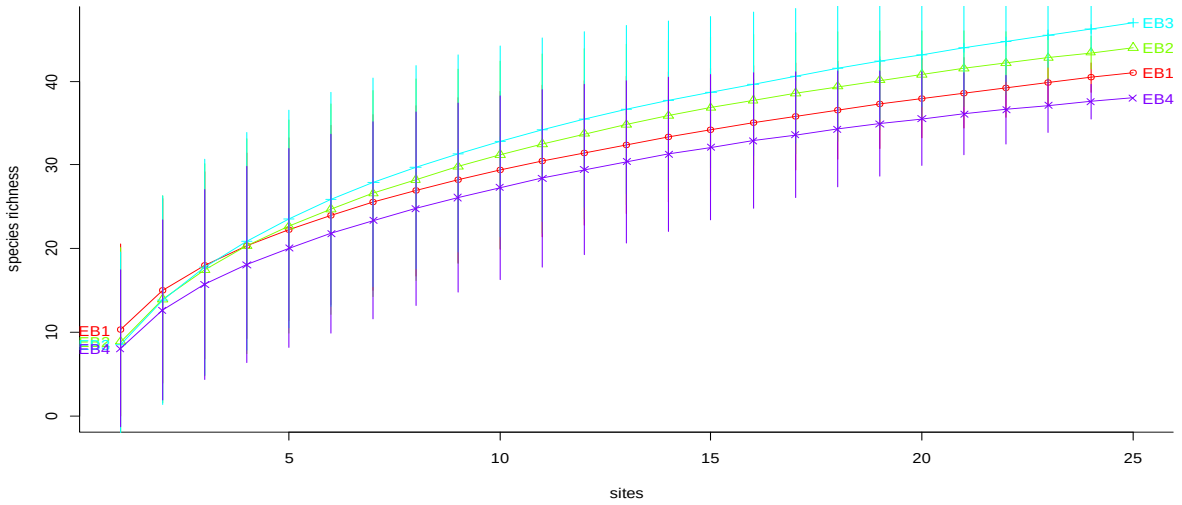


Figure 3. Species accumulation curves (site-based accumulation) for the entire land use system of the study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

Shannon diversity index showed the highest value Ongobo Bakanisa PA and Uke Badiya PA, which is associated with the high evenness in the abundance of species at Ongobo Bakanisa PA as compared to the other three study sites (Table 5).

Table 5. Diversity indices of woody species in entire land use system of the study sites.

Study sites	Shannon diversity index	Species Evenness
Wayu Kumba PA	2.13	0.575
Oda Haro PA	2.14	0.565
Ongobo Bakanisa PA	2.28	0.593
Uke Badiya PA	2.11	0.581

Rényi diversity profiles are curves that also provide information on richness and evenness, as rank abundance curves do. Rényi diversity profiles have the advantage over rank-abundance curves that ordering from lowest to highest diversity is easier. Rènyi diversity profiles showed study site Ongobo Bakanisa PA having the highest number of species; followed by Oda Haro PA, Wayu Kumba PA and the least were Uke Badiya PA (Figure 4a). Rènyi evenness profiles

intersected (Figure 4b) hence the four study site could not be ranked based on tree counts from the least to the most evenly distributed.

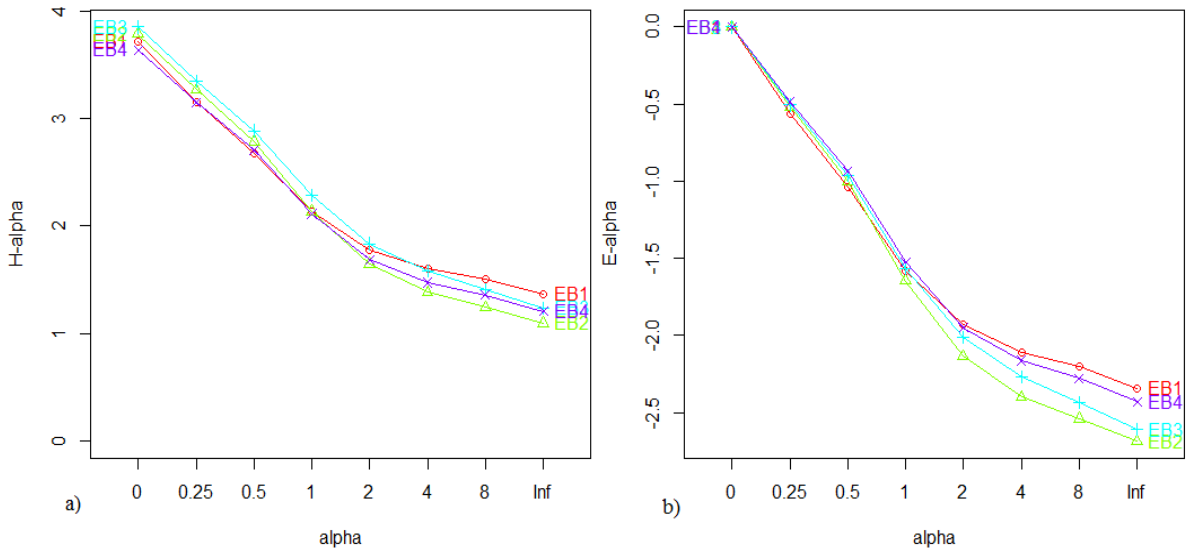


Figure 4. Entire land use **Rènyi** diversity profile (a) and **Rènyi** evenness profile (b) for the four study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

4.1.2. Similarity in species composition

Woody species planted and retained on homesteads/homegardens, crop fields and grazing/pasture land use are remnants of the natural vegetation which has once covered the area. Some of the woody species planted by farmers are also native to the area.

Hence, similarities in woody species composition are expected between the Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA sites of entire land use system. Accordingly, 58.5% of the species in the Wayu Kumba PA are also observed in Oda Haro PA, 58.5% of the woody species recorded in the Wayu Kumba PA were also observed in the Ongobo Bakanisa PA and 41.5% of the woody species recorded in the Wayu Kumba PA were also observed in the Uke Badiya PA sites of entire land use system. Moreover, 70.5% of the woody species observed in Oda Haro PA were also observed in Ongobo Bakanisa PA sites of entire land use system. About 11 species of all 82 woody species recorded from the entire land use system were found to be common to all the study sites (Appendix Table 1).

The Sorensen coefficients of similarity showed highest similarity of woody species composition between Oda Haro PA and Ongobo Bakanisa PA than for the other combinations of the study sites in entire land use system (Table 6).

Table 6. Sorenson similarity percentage in woody species composition among study site in entire land use system.

Study sites	Wayu Kumba PA	Oda Haro PA	Ongobo Bakanisa PA	Uke Badiya PA
Wayu Kumba PA	-	36.1	35.3	30.1
Oda Haro PA	-	-	40.5	34.9
Ongobo Bakanisa PA	-	-	-	36.1
Uke Badiya PA				-

4.1.3. Density, dominance, frequency and importance value index across the study sites.

In Wayu Kumba PA study site it was assessed a total of 9.67 ha (16.2% of total area of entire land use of all study sites) and recorded a total abundance of 4608 woody species/ 476 woody species ha^{-1} and richness of 41 woody species out of 82 woody species recorded all land use system of the study sites.

Analysis of the relative density indicated that *Vernonia amygdalina, Justicia schimperiana, Eucalyptus camaldulensis ad Ricinus communis* were the four most abundant species and constituted about 77.24% of the total density (Figure 5). Hence, *Vernonia amygdalina, Croton macrostachyus, Ricinus communis and Cordia africana* were the frequently occurring species and dominant species were indicated *Eucalyptus camaldulensis, Croton macrostachyus, Vernonia amygdalina, Albizia gummifera and Olea europaea* were the most dominant woody species. To evaluate the IVI of woody species was estimated in Wayu Kumba PA entire land use system. Accordingly, *Eucalyptus camaldulensis, Vernonia amygdalina, Croton macrostachyus, Justicia schimperiana and Ricinus communis,* were the five top importance woody species among the 32 woody species that recorded in entire land use system of at Wayu Kumba PA (Appendix Table 2).

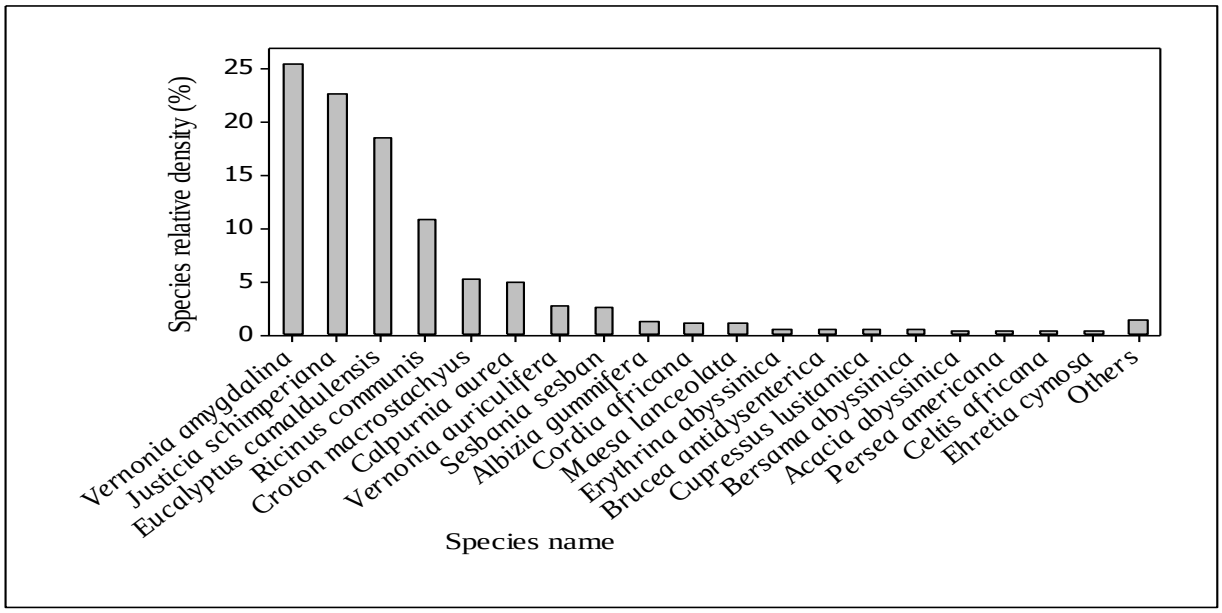


Figure 5. Species relative density at Wayu Kumba PA in entire land use system

In Oda Haro PA study site it was assessed a total of 21.26 ha (35.6% of total area of entire land use of all study sites) and recorded a total abundance of 2829 woody species/133 woody species ha^{-1} and richness of 44 woody species out of 82 woody species recorded all land use system of the study sites.

Eucalyptus camaldulensis is the most abundant woody species followed by *Vernonia amygdalina* and *Erythrina brucei* and the three most abundant and constituted about 67.87% of the total density (Figure 6). An estimate of IVI at Oda Haro PA in Bako Tibe district entire land use showed that *Eucalyptus camaldulensis* is the most importance woody species followed by *Vernonia amygdalina, Cordia africana* and *Erythrina brucei*. *Cordia africana, Croton macrostachyus, Vernonia amygdalina* and *Calpurnia aurea* are the most frequent species recorded in 34.85% and dominant species were indicated *Cordia africana, Eucalyptus camaldulensis, Ficus vasta and Erythrina brucei* were the most dominant woody species (Appendix Table 3).

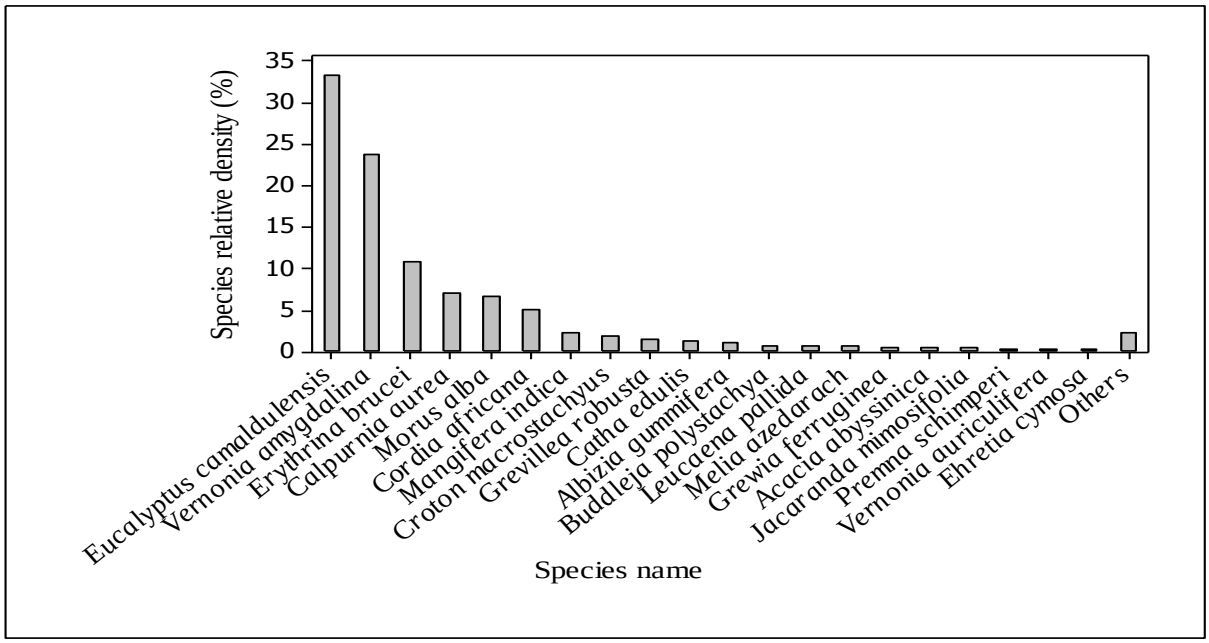


Figure 6. Species relative density at Oda Haro PA in entire land use system.

In Ongobo Bakanisa PA study site it was assessed a total of 17.23 ha (28.9% of total area of entire land use of all study sites) of entire land use system and recorded a total abundance of 3455 woody species/ 201 woody species ha^{-1} and richness 47 woody species out of 82 woody species recorded all land use system of the study sites

Analysis of the relative density showed that *Vernonia amygdalina*, *Calpurnia aurea, Eucalyptus camaldulensis* and *Sesbania sesban* were the four most abundant species and constitute about 73.86% of the total density (Figure 7). Hence, *Cordia africana, Vernonia amygdalina, Croton macrostachyus, Mangifera indica, Eucalyptus camaldulensis and Calpurnia aurea* were the frequently occurring species. The dominant species were indicated *Eucalyptus camaldulensis, Cordia africana, Ficus vasta, Ficus sycomorus* and *Vernonia amygdalina* were the most dominant woody species. To evaluate the IVI of woody species was estimated in Ongobo Bakanisa PA entire land use system. Accordingly, *Eucalyptus camaldulensis, Vernonia amygdalina, Cordia africana, Calpurnia aurea*, *Sesbania sesban* and *Croton macrostachyus* were the six top importance woody species among the 47 woody

species that recorded in entire land use system of at Ongobo Bakanisa PA (Appendix Table 4).

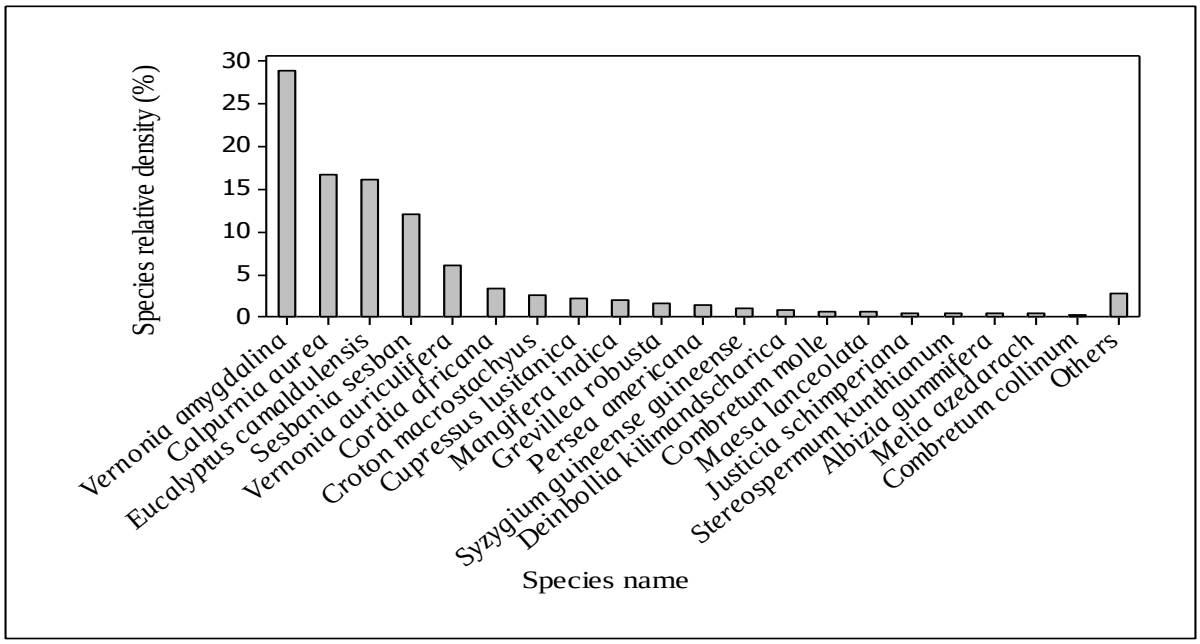


Figure 7. Species relative density at Ongobo Bakanisa PA entire land use system

In Uke Badiya PA study site it was assessed a total of 11.46 ha (19.2% of total area of entire land use of all study sites) of entire land use system and recorded a total abundance of 2415 woody species/ 211 woody species ha^{-1} and richness 38 woody species out of 82 woody species recorded the two land use system of the study sites.

Analyses of the relative density showed that *Jatropha curcas, Vernonia amygdalina* and *Eucalyptus camaldulensis* were the three most abundant species and constitute about 71.18% of the total density (Figure 8). Hence, *Vernonia amygdalina, Jatropha curcas, Cordia africana, Mangifera indica, Eucalyptus camaldulensis, Morus alba* and *Ricinus communis* are the most frequent species recorded in 55.76% in entire land use of Uke Badiya PA. The dominant species were indicated *Eucalyptus camaldulensis, Jatropha curcas, Mangifera indica, Vernonia amygdalina* and *Cordia africana* were the most dominant woody species. To evaluate the IVI of woody species was estimated in entire land use of Uke Badiya PA. Accordingly, *Jatropha curcas, Eucalyptus camaldulensis, Vernonia amygdalina, Cordia africana* and *Mangifera indica* were the five top importance woody species among the 38

woody species that recorded in entire land use system of at Uke Badiya PA (Appendix Table 5).

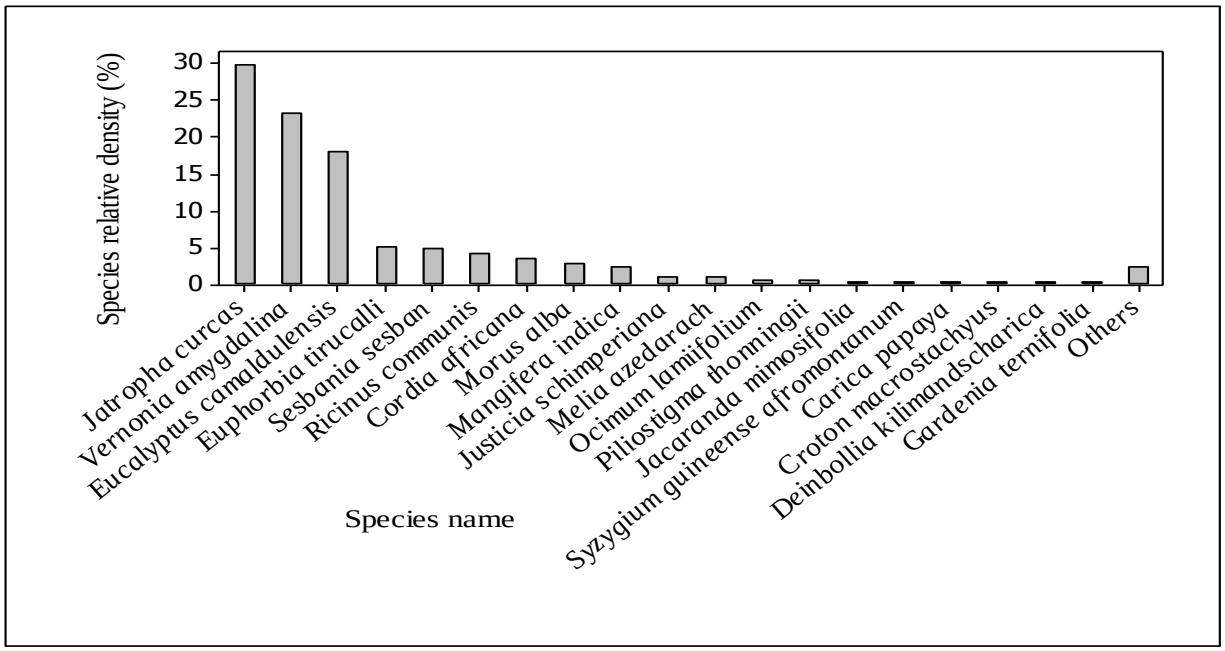


Figure 8. Species relative density at Uke Badiya PA entire land use system

The density of trees per hectare ranged from 133 to 476 with an average of 223 at entire land use system in the study sites. To compared the four study sites a high average density for Wayu Kumba PA, moderate for Uke Badiya PA and smaller for Oda Haro PA and Ongobo Bakanisa PA. The high density of trees in some farms is attributed to trees *Vernonia amygdalina* and *Eucalyptus camaldulensis* planted at very high densities on boundaries and in block arrangements. In some farms dense live fences of *Justicia schimperiana* and *Jatropha curcas*. In Sidama homegarden, Tesfaye Abebe (2005) have reported that high density of trees per hectare ranged from 86 to 1082 with an average of 475. In the Kandyan gardens of Sri Lanka, Perera and Rajapaske (1991) have reported that the number of trees with a diameter of 5 centimeters and above was 92-3736 trees ha^{-1} with 70% containing 500-1500 trees ha^{-1}. Jacob and Alles (1987) have also reported tree density of 65-1700 ha^{-1}. In the highlands of Rwanda, where ecological and demographic factors are more or less similar to the study area, an average density of 731-1689 trees ha^{-1} was reported (Biggelaar and Gold, 1996).

4.1.4. Importance value index

To evaluate the importance of each species, the IVI was estimated for the tree species recorded in the homegardens, crop fields and grazing land/pasture land use of study sites. Accordingly, *Eucalyptus camaldulensis, Vernonia amygdalina, Cordia africana, Croton macrostachyus, and Calpurnia aurea* were the five top structurally importance woody species among the 82 woody species that were recorded in the three land use system of the study sites (Appendix Table 6).

They are common and abundant because of their wide economic and ecological roles in the systems. All, except *Eucalyptus camaldulensis*, are native to the areas, where they widely occur in the remnants of the natural forests. It appears that farmers have selectively maintained more of these species in the process of transformation of the forests to agricultural landscapes, and farmers do encourage natural regeneration of these species, plant their wildlings, and in some cases propagate them.

Eucalyptus camaldulensis grows fast and produces posts and split wood that are highly demanded for housing construction. It is therefore an important cash crop for the farmers. The popularity of eucalyptus among farmers is also reported for the agroforestry systems of Sidama homegarden in Ethiopia, is present in 95% of the farms, and it consisted of 30 to 64% of the tree population at the sites, with an average of 45% .The high density and high proportion of eucalyptus in the southern Ethiopia have definitely contributed to the overall high total number of trees (Tesfaye Abebe, 2005).

Cordia africana is a very important tree in western part of Oromia, its good quality timber is widely marketed in urban areas. In also improves soil properties in cropland and rangeland ecosystems (Abebe Yadessa, 1998). Thus the socioeconomic and ecological benefits of the tree has made it popular among farmers. It is also one of the fast growing native tree species (Legesse Negash, 1995; Tesfaye Abebe, 2000).

Croton macrostachyus is very important shade tree in homegardens. In a study carried out to determine the impact of *Croton macrostachyus* on soil fertility, Yeshanew *et* al (1999) have found that the surface soils from under canopy of *Croton macrostachyus* trees had significantly higher nutrient levels than the open fields.

4.2. Woody Species Diversity in Homegardens

4.2.1. Woody species abundance, richness and diversity

A total of 67 tree and shrub species belonging to 34 families, and a total of 10,259 individuals were recorded from the homestead land use system in the study sites. From the total abundance of tree species were recorded at Wayu Kumba PA, Oda Haro, Ongobo Bakanisa PA and Uke Badiya PA are 3319, 2219, 2476 and 2246 respectively.

The large number of tree and shrub species recorded 67 tree species richness with 34 family were recorded on the homesteads/homegardens puts them among the agroecosystems of different land use system that are rich in tree species. Earlier studies on tree species richness of homegardens have reported, 64 woody species for Arsi Negelle district, Ethiopia (Motuma Tolera, 2006), 120 woody species for Sidama homegarden in Ethiopia (Tesfaye Abebe, 2005), 53 woody species for Chagga homegardens in Tanzania (Fernandes *et* al., 1984), 69 for the compound farms of Nigeria (Okafor and Fernandes, 1987), 77 for Kandy in Srilanka (Perera and Rajapakse, 1990), 83 for Nicaragua (Mendez *et* al., 2001), 129 for Kerala in India (Kumar *et* al., 1994), 168 for Peruvian Amazon (Padoch and Jong, 1991) and 179 for West Java (Soemarwoto, 1987). The number of tree species in study sites medium to most of these figures, but the sampling methodologies employed were different.

The 10 most dominant species contain 88.1% of all the trees that were encountered, although they only constitute 14.9% of the species (Table 7). Most of the dominant species are indigenous, although the most dominant species, *Vernonia amygdalina*, is an indigenous species.

Table 7. The ten most abundant species and their relative proportions in the homesteads/homegardens land use system in the study sites.

Species	Rank	Abundance	Density/ha	% total number	Accumulated %
Vernonia amygdalina	1	3370	175.2	32.8	32.8
Eucalyptus camaldulensis	2	1558	81.0	15.2	48.0
Justicia schimperiana	3	1069	55.6	10.4	58.5
Jatropha curcas	4	722	37.5	7.0	65.5
Ricinus communis	5	593	30.8	5.8	71.3
Sesbania sesban	6	572	29.7	5.6	76.8
Cordia africana	7	315	16.4	3.1	79.9
Erythrina brucei	8	306	15.9	3	82.9
Calpurnia aurea	9	277	14.4	2.7	85.6
Morus alba	10	258	13.4	2.5	88.1
Others (57 species)		1219	63.4	11.9	100

The woody species abundances has shown that *Vernonia amygdalina*, which scored the highest abundance for animal feed, is the most preferred woody species among the studied households in study sites (Table 7). *Eucalyptus camaldulensis* was the next tree species with the highest abundance and very important species for construction wood, fuelwood and income the top ranking priorities of the community in the study sites. Similar results were reported by Alemayehu Duguma and Hager (2009) *Vernonia amygdalina* and *Eucalyptus camaldulensis* species used for animal feed and house construction wood respectively are the scarcest forest products in markets? The two woody species are also characterized by their fast growing habit and preferred among the studied households because of their ability for repetitive coppicing which reduces the costs of establishing new trees. *Vernonia amygdalina* is often grown as boundary planting on farm borders or as live fencing to homesteads. Following the above two woody species, *Justicia schimperiana* (one of the ideal species for life fencing), *Jatropha curcas, Ricinus communis and Sesbania sesba* (second abundance woody species for livestock feed) and next to five woody species with high abundance in homestead niche of the study sites.

The total number of woody species recorded (species richness) at homesteads/homegardens land use system of the study sites of Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 32, 36, 39 and 29 respectively (Figure 9).

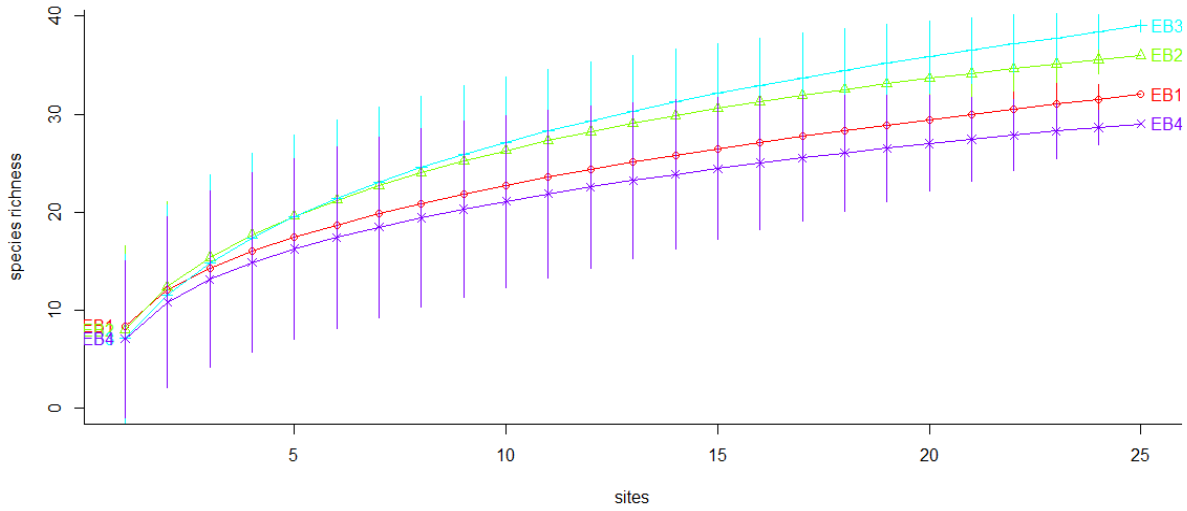


Figure 9. Species accumulation curves (site-based accumulation) for the homesteads/homegardens land use of separate study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

The same methodology of species accumulation curves was used to compare species richness between the various locations (Figure 9). Species richness is greatest in the Ongobo Bakanisa PA (EB3) location, and lowest in the Uke Badiya PA (EB4). A ranking of the other locations can also be observed: for example, study sites can be ranked as EB3 > EB2 > EB1 > EB4.

The previous species accumulation curves did not consider differences in total farm size of the various study sites. When farms are scaled by this criterion, a different pattern was observed (Figure 10). Farm size differences did have a large influence on the differences in species richness as different patterns are observed (Figure 10). Location Oda Haro PA (EB2), however, shows a larger richness for different area sampled than for equal number of farms sampled.

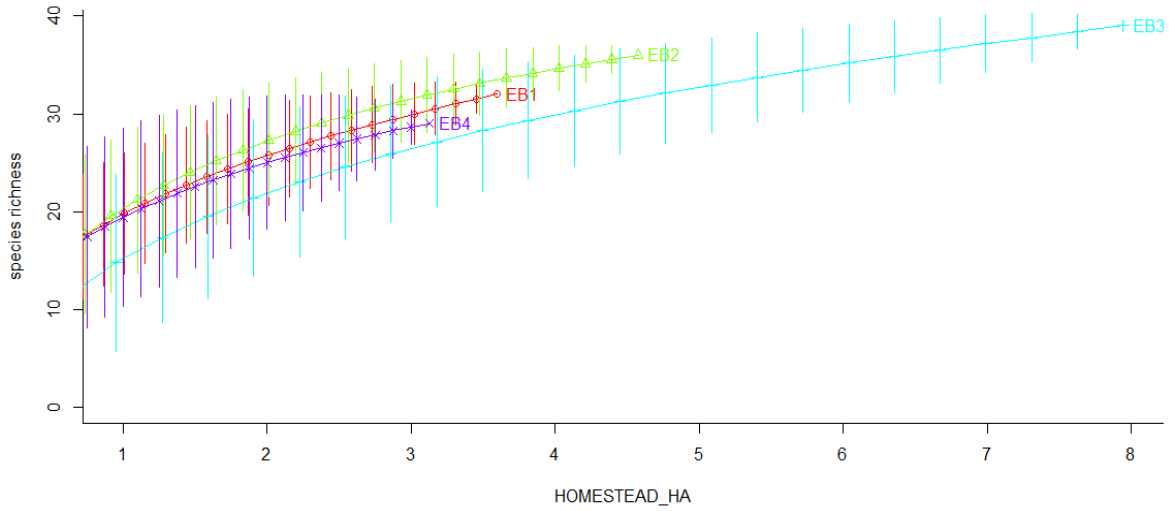


Figure 10. Species accumulation curves for the study sites. The horizontal axis is scaled on the farm sizes recorded for each farm.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

When considering differences in total number of individuals per farm (Figure 11), Uke Badiya PA in Guto Gida district does not obtain the lowest species richness as in previous figures (Figures 9). Oda Haro PA (EB2) has the highest richness at scales in figures (Figures 9). Ongobo Bakanisa PA (EB3) had relatively high levels of species richness in figures 9 showed highest levels in figures (Figure 11).

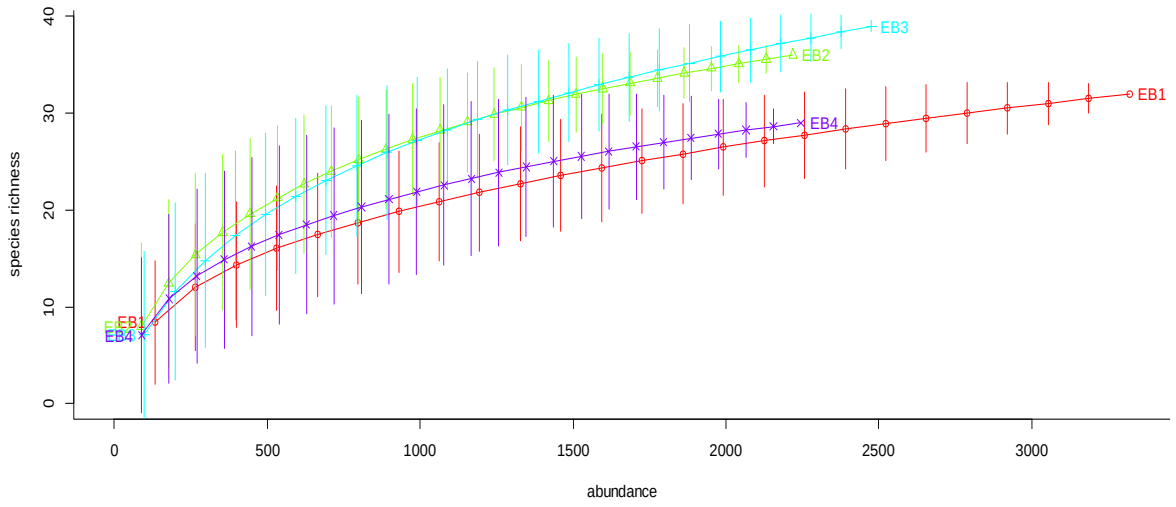


Figure 11. Species accumulation curves for the study sites. The horizontal axis is scaled by the number of trees recorded for each farm.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

Shannon diversity index at homesteads/homegardens land use system level of the farm land assessed showed the highest value Oda Haro PA, Uke Badiya PA, Ongobo Bakanisa PA and Wayu Kumba PA in descending order which is associated with the high evenness in the abundance of species at Oda Haro PA as compared to the other three study sites (Table 8).

Table 8. Diversity indices of tree species diversity in homesteads/homegardens land use system of the study sites.

Study sites	Shannon diversity index	Species Evenness
Wayu Kumba PA	1.80	0.519
Oda Haro PA	2.13	0.596
Ongobo Bakanisa PA	1.94	0.530
Uke Badiya PA	1.95	0.579

Rènyi diversity profiles showed study site Ongobo Bakanisa PA having the highest number of species; followed by Oda Haro PA, Wayu Kumba PA and the least were Uke Badiya PA (Figure 12b). Rènyi evenness profiles intersected (Figure 12a) hence the four study site could not be ranked based on trees counts from the least to the most evenly distributed.

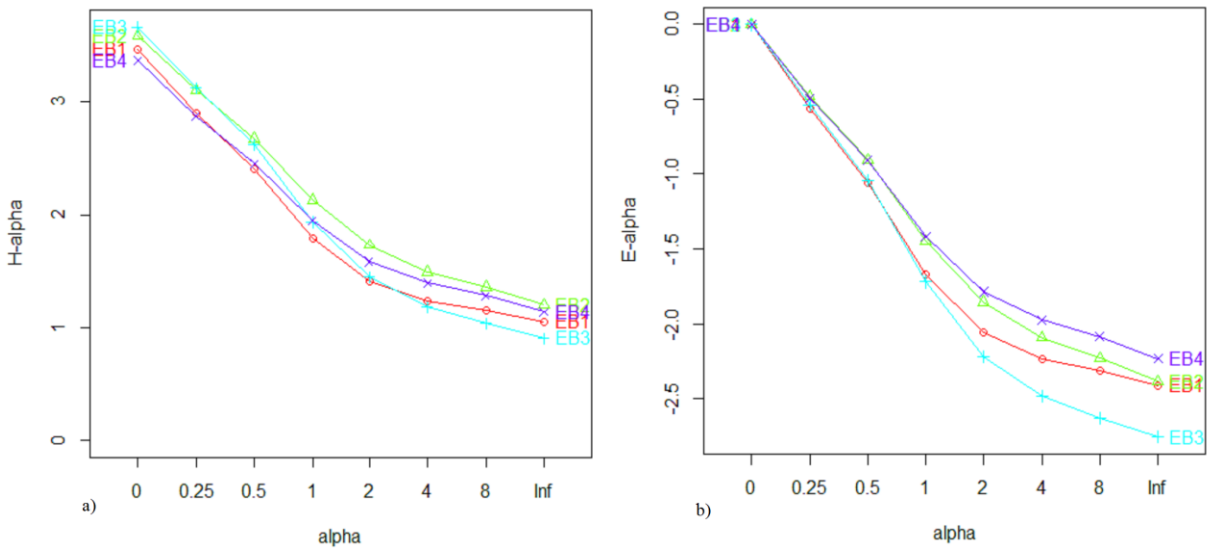


Figure 12. Homesead land use system **Rènyi** diversity profile (a) and **Rènyi** evenness profile (b) for the study sites
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA in Guto Gida district

The diversity indices for tree species generally showed that few species are more abundant than the others. The evenness (E) values of the species between 0.519 and 0.596 indicated dominance of some tree species in homestead land use of the study sites. The evenness values obtained here are comparable to values reported by Tesfaye Abebe (2005) for the homegarden of Sidama Evenness values of 0.37 to 0.64, Kumar *et al*. (1994) for the homegardens of Kerala where Evenness values ranged from 0.24 to 0.71 and Kaya *et al*. (2002) have reported high Evenness values of 0.71 to 0.91 for the forest gardens of Central Maluku, Indonesia, but the sampling methodologies employed were different.

4.2.3. Importance value index in homesteads/homegardens

To evaluate the importance of each species, the IVI was estimated for the woody species recorded in the homegardens land use of the study sites. Accordingly, *Vernonia amygdalina*, *Eucalyptus camaldulensis*, *Cordia africana*, *Croton macrostachyus* and *Mangifera indica* were the five top importance woody species among the 67 woody species that recorded in homesteads/homegardens land use system of the study sites (Appendix Table 7).

In total 67 woody species were recorded in homegardens/homesteads land use system in the study sites. Frequency of occurrence of species across homesteads/homegardens land use system of the study sites was variable (figure 10), but four woody species occurred over 40 out of 100 homegardens *Vernonia amygdalina* was the most frequent species occurring in (84%) of the farms homestead. It followed by *Cordia africana* (73%), *Eucalyptus camaldulensis* (54%), *Croton macrostachus* (53%), *Mangifera indica* (45%) and *Calpurnia aurea* (40%). On the other hand, 15 woody species were very rare each occurring only in one of the homestead. Out of the total number of species, only 31.34% were exotic while the remaining 68.66 % were indigenous.

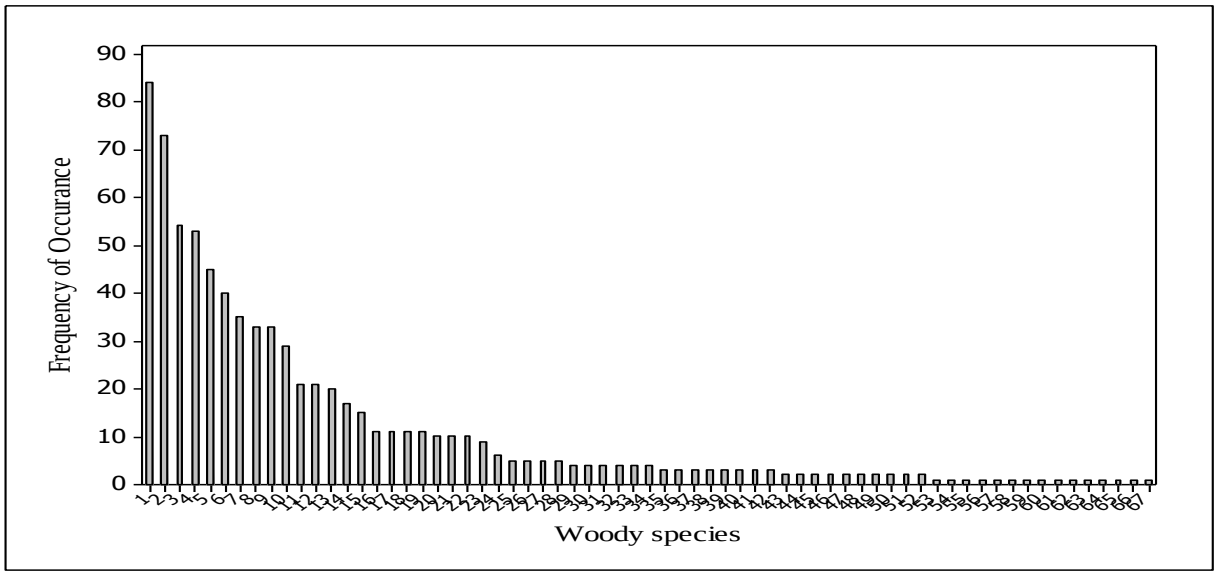


Figure 13. Frequency distribution of the woody species across homestead farms (n=100)

4.3. Woody Species Diversity in Crop field

4.3.1. Woody species abundance, richness and diversity index

To asses woody species in crop field from selected 20 farmers only 18 farmers have crop field and add each plot of crop field a total of 34.93 ha from those to assess the crop fields size of each study area of Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa and Uke Badiya PA are 5.19 ha, 14.35 ha, 7.03 ha and 8.36 ha respectively.

A total of 1,886 abundance and 52 woody species richness were recorded in the crop field of the selected farmers in the study site. From the total abundance of tree species were recorded at Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 1128, 529, 59 and 170 respectively.

The 10 most dominant species contain 90% of all the trees that were encountered, although they only constitute 19.23% of the species (Table 9). Most of the dominant species are exotic species and the most dominant species, *Eucalyptus camaldulensis*, is an exotic species and accounted for 60.4% of all woody species counts in the crop field land use system of the study sites.

Table 9. Abundances (numbers of trees) for the 10 most dominant species in the crop field land use system in the study sites.

Species	Rank	Abundance	Density/ha	% total number	Accumulated %
Eucalyptus camaldulensis	1	1140	32.64	60.4	60.4
Calpurnia aurea	2	157	4.49	8.3	68.8
Croton macrostachyus	3	88	2.52	4.7	73.4
Sesbania sesban	4	75	2.15	4.0	77.4
Cordia africana	5	55	1.57	2.9	80.3
Vernonia auriculifera	6	43	1.23	2.3	82.6
Maesa lanceolata	7	40	1.15	2.1	84.7
Albizia gummifera	8	35	1.00	1.9	86.6
Catha edulis	9	33	0.94	1.7	88.3
Vernonia amygdalina	10	10	0.92	1.7	90.0
Others (42 species)		210	6.01	10	100

The total number of woody species recorded (species richness) at crop field area of Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 26, 21, 16 and 19 respectively.

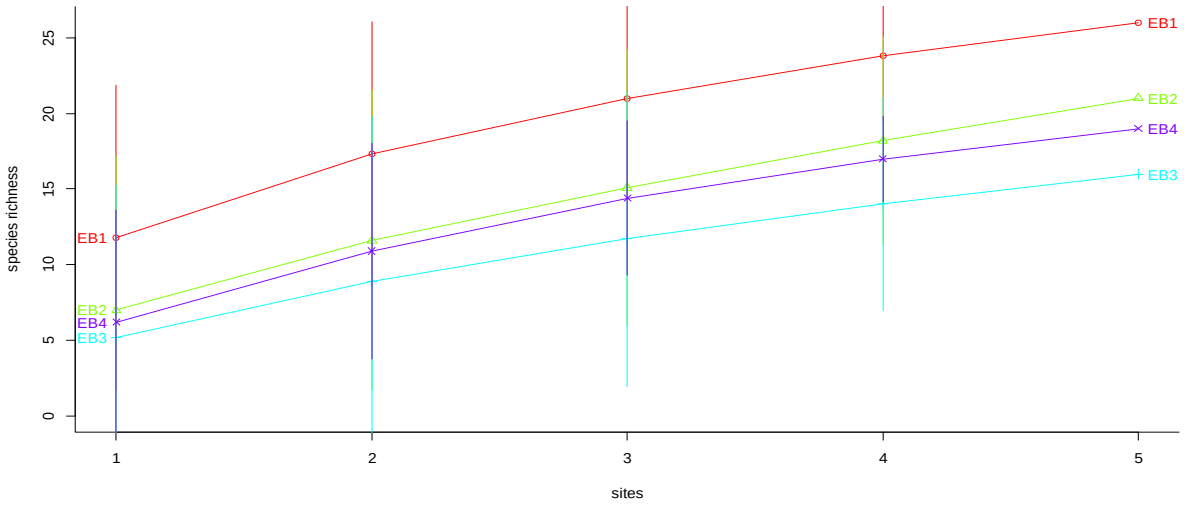


Figure 14. Species accumulation curves (site-based accumulation) for the Crop field of separate study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

The same methodology of species accumulation curves was used to compare species richness between the various locations (Figure 16). Species richness is greatest in the Wayu Kumba PA (EB1) location, and lowest in the Ongobo Bakanisa PA (EB3). A ranking of the other locations can also be observed: for example, study sites can be ranked as EB1 > EB2 > EB4 > EB3.

The previous species accumulation curves did not consider differences in total farm size of the various study sites. When farms are scaled by this criterion, a different pattern was observed (Figure 17). Farm size differences did have a large influence on the differences in species richness as different patterns are observed (Figure 17). Location Oda Haro PA (EB2), however, shows a smallest richness for different area sampled than for equal number of farms sampled.

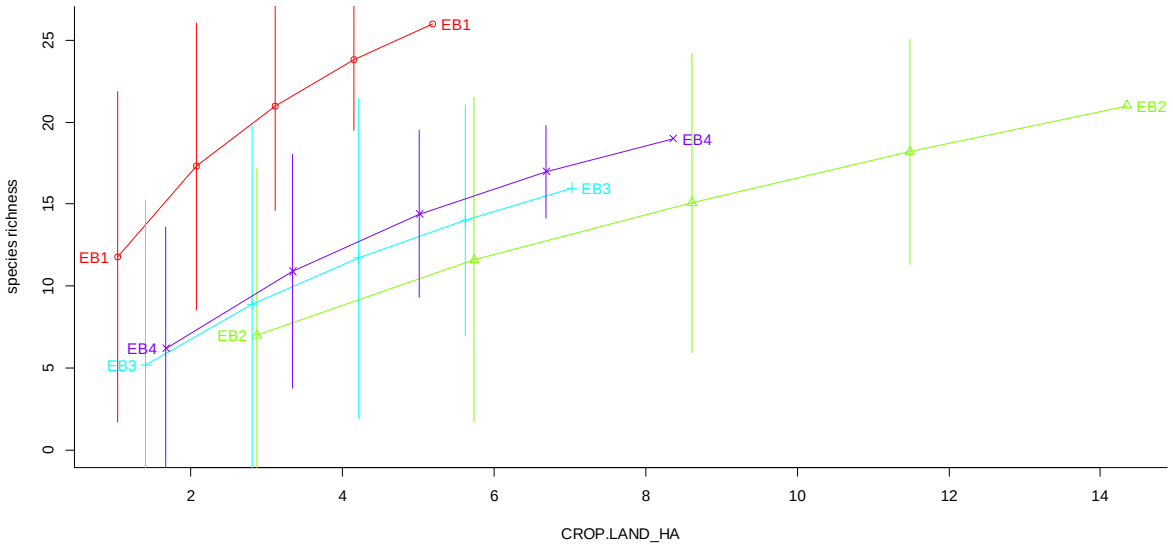


Figure 15. Species accumulation curves for the study sites. The horizontal axis is scaled on the farm sizes recorded for each farm.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

When considering differences in total number of individuals per farm (Figure 18), Wayu Kumba PA (EB1) does not obtain the lowest species richness as in previous figures (Figures 16 and 17) but it obtains lowest species richness in total number of individual per farm.

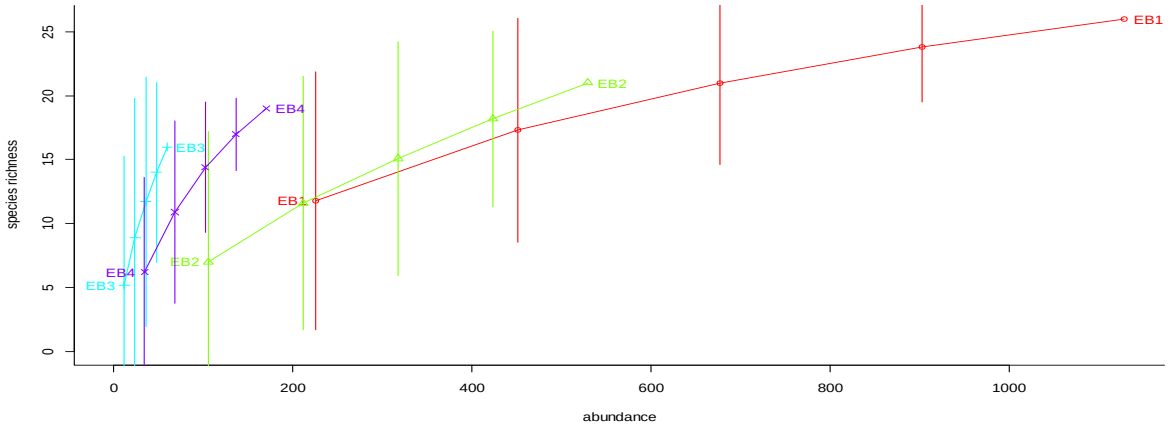


Figure 16. Species accumulation curves for the study sites. The horizontal axis is scaled by the number of trees recorded for each farm.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

Shannon diversity index at crop field use system level of the farm land assessed showed the highest value Ongobo Bakanisa PA, Uke Badiya PA, Wayu Kumba PA and Oda Haro PA in descending order which is associated with the high evenness in the abundance of species at Ongobo Bakanisa PA as compared to the other three study sites (Table 10).

Table 10. Diversity indices of tree species diversity in crop field land use system of the study sites.

Study sites	Shannon diversity index	Species Evenness
Wayu Kumba PA	1.47	0.450
Oda Haro PA	1.06	0.349
Ongobo Bakanisa PA	2.44	0.879
Uke Badiya PA	2.07	0.703

Rènyi diversity profiles showed study site Wayu Kumba PA having the highest number of species; followed by Oda Haro PA, Uke Badiya PA and the least were Ongobo Bakanisa PA (Figure 19a). Rènyi evenness profiles intersected (Figure 19b) and hence the four study site showed Ongobo Bakanisa PA having the most evenly distributed followed by Uke Badiya PA, Oda Haro PA and the least were Wayu Kumba PA.

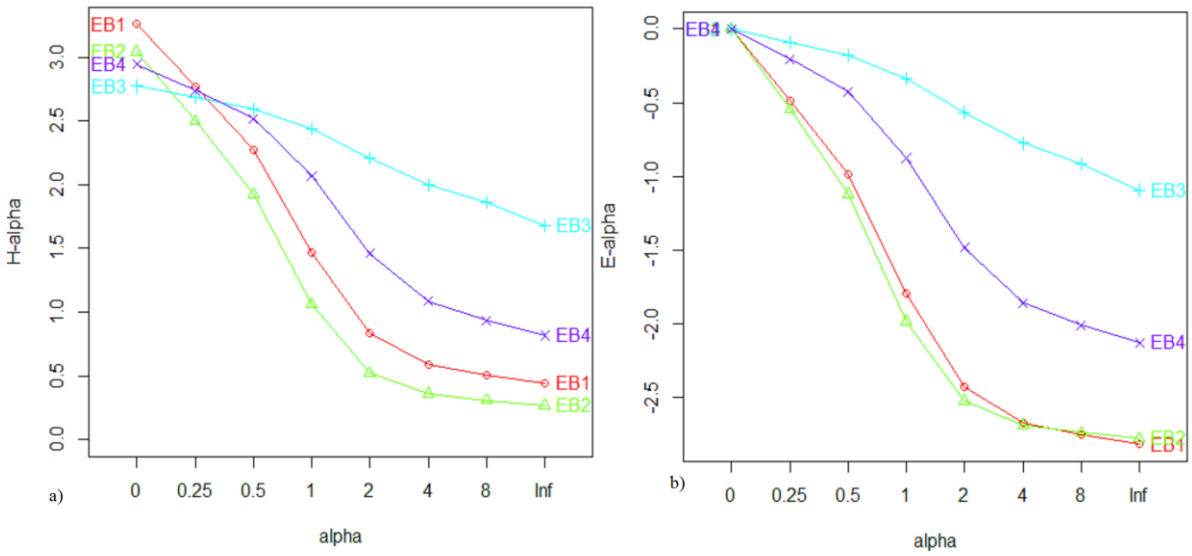


Figure 17. Crop field land use system **Rènyi** diversity profile (a) and **Rènyi** evenness profile (b) for the study sites
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

4.3.3. Importance value index

To evaluate the importance of each species, the IVI was estimated for the woody species recorded in the crop field of the study site. Accordingly, *Eucalyptus camaldulensis, Croton macrostachyus, Cordia africana, Albizia gummifera* and *Calpurnia aurea* were the five top importance woody species among the 52 tree species that recorded in crop field land use system of the study sites (Appendix Table 8).

Frequency of occurrence of species across crop field land use system of the study sites was variable (figure 20), but four woody species occurred over 13 out of 18 crop field *Cordia africana* was the most frequent species occurring in (72%) of the farms crop field. It followed by *Croton macrostachus* (66.7%), *Albizia gummifera* (55.6%), *Eucalyptus camaldulensis* (44.4%), *Stereospermum kunthianum* (38.9%), *Vernonia amygdalina* (38.9%) and *Syzygium guineense (Willd.) DC. Subsp. guineense* (33%). On the other hand, 24 woody species were very rare each occurring only in one of the crop field of the household. Out of the total number of species, only 13.46% were exotic while the remaining 86.54% were indigenous.

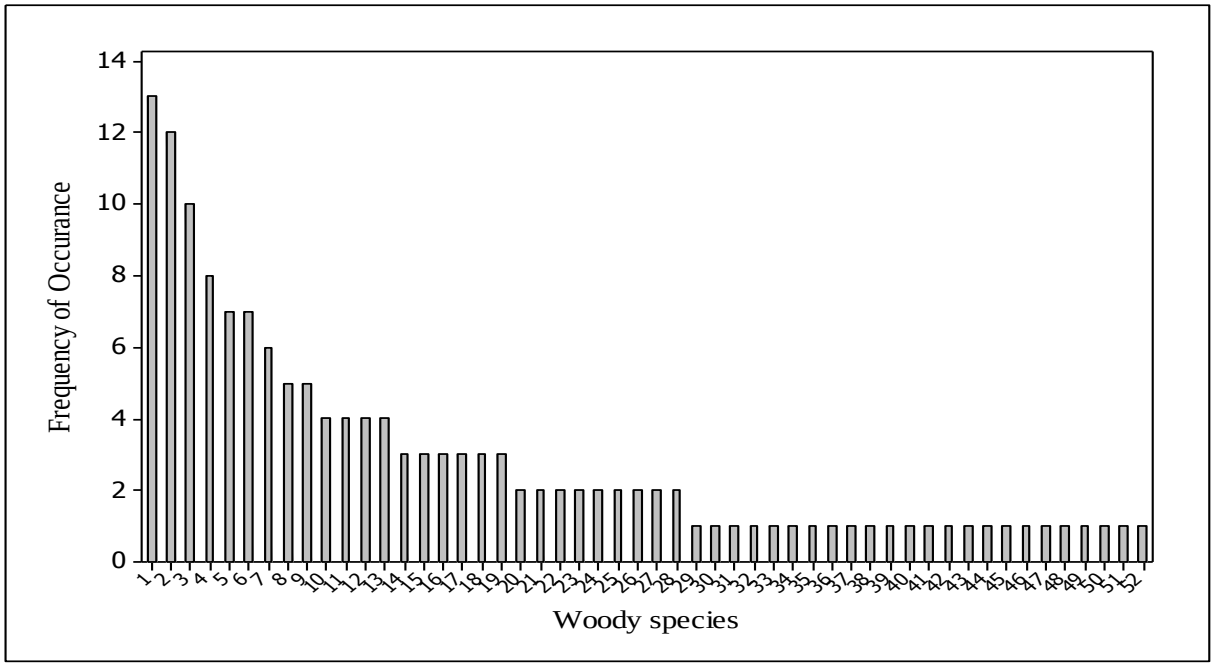


Figure 18. Frequency distribution of the woody species across crop field farms.

4.4. Woody Species Diversity in Grazing/Pasture Land

4.4.1. Woody species abundance, richness and diversity index

To asses woody species in grazing land from selected 20 farmers only 11 farmers have grazing/pasture land and add each plot of grazing land a total of 5.5 ha from those to assess the grazing/pasture land size of each study area of Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 0.875 ha, 2.31 ha, 2.31 ha and 0 ha (from the selected farmers in this sites haven't grazing land) respectively.

A total of 1162 abundance and 29 woody species richness were recorded in the grazing/ pasture land use system of the selected farmers in the study site. From the total abundance of tree species were recorded at Wayu Kumba PA, Oda Haro PA , Ongobo Bakanisa PA and Uke Badiya PA are 161, 81, 920 and 0 (from the selected farmers no farmers have grazing land) respectively. The 10 most dominant species contain 93.40 % of all the trees that were encountered, although they only constitute 34.48% of the species (Table 11). Most of the dominant species are indigenous species and the most dominant species, *Calpurnia aurea*, is an indigenous species and accounted for 48.4% of all woody species counts in the grazing/pasture land use system of the study area.

Table 11. Abundances (numbers of trees) for the 10 most dominant species in the grazing/pasture land use system in the study sites.

Species	Rank	Abundance	Density/ha	% total number	Accumulated %
Calpurnia aurea	1	562	102.27	48.4	48.4
Vernonia auriculifera	2	218	39.67	18.8	67.1
Croton macrostachyus	3	122	22.20	10.5	77.6
Eucalyptus camaldulensis	4	93	16.92	8.0	85.6
Syzygium guineense (Willd.) DC. Subsp. guineense	5	26	4.73	2.2	87.9
Deinbollia kilimandscharica	6	20	3.64	1.7	89.6
Albizia gummifera	7	12	2.18	1.0	90.6
Combretum molle	8	11	2.00	0.9	91.6
Cordia Africana	9	11	2.00	0.9	92.5
Bersama abyssinica	10	10	1.82	0.9	93.4
Others (19 species)		1085	197.5	6.7	100

The total number of woody species recorded (species richness) at grazing/pasture land use system of Wayu Kumba PA, Oda Haro PA, Ongobo Bakanisa PA and Uke Badiya PA are 12, 13, 23 and 0 (from the selected farmers no farmers have grazing land) respectively.

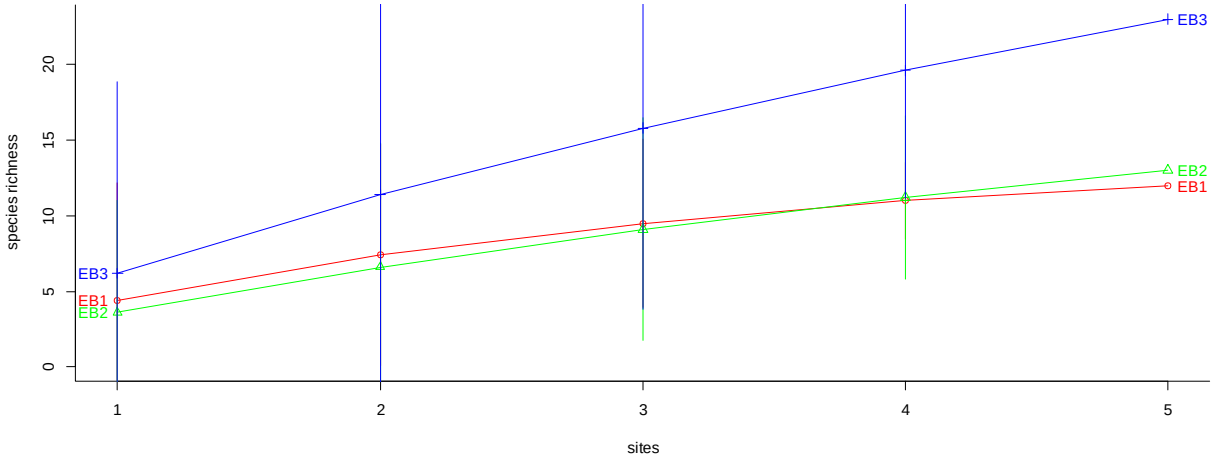


Figure 19. Species accumulation curves (site-based accumulation) for the grazing/pasture land of separate study area.

Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3= Ongobo Bakanisa PA and EB4=Uke Badiya PA.

The same methodology of species accumulation curves was used to compare species richness between the various locations (Figure 19). Species richness is greatest in the Ongobo Bakanisa PA (EB3) location, and lowest in the Wayu Kumba PA (EB1). A ranking of the other locations can also be observed: for example, study areas can be ranked as EB3 > EB2 > EB1.

The previous species accumulation curves did not consider differences in total farm size of the various study area. When farms are scaled by this criterion, a different pattern was observed (Figure 20). Farm size differences did have a large influence on the differences in species richness as different patterns are observed (Figure 20). Location Oda Haro PA (EB2), however, shows a smallest richness for different area sampled than for equal number of farms sampled.

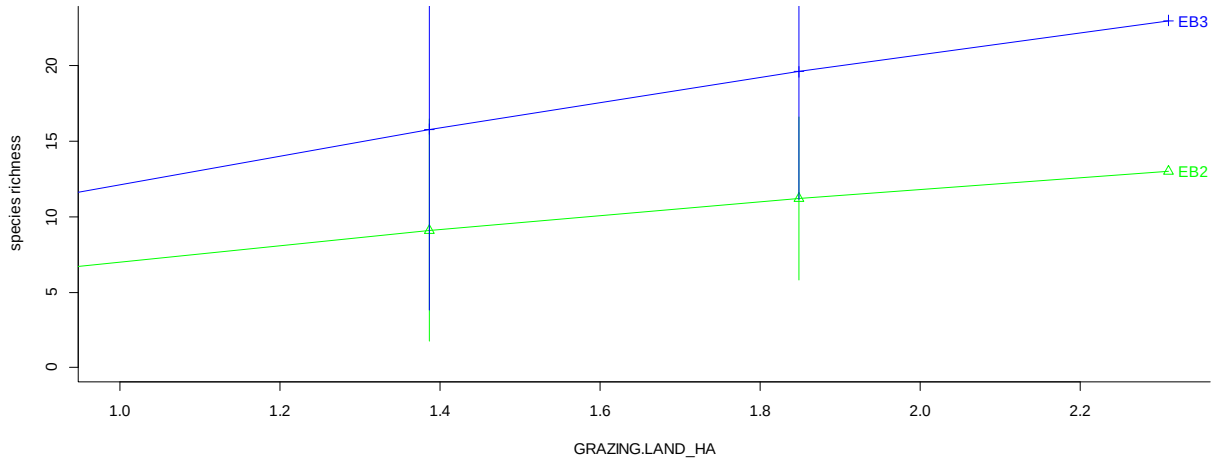


Figure 20. Species accumulation curves for the various study area. The horizontal axis is scaled on the farm sizes recorded for each farm.

Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

Shannon diversity index in grazing/pasture land use system level of the farm land assessed showed the highest value Oda Haro PA, Wayu Kumba PA, Ongobo Bakanisa PA, in descending order which is associated with the high evenness in the abundance of species at Oda Haro PA as compared to the other three study sites (Table 12).

Table 12.Diversity indices of tree species diversity in grazing/pasture land use system of the study sites.

Study sites	Shannon diversity index	Species Evenness
Wayu Kumba PA	1.60	0.642
Oda Haro PA	1.82	0.709
Ongobo Bakanisa PA	1.53	0.487

Rènyi diversity profiles showed study site Ongobo Bakanisa PA having the highest number of species; followed by Oda Haro PA and the least were Wayu Kumba PA (Figure 21a). Rènyi evenness profiles (Figure 21b) and hence the four study site showed Oda Haro PA having the most evenly distributed followed by Wayu Kumba PA and the least were Ongobo Bakanisa PA.

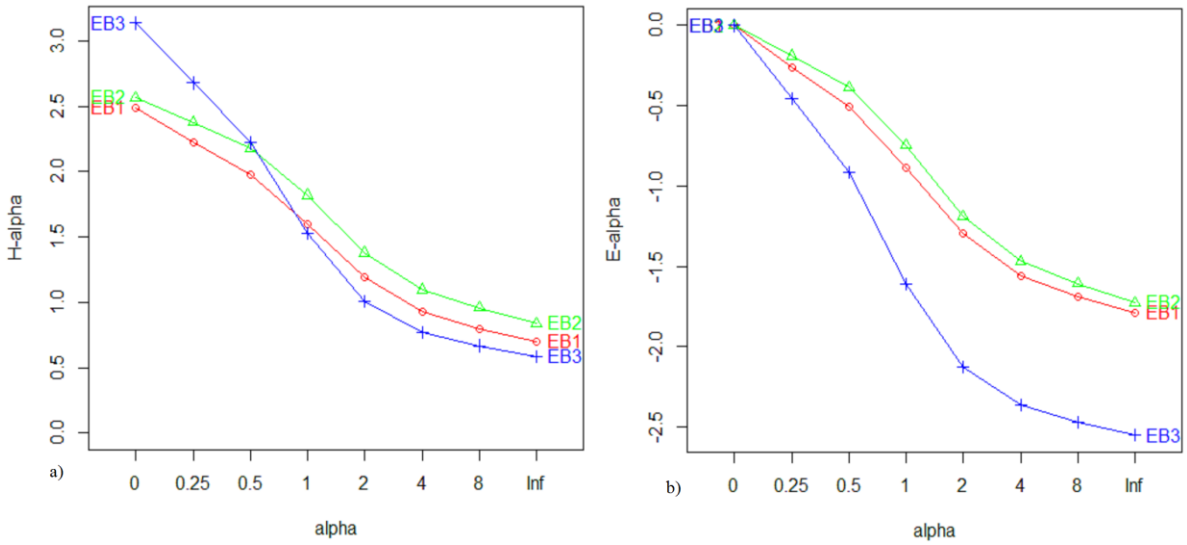


Figure 21. Grazing/pasture land use system **Rènyi** diversity profile (a) and **Rènyi** evenness profile (b) for the four study sites

Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA and EB3=Ongobo Bakanisa PA.

4.4.4. Importance value index

To evaluate the importance of each species, the IVI was estimated for the woody species recorded in the grazing/pasture land use of the study site. Accordingly, *Calpurnia aurea, Croton macrostachyus, Vernonia auriculifera, Eucalyptus camaldulensis and Ficus vasta* were the five top importance tree species among the 29 woody species that recorded in grazing/pasture land use system of the study sites (Appendix Table 9).

In total 29 woody species were recorded in grazing/pasture land of assessed in 11 farmers that have crop field land use system in the study sites. Frequency of occurrence of species across the grazing/pasture land use system of the study sites was variable (Figure 28), but four woody species occurred over 30 out of 11 grazing/pasture land *Croton macrostachyus* was the most frequent species occurring in (72.73%) of the grazing/pasture land. It followed by *Calpurnia aurea* (54.55%), *Albizia gummifera* (45.45%), *Stereospermum kunthianum* (45.45%), *Cordia africana* (36.36%). On the other hand, 12 woody species were very rare each occurring only in one of the grazing/pasture land of the household. Out of the total number of species, only 10.34% were exotic while the remaining 89.66% were indigenous.

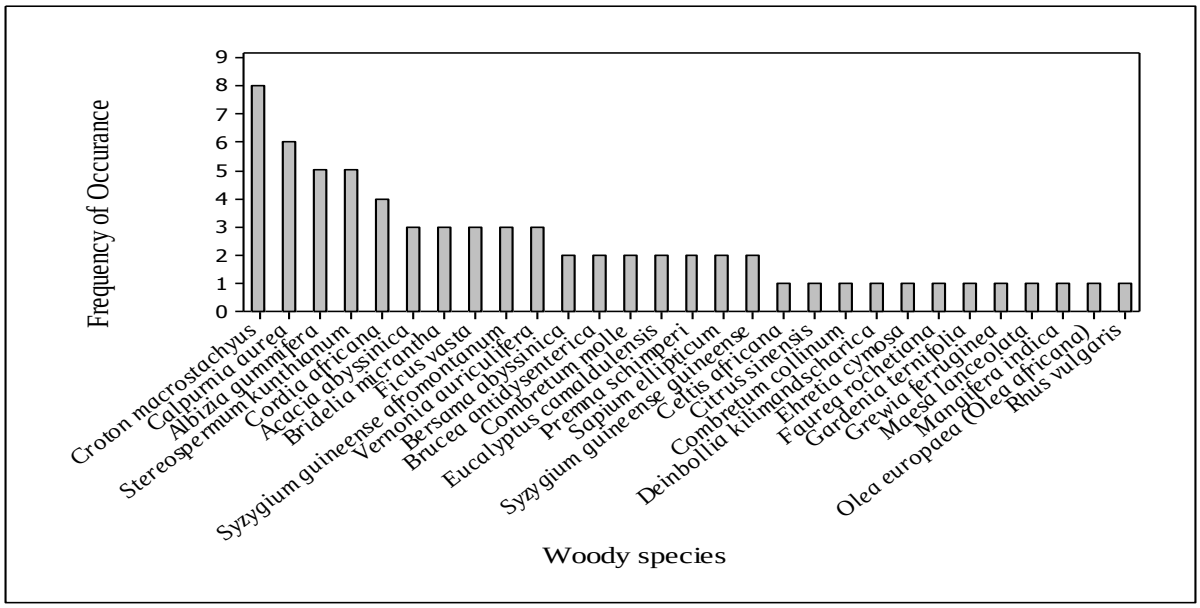


Figure 22. Frequency distribution of the woody species across grazing/pasture land farms.

4.5. The Effects of Homestead/Homegarden Characteristics on the Diversity of Woody Species

4.5.1. Area of homestead/homegarden

Species richness generally increased with the area of the homesteads/homegardens. The correlation analysis between the area of the homesteads/homegardens and tree species richness (r = 0.295) also showed the same trend (Figure 23). About 8.7% of the variations in species richness could be explained by the variations in the area of the homesteads/homegardens.

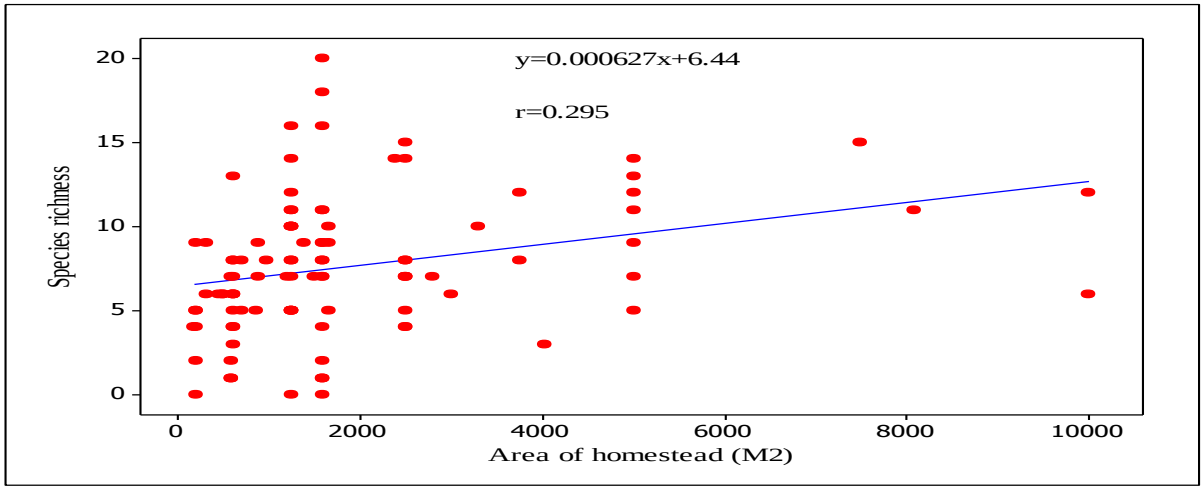


Figure 23. Regression between tree species richness and the area of the homestead land use in the study sites.

To assess the effect of homestead area of the household on the diversity of woody species in homegardens, species richness and Shannon diversity index was estimated. The positive correlation between the woody species richness and the area of the homestead/homegarden indicates that species richness increases with increasing size. Zebene Asfaw and Hulten (2003) and Tesfaye Abebe (2005) also reported a positive relationship between farm size and tree species richness per farm and a similar relationship between wealth status and farm size in southern Ethiopia.

4.5.2. Wealth status of the households

The average area of homesteads/homegardens ranged from 0.018 to 1 ha (Appendix Table 10). It showed a declining trend from rich to poor wealth class with average values of 0.28 ha, 0.21 ha, and 0.16 ha for rich, medium and poor wealth classes respectively. The sizes of homesteads/homegardens differ non-significantly between the wealth classes (P=0.05) and LSD analysis shows non-significant difference between the rich, medium and poor wealth classes.

To assess the effect of wealth status of the household on the diversity of tree species in homegardens, species richness and Shannon diversity index was estimated. The result was showed that the highest average species richness per household for medium household as compare to the rich and poor households and highest average Shannon diversity index per household for the rich households as compared to the medium and poor households. From these result indicated that both species richness (P=0.679) and Shannon diversity index (P=0.276) was non-significant difference at P=0.05 wealth status of the households.

Household wealth status did not affect the species richness and Shannon diversity index of tree species. Boffa *et al.* (2008) also stated that wealth status did not influence either the onfarm abundance or diversity of tree species around Mabira Forest reserve, Uganda. On the contrary, Jarvis *et al*. (2000) and Kindt *et al*. (2004) showed that wealth is an important socioeconomic factor influencing onfarm tree diversity and farmer choices of crop varieties respectively. Motuma Tolera (2006) showed that wealth status of the household influenced the species diversity of homegardens. The rich class was found to own more woody species diversity than the poor.

4.6. Mode of Regeneration and Niche Woody Species in the Study Sites

Woody species which are either planted or retained require different types of management. In the study area indicated that to surveyed total abundance 13,307 and 82 woody species richness were recorded from entire land use such as homegardens, crop fields and grazing/pasture land at the study area.

They owned these woody species through retention of remnant or naturally regenerated indigenous tree species and undertaking plantation activities. Accordingly, 85.6% and 18.4% from the total surveyed of 13,307 woody species abundance established through by plantation and retention respectively. Depending up the abundance (numbers of trees) of tree species *Vernonia amygdalina* is the most abundant woody species that was plantation followed by *Eucalyptus camaldulensis, Justicia schimperiana, Jatropha curcas, Sesbania sesban, Ricinus communis, Erythrina brucei, Morus alba, Calpurnia aurea, Mangifera indica, Cordia africana* and like respectively. And also from maintained tree species *Calpurnia aurea* the most abundant followed by *Vernonia auriculifera, Croton macrostachyus, Ricinus communis, Cordia africana, Albizia gummifera, Eucalyptus camaldulensis, Maesa lanceolata, Vernonia amygdalina, Syzygium guineense (Willd.) DC. Subsp. guineense, Deinbollia kilimandscharica* and like respectively. So from these farmers also both retained and plated some exotics like *Eucalyptus camaldulensis.*

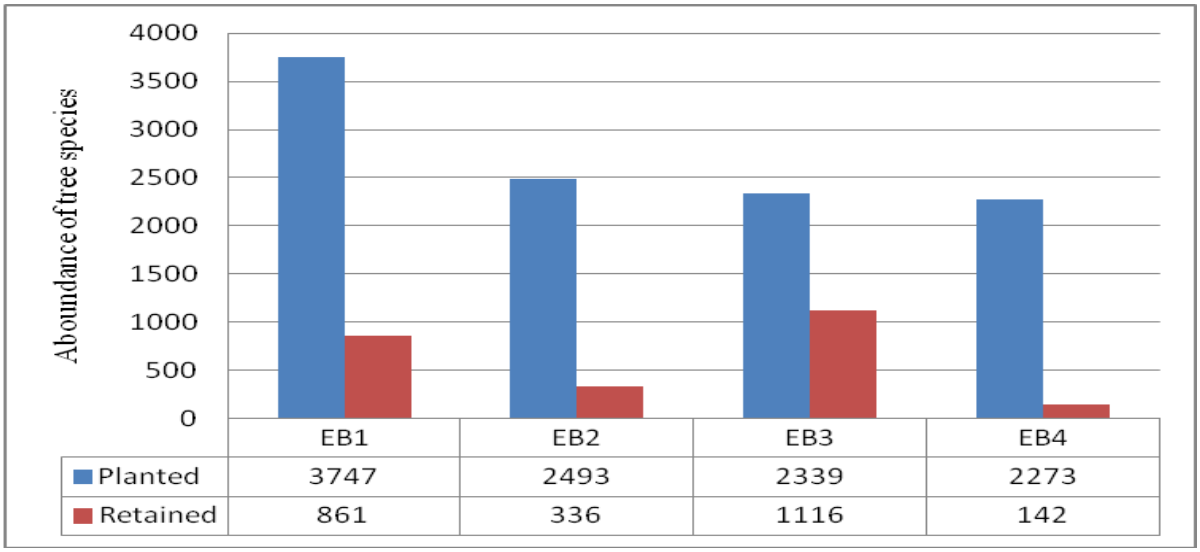


Figure 24. The mode regeneration status of woody species in the study sites
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

Woody species were recoreded in the study sites the total abundance 13,307 and 82 woody species richness from entire land such as homegardens, crop fields and grazing/pasture land use system. From those collected species farmers' planted/retained woody species in the forms of cutting, seed and seedling. Figure 25 was showed that the means of planting woody species in the form seedling 70.86%, seed 11.34% cutting 9.6% and unknown by household 8.55% from the total abundances woody species recorded in the three land use system in the surveyed sites.

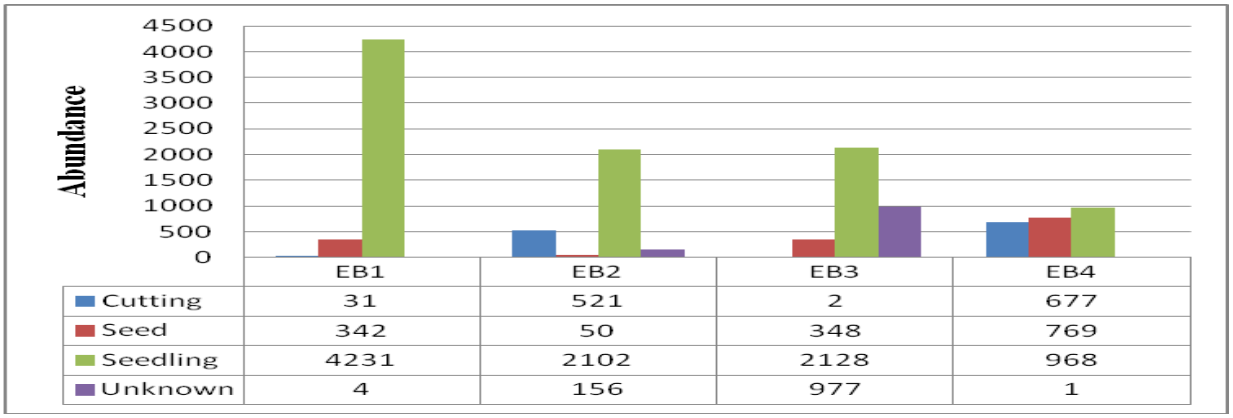


Figure 25.Means of planting woody species in the study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

Maintaining woody species in agricultural landscapes follow certain patterns of distribution and arrangements. According the results showed that different niche to maintain and planting in homesteads, crop fields and grazing/pasture are 10259 (77.1%), 1886 (14.2%) and 1162 (8.7%) respectively. From the results indicated that highest number of woody species maintaining/planting in homesteads/homegardens niche, 68.7% of which are native to the region, indicates the significant role of these systems in the conservation of genetic diversity in the study area.

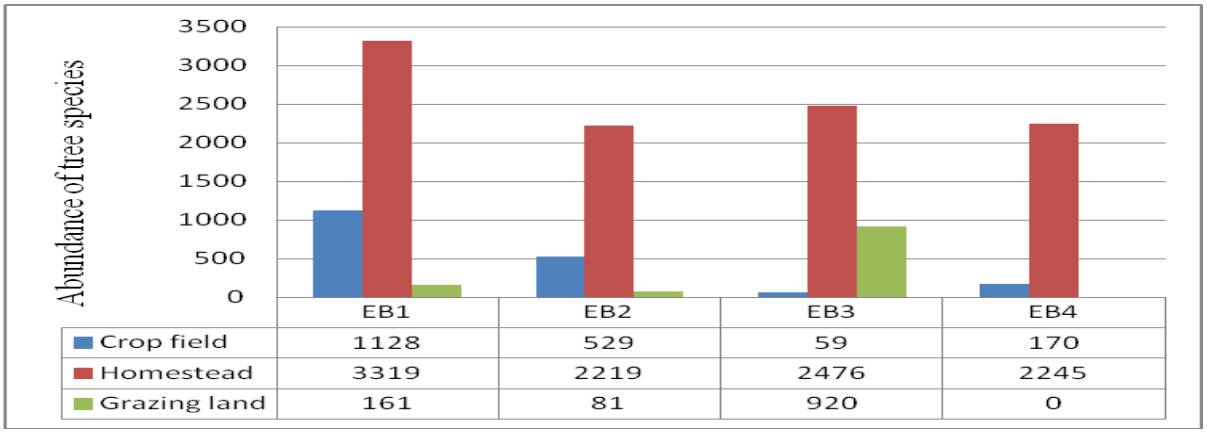
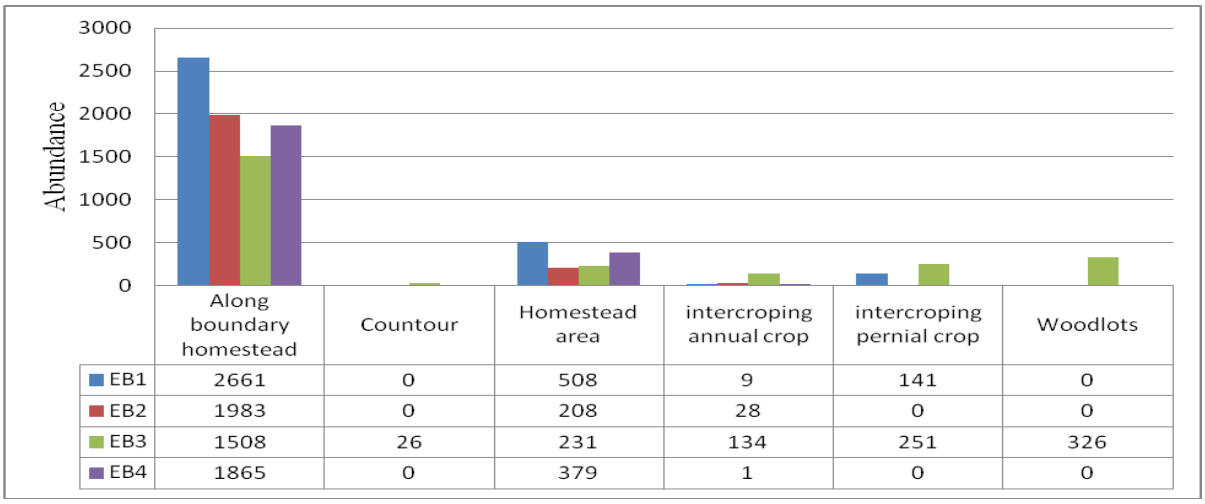


Figure 26. Different land use of woody species abundance
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

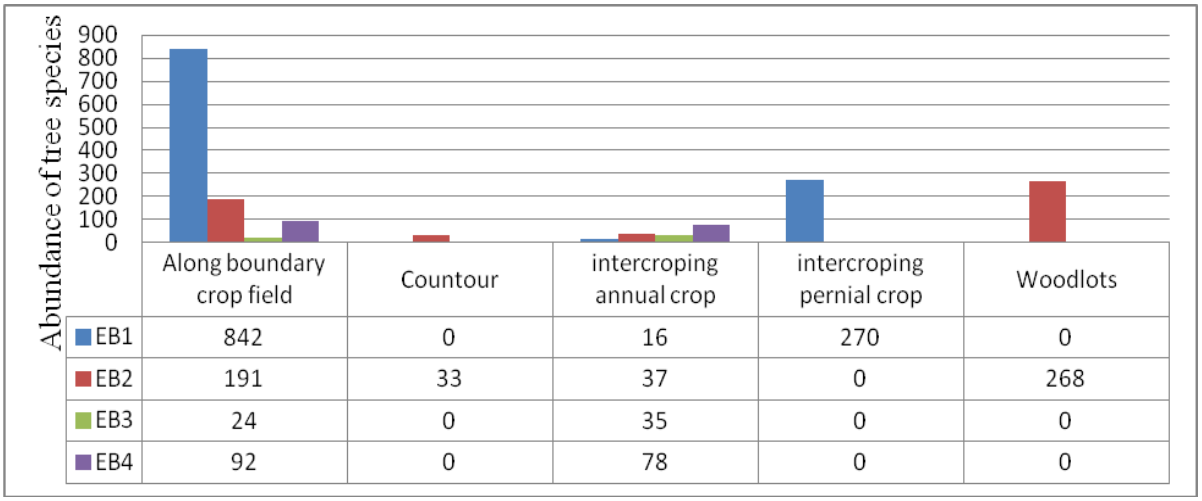
Farmers in the study area have been planting and retaining woody species in different land use system of the study area niches in different planting practices such as homestead area, planting along boundary of homestead, planting along boundary of crop field, planting along boundary of grazing/pasture land, planting with intercropping with annual crop, planting with perennial crop and wood lots. According the result showed that in homesteads/homegardens area different arrangement woody species are exist in retained and planting in different arrangement from a total abundance of tree species existed in homesteads/homegardens area 10,259 from those abundance 8017 (78.15%) along the homestead boundary, 26 (0.25%) contour planting, 1326 (12.93%) homestead area, 172 (1.68%) intercropping with annual crop, 392 (3.82%) intercropping with perennial crop and 326 (3.18%) as form of woodlots in homestead area of land use system.



	Along boundary homestead	Countour	Homestead area	intercroping annual crop	intercroping pernial crop	Woodlots
EB1	2661	0	508	9	141	0
EB2	1983	0	208	28	0	0
EB3	1508	26	231	134	251	326
EB4	1865	0	379	1	0	0

Figure 27. Tree arrangement in homestead land use system of the study sites
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

The result showed that the total abundance of 1,886 woody species existed in the cropfield in different arrangement 1149 (60.92%) along the boundary of crop field, 33 (1.75%) contour, 166 (8.80) intercropping with annual crop, 270 (14.32%) intercropping with perennial crop and 268 (14.21%) as the form of woodlots in the crop field of the land use system (Figure 28).



	Along boundary crop field	Countour	intercroping annual crop	intercroping pernial crop	Woodlots
EB1	842	0	16	270	0
EB2	191	33	37	0	268
EB3	24	0	35	0	0
EB4	92	0	78	0	0

Figure 28. Tree arrangement in crop field land use system in the study sites

Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA.

The result indicated that the total abundance 1,162 of tree species existed in the grazing/pasture land in different arrangement 1,150 (98.97%) inside grazing/pasture land and 12 (1.03%) along the boundary of grazing land in the grazing/pasture land use system of the study sites (Figure 29).

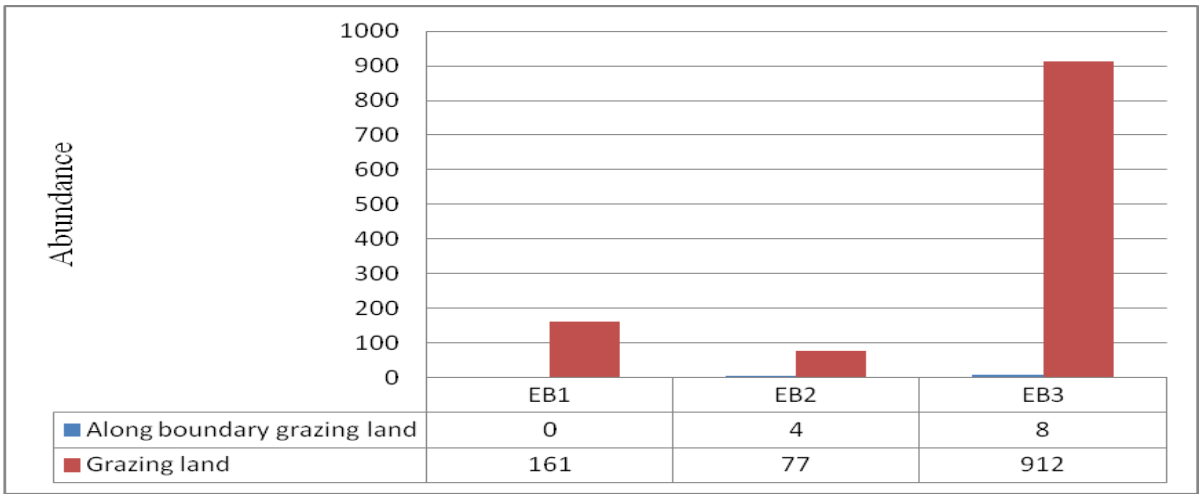


Figure 29. Tree arrangement in grazing/ pasture land use system in the study sites
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa.

Some study, (Tesfaye, 2005) indicated that high number of tree species in the homesteads/ homegardens, 83% of which are native to the region, indicates the significant role of these systems in the conservation of genetic diversity.

On-farm trees can be found in agricultural landscapes in various forms of spatial and temporal arrangements for different purposes. One of the features of on-farm tree management is that the biological characteristics of trees are often taken in to account to determine where it should be grown (Tesfaye, 2005). For instance, trees that contribute positively to agricultural crops are grown dispersed in crop fields while trees that compete with crops are planted separately in block arrangements.

Some study, (Nair, 1993) indicated that tree are planted on farms in different niches Depending on the type of ecological settings, trees will be arranged in different patterns. For example, (Arnold and Dewees,1995) have identified different patterns of planted trees on

farmlands as**:** Trees planted on non-arable or fallow land, trees grown in homestead areas, tree growing along boundaries, intercropping on arable land and mono cropping on arable lands.

4.7. Socioeconomic Characteristics of the Respondents

The total land holding size of the selected household was 190.62 ha and from those total lands of the household used the land for homesteads/homegardens, crop fields and grazing/pasture land are 19.24 ha, 151.35 ha, and 20.03 ha respectively. But inventory was takes place on 59.7 ha (31.3%) of the total land holding size of the selected household in entire study sites, from those land inventory was takes place the farmers used the land for homesteads/homegardens, crop fields and grazing/pasture land are 19.24 ha (100%), 34.93 ha (23%) and 5.5 ha (27.5%) from the total land holding size respectively.

The result of this study indicated that mean land holding owned by the respondents were 1.29 ha, 2.04 ha, 2.01 ha and 2.29 ha at Wayu Kumba PA in Jimma Arjo District (EB1), Oda Haro PA in Bako Tibe district (EB2), Ongobo Bakanisa PA in Gobu Seyo district (EB3) and Uke Badiya PA in Guto Gida (EB4) respectively. The overall mean land holding of the selected households in the study sites was 1.9 ha (Table 13).

As categorical variable, the type of the household head was recorded, with 92 farms categorised as male-headed and 8 farms characterised as female-headed (7 without husband and 1 with an absentee husband). Family size of the selected households ranged between 1-19 persons with a mean of 6 persons per households.

Besides the biophysical aspects, the socio-economic characteristics of the sampled households owning the sampled farms in the study sites were assessed. In the study sites, male respondents accounted for 92% and 8% were females of the sampled household.

From the total respondents 40% were with no formal education, 49% with primary education and the rest 11% attended secondary education. The mean farm size of the household in the study area was 1.9 ha of land (Table 13).

Table 13. The socio-economic profile of sampled households (n=100)

Socio economic parameters		Study site			
		Jimma Arjo	Bako Tibe	Gobu Seyo	Guto Gida
House hold head	Male (%)	88	92	92	96
	Female (%)	12	8	8	4
	Total	100	100	100	100
Education	No formal Education (%)	64	52	12	32
	Primary Education (%)	28	36	72	60
	Secondary Education (%)	8	12	16	8
	Total	100	100	100	100
Average family size		6.7	6.1	6.6	5.7
Male average family size		3.2	3.2	3.4	3.0
Female Average family size		3.5	2.8	3.2	2.6
Average land holding size (ha)		1.3	2.0	2.0	2.3
Average homestead area (ha)		0.14	0.18	0.32	0.12
Agro-ecology		Waynedega tepid mid highland	Kola warm lowland	Waynedega tepid mid highland	Kola warm lowland
Altitude	Minimum	2029	1641	1668	1325
	Maximum	2209	1851	1901	1381

4.7.1. Socio economic purpose of maintain woody species in the study sites

Respondents mentioned that they have been obtaining diverse types of benefits from their woody species maintaining natural regenerated/planting. From those benefits that listed by farmers such as bee forage, charcoal production, firewood, fodder, fruit, incomes, live fence, medicinal, shade soil fertility, timber and windbreak purposes. According the respondents from the total survey of 13,307 tree abundance in the entire land use system of the area the 5 (0.04%) uses for bee-forage, 2 (0.02%) for charcoal, 3990 (29.98%) for firewood, 1711 (12.86%) for animal fodder, 295 (2.22%) for fruit, 1708 (12.84%) incomes, 5054 (37.98%) live-fence, 13 (0.10%) for medicinal value, 32 (0.24%) for shade, 4 (0.03%) for soil fertility,

466 (3.50%) for timber and 27 (0.20%) for windbreak purpose to retained/ planting the trees in agricultural landscape of the study sites.

Among these benefits, about 37.98% used for life-fence followed 29.98% for firewood, 12.86% for fodder, 12.84% for incomes and such like that in the entire land use system of the study sites (Figure 38).

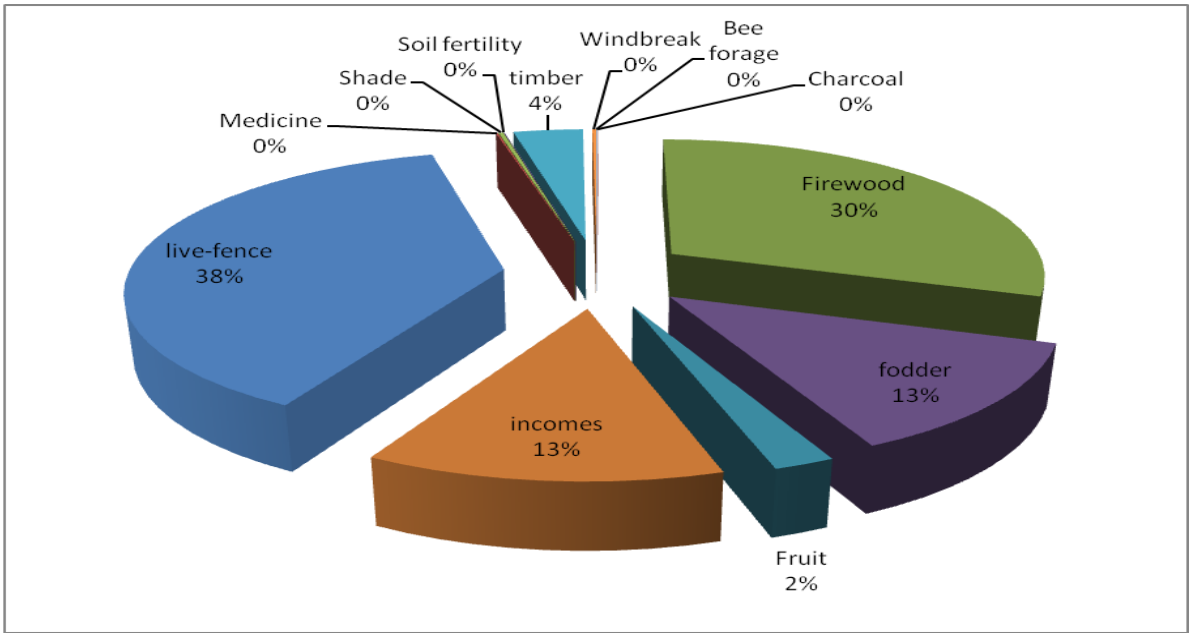


Figure 30.Farmers' reason for retained/planting woody species in entire land use system of the study sites.
Key: EB1=Wayu Kumba PA; EB2=Oda Haro PA; EB3=Ongobo Bakanisa PA and EB4=Uke Badiya PA

Some study, (Arnold, 1999) reported that in most part of the developing world rural people managed and recognized the role of trees in providing a number of important goods and services. Another study, (Atta-Krah *et al*., 2004), confirmed that farmers actively plant or managing trees on their farms can be seen as an indicator of the fact that they appreciate trees in their farming systems. Tesfaye (2005) reported that on-farm trees can be used for different purposes. They provide firewood, timber, wood for different purposes (local construction, farm implements and household utensils), fodder, food, medicine, and they also play beneficial ecological roles such as erosion control and soil fertility improvement.

5. CONCLUSIONS AND RECOMMENDATIONS

Preserving biodiversity through nature reserves and other protected areas is an important short-term step but it is not sufficient to solve the problem of biodiversity loss. The role of biological diversity for ecosystem functions is not limited to protected areas. The result of the present study confirms that the agricultural landscape can play a significant role in the conservation of native woody species. Moreover, the presence of woody species in these landscapes may favour the survival of other organisms and hence contribute to a wider conservation of biological diversity. The trees in the agricultural landscapes can also satisfy farmers' need of wood products. By doing so, they might also indirectly contribute to the conservation of biodiversity through lessening the pressure that otherwise could be exerted on protected forests.

The high species richness in homesteads/homegardens may lead to the assumption that ownership right is playing an important role in preserving woody species diversity. Even if, farmers are still utilizing the woody resources on their crop fields, there is no as such legal right to utilize them. There is a feeling that the properties in the homegardens are under full control of the farmer for protection as well as utilization. This is true because they collect seedlings from natural forests and any other areas to plant in their homegardens. In addition the introductions of fruit trees also play a great role in enhancing the woody species diversity of homegardens as compared to other areas.

The declining trend of woody species in the crop fields shows that the woody species diversity on the crop fields is hardly sustainable unless an extension intervention is devised with the community to regenerate and/or introduce woody species in the crop fields. Instead of focusing only on increasing crop production per unit area, agricultural policies also has to encourage the inclusion of diverse woody species that are of a high value, both ecologically as well as economically, without hampering agricultural production ensuring sustainability of production and food security. The trend towards monocultures should be reversed since these

simplified systems are characterized by low levels of diversity and are prone to perturbations and lower levels of resilience. Based on the findings, the following points are recommended.

1. This study focused mainly on the assessment of the diversity of woody species in agricultural landscapes. Further studies on the effects of conversion of forest land into agricultural land on the genetic diversity of woody species, and species diversity of other life forms like herbaceous plants and other organisms are recommended.

2. Further studies are also recommended on the possible link between the decline of woody species with increasing cultivation period and crop production. Free grazing is the main problem in the study area for tree planting on-farm (crop-fields) land with decreased woody species diversity is also a study sites that should be of interest when developing control polices in free grazing land in crop fields during the dry seasons.

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7. APPENDICES

Appendix Table 1. List of all woody species recorded and similarity in composition of woody species among the study site of entire land use system.

Species name	1	2	3	4	1X2	1X3	1X4	2X3	2x4	3x4	1X2X3X4
Acacia abyssinica	x	x	x	0	x	x	0	x	0	0	0
Acacia seyal	0	x	0	0	0	0	0	0	0	0	0
Albizia gummifera	x	x	x	x	x	x	x	x	x	x	x
Allophylus abyssinicus	x	0	0	0	0	0	0	0	0	0	0
Annona senegalensis	x	0	0	0	0	0	0	0	0	0	0
Anogeissus leiocarpa	0	0	0	x	0	0	0	0	0	0	0
Apodytes dimidiata	x	0	0	0	0	0	0	0	0	0	0
Bersama abyssinica	x	0	0	0	0	0	0	0	0	0	0
Bridelia micrantha	0	x	x	0	0	0	0	x	0	0	0
Brucea antidysenterica	x	0	0	0	0	0	0	0	0	0	0
Buddleja polystachya	x	x	0	0	x	0	0	0	0	0	0
Caesalpinia decapetala	0	0	x	0	0	0	0	0	0	0	0
Cajanus cajan	0	0	x	x	0	0	0	0	0	x	0
Calliandra calothyrsus	0	x	0	0	0	0	0	0	0	0	0
Calpurnia aurea	x	x	x	x	x	x	x	x	x	x	x
Carica papaya	x	x	x	x	x	x	x	x	x	x	x
Casimiroa edulis	x	0	x	0	0	x	0	0	0	0	0
Casuarina equisetifolia	0	0	x	0	0	0	0	0	0	0	0
Catha edulis	0	x	0	0	0	0	0	0	0	0	0
Celtis africana	x	x	x	0	x	x	0	x	0	0	0
Citrus aurantifolia	0	x	0	0	0	0	0	0	0	0	0
Citrus reticulata	0	0	x	0	0	0	0	0	0	0	0
Citrus sinensis	0	0	x	0	0	0	0	0	0	0	0
Combretum collinum	0	0	x	x	0	0	0	0	0	x	0
Combretum molle	0	x	x	x	0	0	0	x	x	x	0
Cordia africana	x	x	x	x	x	x	x	x	x	x	x
Croton macrostachyus	x	x	x	x	x	x	x	x	x	x	x
Cupressus lusitanica	x	0	x	x	0	x	x	0	0	x	0
Deinbollia kilimandscharica	0	0	x	x	0	0	0	0	0	x	0
Delonix regia	0	0	0	x	0	0	0	0	0	0	0
Dombeya torrida	0	0	0	x	0	0	0	0	0	0	0
Ehretia cymosa	x	x	x	0	x	x	0	x	0	0	0
Ekebergia capensis	x	x	x	0	x	x	0	x	0	0	0
Entada abyssinica	0	x	0	x	0	0	0	0	x	0	0
Erythrina abyssinica	x	0	0	0	0	0	0	0	0	0	0
Erythrina brucei	x	x	0	0	x	0	0	0	0	0	0
Eucalyptus camaldulensis	x	x	x	x	x	x	x	x	x	x	x

Euphorbia abyssinica	0	0	x	0	0	0	0	0	0	0	0
Euphorbia tirucalli	0	0	0	x	0	0	0	0	0	0	0
Faurea rochetiana	0	0	x	0	0	0	0	0	0	0	0
Ficus ovata	0	x	0	0	0	0	0	0	0	0	0
Ficus sur	x	0	0	0	0	0	0	0	0	0	0
Ficus sycomorus	0	x	x	x	0	0	0	x	x	x	0
Ficus thonningii	x	x	0	x	x	0	x	0	x	0	0
Ficus vasta	x	x	x	0	x	x	0	x	0	0	0
Gardenia ternifolia	0	x	x	x	0	0	0	x	x	x	0
Grevillea robusta	x	x	x	x	x	x	x	x	x	x	x
Grewia bicolor	0	0	0	x	0	0	0	0	0	0	0
Grewia ferruginea	0	x	x	0	0	0	0	x	0	0	0
Jacaranda mimosifolia	0	x	x	x	0	0	0	x	x	x	0
Jatropha curcas	0	0	0	x	0	0	0	0	0	0	0
Justicia schimperiana	x	0	x	x	0	x	x	0	0	x	0
Leucaena pallida	0	x	0	x	0	0	0	0	x	0	0
Maesa lanceolata	x	x	x	0	x	x	0	x	0	0	0
Mangifera indica	x	x	x	x	x	x	x	x	x	x	x
Maytenus arbutifolia	0	0	0	x	0	0	0	0	0	0	0
Melia azedarach	0	x	x	x	0	0	0	x	x	x	0
Millettia ferruginia	x	0	0	0	0	0	0	0	0	0	0
Morus alba	x	x	x	x	x	x	x	x	x	x	x
Ocimum lamiifolium	0	0	0	x	0	0	0	0	0	0	0
Olea europaea	x	0	0	0	0	0	0	0	0	0	0
Olinia rochetiana	x	0	0	0	0	0	0	0	0	0	0
Persea americana	x	x	x	0	x	x	0	x	0	0	0
Piliostigma thonningii	0	x	x	x	0	0	0	x	x	x	0
Pittosporum viridiflorum	x	0	0	0	0	0	0	0	0	0	0
Premna schimperi	x	x	x	0	x	x	0	x	0	0	0
Prunus persica	x	x	0	x	x	0	x	0	x	0	0
Psidium guajava	0	0	x	0	0	0	0	0	0	0	0
Rhus vulgaris	0	0	x	0	0	0	0	0	0	0	0
Ricinus communis	x	0	0	x	0	0	x	0	0	0	0
Sapium ellipticum	0	x	x	0	0	0	0	x	0	0	0
Schrebera alata	0	x	0	0	0	0	0	0	0	0	0
Sesbania sesban	x	0	x	x	0	x	x	0	0	x	0
Spathodea campanulata (nilotica)	0	0	x	0	0	0	0	0	0	0	0
Stereospermum kunthianum	0	x	x	x	0	0	0	x	x	x	0
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	x	x	x	x	x	x	x	x	x	x	x
Syzygium guineense (Willd.) DC. Subsp.	0	x	x	0	0	0	0	x	0	0	0

guineense											
Terminalia laxiflora	0	0	0	x	0	0	0	0	0	0	0
Vangueria apiculata	0	x	0	0	0	0	0	0	0	0	0
Vepris nobilis	x	0	0	0	0	0	0	0	0	0	0
Vernonia amygdalina	x	x	x	x	x	x	x	x	x	x	x
Vernonia auriculifera	x	x	x	0	x	x	0	x	0	0	0
Total	41	44	47	38	24	24	17	31	22	24	11

Key: 0= absent x= present, species in the study site.
1=Wayu Kumba; 2=Oda Haro PA; 3=Ongobo Bakanisa PA and 4=Uke Badiya PA

Appendix Table 2. List of woody species encountered at Wayu Kumba PA entire land use system Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI%
Eucalyptus camaldulensis	88.21	4.50	18.51	38.92	61.93
Vernonia amygdalina	120.99	10.03	25.39	11.82	47.25
Croton macrostachyus	24.41	9.34	5.12	15.76	30.23
Justicia schimperiana	107.65	6.57	22.59	0.15	29.31
Ricinus communis	51.19	7.61	10.74	1.83	20.19
Albizia gummifera	5.69	6.92	1.19	10.47	18.58
Cordia africana	5.17	7.61	1.09	3.30	12.00
Calpurnia aurea	23.06	5.88	4.84	0.47	11.19
Vernonia auriculifera	12.51	7.27	2.63	0.20	10.09
Sesbania sesban	12.1	4.84	2.54	0.53	7.91
Celtis africana	1.14	2.08	0.24	4.01	6.33
Olea europaea (Olea africana)	0.93	1.38	0.20	4.49	6.07
Maesa lanceolata	4.86	3.11	1.02	0.30	4.43
Erythrina abyssinica	2.38	2.42	0.50	1.22	4.14
Brucea antidysenterica	2.28	3.11	0.48	0.05	3.64
Ehretia cymosa	1.14	2.77	0.24	0.37	3.38
Ficus vasta	0.21	0.69	0.04	1.93	2.67
Cupressus lusitanica	2.28	1.73	0.48	0.42	2.63
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.31	1.04	0.07	1.17	2.27
Acacia abyssinica	1.45	1.04	0.30	0.60	1.94
Bersama abyssinica	2.17	1.38	0.46	0.06	1.90
Apodytes dimidiata	0.31	0.69	0.07	0.39	1.14
Millettia ferruginia	0.41	0.69	0.09	0.36	1.14

Persea americana	1.24	0.69	0.26	0.06	1.01
Ekebergia capensis	0.31	0.69	0.07	0.10	0.86
Morus alba	0.31	0.69	0.07	0.01	0.77
Ficus thonningii	0.1	0.35	0.02	0.25	0.62
Casimiroa edulis	0.72	0.35	0.15	0.08	0.58
Carica papaya	0.52	0.35	0.11	0.08	0.54
Prunus persica	0.62	0.35	0.13	0.05	0.52
Erythrina brucei	0.41	0.35	0.09	0.09	0.52
Buddleja polystachya	0.41	0.35	0.09	0.09	0.52
Olinia rochetiana	0.1	0.35	0.02	0.13	0.49
Allophylus abyssinicus	0.1	0.35	0.02	0.11	0.48
Ficus sur	0.1	0.35	0.02	0.09	0.46
Pittosporum viridiflorum	0.21	0.35	0.04	0.00	0.39
Grevillea robusta	0.1	0.35	0.02	0.01	0.38
Premna schimperi	0.1	0.35	0.02	0.01	0.37
Annona senegalensis	0.1	0.35	0.02	0.00	0.37
Vepris nobilis	0.1	0.35	0.02	0.00	0.37
Mangifera indica	0.1	0.35	0.02	0.00	0.37
Total		100.00	100.00	100.00	300.00

Appendix Table 3. List of woody species encountered at Oda Haro PA entire land use system Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI%
Eucalyptus camaldulensis	44.4	5.33	33.37	20.48	59.18
Vernonia amygdalina	31.51	8.61	23.68	8.85	41.14
Cordia africana	6.54	11.07	4.91	21.66	37.64
Erythrina brucei	14.39	4.51	10.82	9.68	25.01
Croton macrostachyus	2.35	9.02	1.77	5.03	15.81
Calpurnia aurea	9.17	6.15	6.89	1	14.04
Morus alba	8.75	6.15	6.57	1.21	13.93
Ficus vasta	0.14	1.23	0.11	10.47	11.81
Mangifera indica	2.82	4.92	2.12	4.45	11.49
Albizia gummifera	1.32	5.74	0.99	2.18	8.9
Grevillea robusta	1.88	3.28	1.41	0.42	5.11
Melia azedarach	0.85	2.05	0.64	1.1	3.79
Bridelia micrantha	0.28	2.05	0.21	1.51	3.77
Acacia abyssinica	0.47	2.46	0.35	0.68	3.5

Ficus sycomorus	0.14	1.23	0.11	2.15	3.49
Ehretia cymosa	0.33	2.46	0.25	0.52	3.22
Stereospermum kunthianum	0.24	1.64	0.18	1.36	3.17
Catha edulis	1.69	1.23	1.27	0.16	2.66
Jacaranda mimosifolia	0.47	1.64	0.35	0.52	2.52
Sapium ellipticum	0.14	0.41	0.11	1.87	2.39
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.09	0.82	0.07	1.41	2.3
Grewia ferruginea	0.66	1.64	0.49	0.05	2.19
Buddleja polystachya	0.89	1.23	0.67	0.2	2.11
Leucaena pallida	0.89	1.23	0.67	0.05	1.96
Celtis africana	0.19	1.64	0.14	0.15	1.93
Combretum molle	0.14	0.82	0.11	0.71	1.63
Ficus thonningii	0.24	1.23	0.18	0.2	1.61
Premna schimperi	0.38	1.23	0.28	0.04	1.55
Ficus ovata	0.24	1.23	0.18	0.14	1.54
Vernonia auriculifera	0.38	1.23	0.28	0.01	1.52
Syzygium guineense (Willd.) DC. Subsp. guineense	0.24	0.82	0.18	0.25	1.25
Schrebera alata	0.05	0.41	0.04	0.57	1.01
Entada abyssinica	0.09	0.82	0.07	0.07	0.96
Piliostigma thonningii	0.09	0.41	0.07	0.44	0.92
Acacia seyal	0.05	0.41	0.04	0.15	0.59
Carica papaya	0.09	0.41	0.07	0.11	0.59
Ekebergia capensis	0.09	0.41	0.07	0.05	0.53
Persea americana	0.09	0.41	0.07	0.02	0.5
Calliandra calothyrsus	0.05	0.41	0.04	0.01	0.46
Citrus aurantifolia	0.05	0.41	0.04	0.01	0.46
Gardenia ternifolia	0.05	0.41	0.04	0.02	0.46
Maesa lanceolata	0.05	0.41	0.04	0.01	0.46
Prunus persica	0.05	0.41	0.04	0.02	0.46
Vangueria apiculata	0.05	0.41	0.04	0.01	0.45
Total		100.00	100.00	100.00	300.00

Appendix Table 4. List of woody species encountered at Ongobo Bakanisa PA entire land use system Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI%
Eucalyptus camaldulensis	32.39	6.84	16.15	29.44	52.42
Vernonia amygdalina	58.1	8.12	28.97	5.99	43.08
Cordia africana	6.5	10.26	3.24	11.09	24.59
Calpurnia aurea	33.43	6.41	16.67	0.33	23.41
Sesbania sesban	24.2	3.42	12.07	1.05	16.54
Croton macrostachyus	5.17	8.12	2.58	5.08	15.77
Mangifera indica	3.95	7.26	1.97	4.53	13.76
Ficus vasta	0.23	1.71	0.12	9.33	11.15
Ficus sycomorus	0.52	1.71	0.26	7.23	9.2
Deinbollia kilimandscharica	1.51	2.14	0.75	4.98	7.87
Vernonia auriculifera	12.01	1.71	5.99	0.11	7.81
Stereospermum kunthianum	0.87	4.7	0.43	2.45	7.59
Combretum molle	1.16	2.14	0.58	4.16	6.87
Syzygium guineense (Willd.) DC.					
Subsp. guineense	1.8	1.71	0.9	3.86	6.47
Cupressus lusitanica	4.35	2.56	2.17	1.17	5.91
Persea americana	2.55	2.99	1.27	0.68	4.95
Albizia gummifera	0.75	2.56	0.38	1.13	4.07
Grevillea robusta	3.25	2.14	1.62	0.24	4.00
Spathodea campanulata (nilotica)	0.41	2.56	0.2	0.66	3.43
Maesa lanceolata	1.04	2.56	0.52	0.1	3.19
Syzygium guineense (Willd.) DC.					
Subsp. afromontanum F.White	0.52	1.71	0.26	0.92	2.89
Combretum collinum	0.58	1.28	0.29	1.04	2.61
Melia azedarach	0.64	1.71	0.32	0.48	2.51
Faurea rochetiana	0.29	0.43	0.14	1.74	2.32
Carica papaya	0.46	1.71	0.23	0.19	2.13
Justicia schimperiana	0.93	0.85	0.46	0.01	1.32
Citrus sinensis	0.41	0.85	0.2	0.08	1.14
Gardenia ternifolia	0.12	0.85	0.06	0.09	1.00
Morus alba	0.12	0.85	0.06	0.09	1.00
Piliostigma thonningii	0.12	0.43	0.06	0.46	0.94
Jacaranda mimosifolia	0.12	0.85	0.06	0	0.92

Casimiroa edulis	0.29	0.43	0.14	0.29	0.86
Sapium ellipticum	0.12	0.43	0.06	0.36	0.84
Ehretia cymosa	0.29	0.43	0.14	0.14	0.71
Ekebergia capensis	0.12	0.43	0.06	0.15	0.64
Caesalpinia decapetala	0.35	0.43	0.17	0	0.60
Celtis africana	0.06	0.43	0.03	0.09	0.55
Rhus vulgaris	0.12	0.43	0.06	0.06	0.55
Acacia abyssinica	0.06	0.43	0.03	0.08	0.54
Citrus reticulata	0.12	0.43	0.06	0.04	0.52
Grewia ferruginea	0.12	0.43	0.06	0.02	0.51
Bridelia micrantha	0.06	0.43	0.03	0.04	0.50
Euphorbia abyssinica	0.12	0.43	0.06	0.01	0.50
Cajanus cajan	0.06	0.43	0.03	0	0.46
Casuarina equisetifolia	0.06	0.43	0.03	0	0.46
Premna schimperi	0.06	0.43	0.03	0	0.46
Psidium guajava	0.06	0.43	0.03	0	0.46
Total		100.00	100.00	100.00	300.00

Appendix Table 5. List of woody species encountered at Ongobo Bakanisa PA entire land use system Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI%
Jatropha curcas	63	8.17	29.9	13.79	51.86
Eucalyptus camaldulensis	38.05	7.69	18.05	20.98	46.72
Vernonia amygdalina	48.95	10.58	23.23	9.26	43.07
Cordia africana	6.98	8.17	3.31	11.27	22.76
Mangifera indica	4.8	8.17	2.28	10.85	21.30
Morus alba	5.85	6.73	2.77	1.67	11.18
Ricinus communis	8.55	6.25	4.06	0.69	11
Sesbania sesban	9.86	5.77	4.68	0.24	10.68
Melia azedarach	2.09	5.29	0.99	2.6	8.88
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.61	1.44	0.29	6.67	8.41
Euphorbia tirucalli	10.38	2.4	4.93	0.66	8.00
Piliostigma thonningii	1.05	3.37	0.5	3.13	7.00

Terminalia laxiflora	0.44	0.96	0.21	3.22	4.39
Jacaranda mimosifolia	0.61	1.92	0.29	2.1	4.32
Carica papaya	0.52	2.4	0.25	0.84	3.49
Gardenia ternifolia	0.52	1.44	0.25	1.65	3.34
Deinbollia kilimandscharica	0.52	0.96	0.25	2.08	3.29
Croton macrostachyus	0.52	2.4	0.25	0.25	2.90
Combretum collinum	0.44	1.44	0.21	0.98	2.63
Stereospermum kunthianum	0.44	1.44	0.21	0.9	2.55
Combretum molle	0.35	1.44	0.17	0.66	2.27
Justicia schimperiana	2.09	0.96	0.99	0.03	1.98
Maytenus arbutifolia	0.26	0.96	0.12	0.72	1.80
Entada abyssinica	0.17	0.48	0.08	1.17	1.73
Ocimum lamiifolium	1.13	0.96	0.54	0.03	1.53
Ficus thonningii	0.17	0.96	0.08	0.47	1.51
Grewia bicolor	0.26	0.48	0.12	0.77	1.38
Albizia gummifera	0.26	0.96	0.12	0.27	1.35
Leucaena pallida	0.44	0.96	0.21	0.1	1.26
Ficus sycomorus	0.09	0.48	0.04	0.7	1.22
Anogeissus leiocarpa	0.09	0.48	0.04	0.54	1.06
Calpurnia aurea	0.17	0.96	0.08	0.01	1.05
Delonix regia	0.35	0.48	0.17	0.33	0.98
Dombeya torrida	0.09	0.48	0.04	0.31	0.83
Cajanus cajan	0.26	0.48	0.12	0.02	0.63
Grevillea robusta	0.17	0.48	0.08	0.02	0.58
Prunus persica	0.09	0.48	0.04	0.01	0.54
Cupressus lusitanica	0.09	0.48	0.04	0	0.52
Total		100.00	100.00	100.00	300.00

Appendix Table 6. List of woody species encountered at four study sites entire land use system, Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI (%)
Eucalyptus camaldulensis	46.78	6.71	20.97	29.12	56.80
Vernonia amygdalina	57.02	9.40	25.57	9.02	43.98
Cordia africana	6.39	8.61	2.86	11.55	23.03
Croton macrostachyus	6.39	6.38	2.86	8.02	17.26
Calpurnia aurea	16.69	4.81	7.48	0.53	12.82
Justicia schimperiana	18.12	2.35	8.12	0.05	10.53
Mangifera indica	3.08	5.15	1.38	3.70	10.22
Sesbania sesban	10.84	3.69	4.86	0.50	9.05
Ricinus communis	9.94	3.91	4.46	0.67	9.04
Albizia gummifera	1.66	3.91	0.74	4.36	9.02
Jatropha curcas	12.10	1.90	5.43	1.43	8.76
Ficus vasta	0.15	0.89	0.07	6.29	7.25
Erythrina brucei	5.20	1.34	2.33	2.75	6.42
Morus alba	4.32	3.58	1.94	0.54	6.06
Vernonia auriculifera	5.63	2.68	2.52	0.10	5.31
Ficus sycomorus	0.22	0.89	0.10	2.78	3.78
Melia azedarach	0.89	2.24	0.40	0.72	3.35
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.35	1.23	0.16	1.74	3.12
Stereospermum kunthianum	0.42	1.45	0.19	1.19	2.83
Grevillea robusta	1.66	1.79	0.74	0.19	2.73
Celtis africana	0.27	1.23	0.12	1.37	2.72
Combretum molle	0.45	1.01	0.20	1.48	2.69
Deinbollia kilimandscharica	0.54	0.67	0.24	1.67	2.58
Cupressus lusitanica	1.64	1.34	0.74	0.48	2.56
Maesa lanceolata	1.11	1.68	0.50	0.13	2.30
Ehretia cymosa	0.39	1.57	0.17	0.31	2.04
Syzygium guineense (Willd.) DC. Subsp. guineense	0.60	0.56	0.27	1.20	2.03
Olea europaea	0.15	0.45	0.07	1.45	1.97
Persea americana	0.97	1.12	0.44	0.22	1.78
Jacaranda mimosifolia	0.32	1.12	0.14	0.37	1.63
Piliostigma thonningii	0.27	0.89	0.12	0.58	1.60
Carica papaya	0.35	1.23	0.16	0.20	1.59
Euphorbia tirucalli	1.99	0.56	0.89	0.07	1.52
Acacia abyssinica	0.42	0.89	0.19	0.41	1.49
Erythrina abyssinica	0.39	0.56	0.17	0.40	1.13

Sapium ellipticum	0.08	0.34	0.04	0.63	1.00
Gardenia ternifolia	0.15	0.67	0.07	0.20	0.94
Ficus thonningii	0.13	0.67	0.06	0.19	0.92
Spathodea campanulata	0.12	0.67	0.05	0.19	0.92
Brucea antidysenterica	0.37	0.67	0.17	0.02	0.85
Combretum collinum	0.25	0.34	0.11	0.41	0.85
Bridelia micrantha	0.12	0.34	0.05	0.44	0.82
Leucaena pallida	0.40	0.56	0.18	0.03	0.76
Buddleja polystachya	0.39	0.45	0.17	0.09	0.71
Faurea rochetiana	0.08	0.11	0.04	0.51	0.66
Catha edulis	0.60	0.34	0.27	0.04	0.65
Premna schimperi	0.17	0.56	0.08	0.01	0.65
Bersama abyssinica	0.35	0.45	0.16	0.02	0.62
Terminalia laxiflora	0.08	0.22	0.04	0.33	0.59
Ekebergia capensis	0.12	0.45	0.05	0.09	0.59
Grewia ferruginea	0.27	0.45	0.12	0.02	0.59
Prunus persica	0.13	0.45	0.06	0.02	0.53
Entada abyssinica	0.07	0.34	0.03	0.14	0.51
Casimiroa edulis	0.20	0.22	0.09	0.11	0.42
Ficus ovata	0.08	0.34	0.04	0.04	0.41
Millettia ferruginia	0.07	0.22	0.03	0.12	0.37
Apodytes dimidiata	0.05	0.22	0.02	0.13	0.37
Ocimum lamiifolium	0.22	0.22	0.10	0.00	0.32
Maytenus arbutifolia	0.05	0.22	0.02	0.07	0.32
Schrebera alata	0.02	0.11	0.01	0.16	0.28
Cajanus cajan	0.07	0.22	0.03	0.00	0.26
Grewia bicolor	0.05	0.11	0.02	0.08	0.21
Citrus sinensis	0.12	0.11	0.05	0.02	0.19
Delonix regia	0.07	0.11	0.03	0.03	0.18
Anogeissus leiocarpa	0.02	0.11	0.01	0.06	0.17
Acacia seyal	0.02	0.11	0.01	0.04	0.16
Olinia rochetiana	0.02	0.11	0.01	0.04	0.16
Caesalpinia decapetala	0.10	0.11	0.05	0.00	0.16
Allophylus abyssinicus	0.02	0.11	0.01	0.04	0.16
Dombeya torrida	0.02	0.11	0.01	0.03	0.15
Ficus sur	0.02	0.11	0.01	0.03	0.15
Rhus vulgaris	0.03	0.11	0.02	0.02	0.15
Citrus reticulata	0.03	0.11	0.02	0.01	0.14
Euphorbia abyssinica	0.03	0.11	0.02	0.00	0.13
Pittosporum viridiflorum	0.03	0.11	0.02	0.00	0.13
Calliandra calothyrsus	0.02	0.11	0.01	0.00	0.12
Citrus aurantifolia	0.02	0.11	0.01	0.00	0.12
Vangueria apiculata	0.02	0.11	0.01	0.00	0.12
Psidium guajava	0.02	0.11	0.01	0.00	0.12

Casuarina equisetifolia	0.02	0.11	0.01	0.00	0.12
Annona senegalensis	0.02	0.11	0.01	0.00	0.12
Vepris nobilis	0.02	0.11	0.01	0.00	0.12
Total		100.00	100.00	100.00	300.00

Appendix Table 7. List of woody species encountered at study sites at homestead land use system, Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI (%)
Vernonia amygdalina	175.19	10.98	32.85	15.46	59.29
Eucalyptus camaldulensis	80.99	7.06	15.19	26.54	48.79
Cordia africana	16.38	9.54	3.07	13.91	26.53
Croton macrostachyus	8.89	6.93	1.67	5.50	14.09
Mangifera indica	8.99	5.88	1.69	5.90	13.47
Justicia schimperiana	55.57	2.75	10.42	0.09	13.26
Jatropha curcas	37.53	2.22	7.04	2.47	11.73
Ricinus communis	30.83	4.58	5.78	1.15	11.51
Sesbania sesban	29.74	4.31	5.58	0.86	10.75
Erythrina brucei	15.91	1.44	2.98	4.71	9.13
Calpurnia aurea	14.40	5.23	2.70	0.59	8.52
Morus alba	13.41	4.31	2.51	0.94	7.77
Albizia gummifera	2.70	3.79	0.51	1.85	6.15
Ficus vasta	0.10	0.26	0.02	5.01	5.29
Melia azedarach	2.76	2.61	0.52	1.24	4.37
Vernonia auriculifera	3.90	2.75	0.73	0.07	3.55
Grevillea robusta	5.09	1.96	0.96	0.33	3.25
Cupressus lusitanica	4.83	1.44	0.91	0.82	3.16
Ficus sycomorus	0.42	0.52	0.08	2.24	2.84
Celtis africana	0.57	1.18	0.11	1.22	2.50
Persea americana	3.02	1.31	0.57	0.38	2.26
Jacaranda mimosifolia	0.99	1.31	0.19	0.63	2.13
Carica papaya	1.09	1.44	0.20	0.35	1.99
Olea europaea	0.21	0.26	0.04	1.65	1.95
Euphorbia tirucalli	6.19	0.65	1.16	0.12	1.93
Ehretia cymosa	0.94	1.44	0.18	0.27	1.89
Maesa lanceolata	1.09	1.31	0.20	0.10	1.61
Stereospermum kunthianum	0.42	0.78	0.08	0.46	1.32
Erythrina abyssinica	0.99	0.52	0.19	0.53	1.24
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.16	0.39	0.03	0.79	1.21
Piliostigma thonningii	0.31	0.65	0.06	0.31	1.02

Combretum molle	0.21	0.26	0.04	0.71	1.01
Spathodea campanulata	0.31	0.65	0.06	0.28	0.99
Leucaena pallida	1.25	0.65	0.23	0.04	0.93
Acacia abyssinica	0.36	0.52	0.07	0.31	0.90
Syzygium guineense (Willd.) DC. Subsp. guineense	0.42	0.39	0.08	0.43	0.90
Buddleja polystachya	1.20	0.52	0.22	0.15	0.90
Ficus thonningii	0.31	0.52	0.06	0.15	0.73
Prunus persica	0.42	0.52	0.08	0.04	0.64
Deinbollia kilimandscharica	0.16	0.39	0.03	0.22	0.64
Casimiroa edulis	0.62	0.26	0.12	0.19	0.57
Grewia ferruginea	0.68	0.39	0.13	0.02	0.54
Ficus ovata	0.26	0.39	0.05	0.07	0.51
Premna schimperi	0.31	0.39	0.06	0.02	0.47
Gardenia ternifolia	0.16	0.39	0.03	0.01	0.43
Brucea antidysenterica	0.16	0.39	0.03	0.00	0.43
Ocimum lamiifolium	0.68	0.26	0.13	0.01	0.39
Bridelia micrantha	0.16	0.26	0.03	0.09	0.38
Ekebergia capensis	0.21	0.26	0.04	0.05	0.35
Millettia ferruginia	0.16	0.13	0.03	0.19	0.35
Entada abyssinica	0.10	0.26	0.02	0.03	0.31
Combretum collinum	0.05	0.13	0.01	0.16	0.31
Sapium ellipticum	0.05	0.13	0.01	0.16	0.31
Cajanus cajan	0.21	0.26	0.04	0.00	0.30
Catha edulis	0.16	0.26	0.03	0.01	0.30
Delonix regia	0.21	0.13	0.04	0.06	0.23
Olinia rochetiana	0.05	0.13	0.01	0.07	0.21
Caesalpinia decapetala	0.31	0.13	0.06	0.00	0.19
Euphorbia abyssinica	0.10	0.13	0.02	0.01	0.16
Pittosporum viridiflorum	0.10	0.13	0.02	0.00	0.15
Calliandra calothyrsus	0.05	0.13	0.01	0.01	0.15
Citrus aurantifolia	0.05	0.13	0.01	0.01	0.15
Vangueria apiculata	0.05	0.13	0.01	0.00	0.14
Psidium guajava	0.05	0.13	0.01	0.00	0.14
Casuarina equisetifolia	0.05	0.13	0.01	0.00	0.14
Annona senegalensis	0.05	0.13	0.01	0.00	0.14
Vepris nobilis	0.05	0.13	0.01	0.00	0.14
Total		100.00	100.00	100.00	300.00

Appendix Table 8. List of woody species encountered at study sites at crop field land use system ,Importance Value Index in decreasing order.

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI (%)
Eucalyptus camaldulensis	32.64	5.37	60.45	42.69	108.51
Croton macrostachyus	2.52	8.05	4.67	7.01	19.73
Cordia africana	1.57	8.72	2.92	7.82	19.46
Albizia gummifera	1.00	6.71	1.86	9.89	18.45
Calpurnia aurea	4.49	2.01	8.32	0.25	10.58
Ficus vasta	0.11	2.68	0.21	6.14	9.03
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	0.29	4.03	0.53	3.53	8.08
Ficus sycomorus	0.14	2.68	0.27	4.97	7.92
Stereospermum kunthianum	0.31	4.70	0.58	1.62	6.90
Vernonia amygdalina	0.92	4.70	1.70	0.28	6.67
Combretum molle	0.34	3.36	0.64	2.19	6.18
Maesa lanceolata	1.15	3.36	2.12	0.24	5.71
Sesbania sesban	2.15	0.67	3.98	0.02	4.67
Piliostigma thonningii	0.29	2.68	0.53	1.35	4.56
Vernonia auriculifera	1.23	2.01	2.28	0.08	4.37
Deinbollia kilimandscharica	0.26	2.01	0.48	1.54	4.04
Brucea antidysenterica	0.46	2.68	0.85	0.04	3.58
Acacia abyssinica	0.29	2.01	0.53	0.26	2.81
Terminalia laxiflora	0.14	1.34	0.27	1.11	2.72
Ehretia cymosa	0.11	2.01	0.21	0.34	2.56
Catha edulis	0.94	0.67	1.75	0.13	2.55
Erythrina abyssinica	0.11	2.01	0.21	0.29	2.52
Olea europaea	0.09	0.67	0.16	1.41	2.24
Gardenia ternifolia	0.14	1.34	0.27	0.57	2.17
Justicia schimperiana	0.34	1.34	0.64	0.00	1.98
Bersama abyssinica	0.31	1.34	0.58	0.03	1.95
Apodytes dimidiata	0.09	1.34	0.16	0.42	1.92
Bridelia micrantha	0.03	0.67	0.05	1.13	1.86
Celtis africana	0.11	0.67	0.21	0.95	1.83
Ficus thonningii	0.06	1.34	0.11	0.34	1.79
Maytenus arbutifolia	0.09	1.34	0.16	0.25	1.75
Ekebergia capensis	0.09	1.34	0.16	0.20	1.70
Mangifera indica	0.09	1.34	0.16	0.07	1.57
Combretum collinum	0.17	0.67	0.32	0.46	1.44
Schrebera alata	0.03	0.67	0.05	0.53	1.26
Entada abyssinica	0.06	0.67	0.11	0.40	1.18

Grewia bicolor	0.09	0.67	0.16	0.27	1.10
Erythrina brucei	0.11	0.67	0.21	0.10	0.98
Syzygium guineense (Willd.) DC. Subsp. guineense	0.06	0.67	0.11	0.20	0.97
Cupressus lusitanica	0.14	0.67	0.27	0.02	0.96
Anogeissus leiocarpa	0.03	0.67	0.05	0.19	0.91
Acacia seyal	0.03	0.67	0.05	0.14	0.86
Allophylus abyssinicus	0.03	0.67	0.05	0.12	0.85
Dombeya torrida	0.03	0.67	0.05	0.11	0.83
Spathodea campanulata	0.03	0.67	0.05	0.11	0.83
Citrus sinensis	0.06	0.67	0.11	0.04	0.82
Ficus sur	0.03	0.67	0.05	0.09	0.82
Citrus reticulata	0.06	0.67	0.11	0.04	0.81
Premna schimperi	0.06	0.67	0.11	0.00	0.78
Millettia ferruginia	0.03	0.67	0.05	0.03	0.75
Grewia ferruginea	0.03	0.67	0.05	0.00	0.73
Grevillea robusta	0.03	0.67	0.05	0.00	0.72
Total		100.00	100.00	100.00	300.00

Appendix Table 9. List of woody species encountered at study sites at grazing land use system Importance Value Index in decreasing order

Woody species density ha^{-1}, %RF=Percent Relative frequency, %RA=Percent Relative abundance, %RD =Percent Relative dominance and %IVI=Percent Importance Value Index.

Species name	Density ha^{-1}	RF (%)	RA (%)	RD (%)	IVI (%)
Calpurnia aurea	102.27	8.70	48.36	0.94	58.00
Croton macrostachyus	22.20	11.59	10.50	22.49	44.58
Vernonia auriculifera	39.67	4.35	18.76	0.29	23.40
Eucalyptus camaldulensis	16.92	2.90	8.00	7.95	18.85
Ficus vasta	0.55	4.35	0.26	12.73	17.33
Cordia africana	2.00	5.80	0.95	9.56	16.31
Syzygium guineense (Willd.) DC. Subsp. guineense	4.73	2.90	2.24	7.29	12.42
Deinbollia kilimandscharica	3.64	1.45	1.72	8.85	12.02
Stereospermum kunthianum	1.09	7.25	0.52	3.58	11.35
Albizia gummifera	2.18	7.25	1.03	2.66	10.94
Sapium ellipticum	0.73	2.90	0.34	4.38	7.63
Combretum molle	2.00	2.90	0.95	3.38	7.22
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	1.46	4.35	0.69	1.80	6.84
Acacia abyssinica	1.46	4.35	0.69	1.24	6.28
Faurea rochetiana	0.91	1.45	0.43	4.16	6.04
Bridelia micrantha	0.55	4.35	0.26	0.34	4.95

Celtis africana	0.18	1.45	0.09	3.12	4.66
Mangifera indica	1.46	1.45	0.69	2.15	4.29
Bersama abyssinica	1.82	2.90	0.86	0.09	3.85
Combretum collinum	1.46	1.45	0.69	1.42	3.55
Brucea antidysenterica	0.55	2.90	0.26	0.01	3.17
Premna schimperi	0.36	2.90	0.17	0.03	3.10
Olea europaea (Olea africana)	0.36	1.45	0.17	0.64	2.26
Citrus sinensis	0.91	1.45	0.43	0.09	1.97
Ehretia cymosa	0.18	1.45	0.09	0.38	1.91
Maesa lanceolata	0.91	1.45	0.43	0.01	1.89
Rhus vulgaris	0.36	1.45	0.17	0.15	1.77
Gardenia ternifolia	0.18	1.45	0.09	0.20	1.73
Grewia ferruginea	0.36	1.45	0.17	0.05	1.68
Total		100.00	100.00	100.00	300.00

Appendix Table 10.Wealth status of the household, area of homestead/homegarden (m^2), total number of woody species recorded and different diversity indices of tree species in homesteads/homegardens of sample households at the study sites.

Household Code	Area of Homestead (m^2)	Wealth Status	Abundance	Density	Richness	Shannon Diversity	Simpson Index
EB1H002	2500	Poor	27	108	8	1.673	0.754
EB1H005	1250	Medium	178	1424	10	1.424	0.675
EB1H007	1250	Poor	130	1040	5	0.336	0.132
EB1H011	625	Poor	143	2288	7	1.335	0.699
EB1H016	1250	Medium	74	592	7	1.048	0.494
EB1H017	625	Medium	18	288	4	1.292	0.698
EB1H019	2500	Poor	465	1860	4	0.529	0.245
EB1H020	625	Medium	182	2912	6	1.116	0.584
EB1H021	1250	Rich	149	1192	11	1.597	0.695
EB1H022	3750	Medium	80	213	8	1.877	0.830
EB1H025	1250	Poor	102	816	11	1.739	0.755
EB1H028	1250	Poor	90	720	8	1.418	0.638
EB1H030	625	Poor	48	768	4	0.555	0.261
EB1H034	312.5	Poor	84	2688	6	1.114	0.536
EB1H036	2500	Medium	57	228	7	1.254	0.603
EB1H037	1250	Poor	79	632	12	2.114	0.851
EB1H040	2500	Medium	388	1552	15	1.578	0.678
EB1H049	3750	Medium	131	349	12	1.772	0.771
EB1H050	1250	Poor	171	1368	10	1.260	0.627
EB1H054	625	Poor	56	896	5	1.135	0.580
EB1H058	1250	Medium	295	2360	14	1.266	0.520

EB1H060	1250	Poor	83	664	10	1.701	0.734
EB1H062	625	Poor	126	2016	13	1.430	0.594
EB1H072	625	Medium	93	1488	8	1.515	0.720
EB1H903	1250	Medium	70	560	5	0.975	0.566
EB2H328	2500	Medium	30	120	7	1.327	0.624
EB2H334	1600	Medium	101	631	9	1.266	0.583
EB2H335	1600	Medium	5	31	2	0.500	0.320
EB2H339	1600	Poor	33	206	4	1.058	0.602
EB2H343	1600	Rich	9	56	1	0.000	0.000
EB2H348	2400	Medium	190	792	14	1.787	0.762
EB2H349	1600	Medium	38	238	7	1.202	0.562
EB2H351	1200	Medium	68	567	7	1.226	0.627
EB2H354	1400	Rich	44	314	9	1.701	0.748
EB2H357	1600	Medium	72	450	11	2.059	0.851
EB2H359	1600	Poor	0	0	0	0.000	1.000
EB2H361	1600	Poor	129	806	16	1.991	0.768
EB2H362	1600	Medium	119	744	18	2.335	0.857
EB2H366	1600	Medium	28	175	7	1.620	0.755
EB2H368	200	Poor	30	1500	5	1.378	0.713
EB2H369	5000	Poor	252	504	12	0.746	0.281
EB2H370	1600	Medium	556	3475	8	1.060	0.576
EB2H371	5000	Poor	59	118	7	1.377	0.660
EB2H374	3300	Poor	74	224	10	1.674	0.737
EB2H381	1600	Poor	101	631	9	1.459	0.675
EB2H384	900	Poor	91	1011	9	1.326	0.580
EB2H390	1600	Poor	1	6	1	0.000	0.000
EB2H392	200	Medium	36	1800	9	1.762	0.773
EB2H394	1250	Poor	94	752	10	1.594	0.680
EB2H399	1600	Medium	59	369	8	1.623	0.745
EB3H224	5000	Medium	244	488	14	1.426	0.594
EB3H228	2800	Poor	41	146	7	1.043	0.451
EB3H229	600	Poor	6	100	1	0.000	0.000
EB3H236	2500	Medium	56	224	14	1.919	0.738
EB3H237	5000	Poor	68	136	9	1.339	0.588
EB3H238	1250	Medium	16	128	5	1.424	0.727
EB3H239	1250	Medium	0	0	0	0.000	1.000
EB3H241	500	Medium	212	4240	6	0.722	0.431
EB3H243	4025	Poor	5	12	3	0.950	0.560
EB3H250	450	Poor	43	956	6	1.007	0.481
EB3H251	2500	Medium	125	500	7	1.051	0.535
EB3H260	200	Medium	0	0	0	0.000	1.000
EB3H262	5000	Poor	243	486	5	0.727	0.404

EB3H271	10000	Medium	19	19	6	1.511	0.715
EB3H276	200	Poor	6	300	4	1.242	0.667
EB3H279	10000	Rich	45	45	12	1.947	0.788
EB3H280	200	Rich	12	600	5	1.314	0.667
EB3H283	200	Poor	22	1100	2	0.586	0.397
EB3H292	990	Medium	51	515	8	1.458	0.641
EB3H293	310	Medium	41	1323	9	1.824	0.802
EB3H294	8090	Medium	76	94	11	1.573	0.641
EB3H299	5000	Rich	52	104	11	1.979	0.814
EB3H300	7500	Medium	655	873	15	1.473	0.651
EB3H304	5000	Medium	359	718	13	1.421	0.669
EB3H323	870	Medium	79	908	5	1.220	0.648
EB4H075	625	Poor	120	1920	8	1.297	0.676
EB4H076	600	Medium	252	4200	7	0.704	0.364
EB4H079	625	Poor	23	368	6	1.276	0.620
EB4H081	625	Poor	58	928	3	0.686	0.438
EB4H084	500	Poor	59	1180	6	1.137	0.559
EB4H086	180	Rich	9	500	4	1.215	0.667
EB4H094	625	Poor	43	688	6	1.265	0.634
EB4H096	1250	Medium	18	144	5	0.961	0.457
EB4H097	1250	Medium	179	1432	8	1.467	0.675
EB4H102	1600	Poor	273	1706	20	1.970	0.797
EB4H110	1250	Poor	346	2768	16	1.510	0.611
EB4H111	1670	Medium	107	641	5	1.031	0.592
EB4H116	700	Medium	41	586	8	1.552	0.716
EB4H117	1670	Poor	126	754	9	1.413	0.619
EB4H122	2500	Medium	164	656	8	1.437	0.670
EB4H127	600	Medium	11	183	1	0.000	0.000
EB4H131	2500	Poor	27	108	5	1.018	0.483
EB4H133	900	Poor	80	889	7	1.018	0.442
EB4H134	1600	Poor	94	588	11	1.842	0.798
EB4H135	600	Medium	2	33	2	0.693	0.500
EB4H137	1670	Poor	16	96	10	2.155	0.867
EB4H140	700	Poor	29	414	5	1.413	0.725
EB4H143	3000	Poor	47	157	6	1.085	0.563
EB4H150	1500	Medium	62	413	7	1.392	0.698
EB4H164	2500	Medium	59	236	4	0.957	0.567
Total	19,2362.5		10,259	533.3			

Key: EB1= Wayu Kumba PA in Jimma Arjo district; EB2= Oda Haro PA in Bako Tibe district; EB3= Ongobo Bakanisa PA in Gobu Seyo district and EB4= Uke Badiya PA in Guto Gida district

Appendix Table 11.Scientific name, family, local name and origion of woody species recoreded on the land use of studied household of the study sites.

Scientific name with Authors	Family	Local Name	Origin
Acacia abyssinica Hochst. ex Benth.	Fabaceae	Laaftoo	Indigenous
Acacia seyal Del.	Fabaceae	Doddota	Indigenous
Albizia gummifera (J.F.Gmel.) C.A.Sm.	Fabaceae	Mukarbaa/Imala	Indigenous
Allophylus abyssinicus (Hochst.) Radlkofer	Sapindaceae	Malqaqqoo	Indigenous
Annona senegalensis Pers.	Annonaceae	Gishxaa/Goraa	Indigenous
Anogeissus leiocarpa (DC.) Guill. & Perr.	Combretaceae	Mokkii	Indigenous
Apodytes dimidiata E.Mey.ex Arn	Icacinaceae	Wandabiyoo	Indigenous
Bersama abyssinica Fresen.	Melianthaceae	Lolchiisaa	Indigenous
Bridelia micrantha (Hochst.) Baill.	Euphorbiaceae	Galaanoo	Indigenous
Brucea antidysenterica Lam	Simaroubaceae	Qomanyoo	Indigenous
Buddleja polystachya Fresen.	Loganiaceae	Anfaarree	Indigenous
Caesalpinia decapetala (Roth) Alston.	Leguminoseae	Qonxirii	Exotic
Cajanus cajan (Linn.) Millsp.	Fabaceae	Atara gugee	Exotic
Calliandra calothyrsus Meissn	Mimosaceae	Kaalaandaraa	Exotic
Calpurnia aurea (Ait.) Benth.	Fabaceae	Ceekaa	Indigenous
Carica papaya Linn.	Caricaceae	Paappaayyaa	Exotic
Casimiroa edulis La Llave	Rutaceae	Kaazmiir/Kookii	Exotic
Casuarina equisetifolia L.	Casuarinaceae	Shiwaashuwwee	Exotic
Catha edulis Forsk.	Celastraceae	Caatii	Indigenous
Celtis africana Burm.f.	Celtidaceae	Cayii	Indigenous
Citrus aurantifolia (Christm.)	Rutaceae	Loomii	Exotic
Citrus reticulata Blanco.	Rutaceae	Mandariinii	Exotic
Citrus sinensis (L.) Osbeck.	Rutaceae	Burtukaana	Exotic
Combretum collinum Fresen.	Combretaceae	Dhandhansa	Indigenous
Combretum molle R.Br. ex G.Don.	Combretaceae	Adda-jaboo /Rukeensa/Qanqalcha	Indigenous
Cordia africana Lam.	Boraginaceae	Waddeessa	Indigenous

Croton macrostachyus Hochst. ex Delile	Euphorbiaceae	Bakkanniisa	Indigenous
Cupressus lusitanica Mill.	Cupressaceae	Gaattiraa	Exotic
Deinbollia kilimandscharica Taub.	Sapindaceae	Dabaqqaa	Indigenous
Delonix regia (Hook.) Raf.	Fabaceae	Muka Dirre-Daawaa	Exotic
Dombeya torrida (J.F. Gmel.)	Sterculiaceae	Daannisa/Shakshak	Indigenous
Ehretia cymosa Thonn.	Boraginaceae	Ulaagaa	Indigenous
Ekebergia capensis Sparrm.	Meliaceae	Somboo	Indigenous
Entada abyssinica Steud. ex A.Rich.	Fabaceae	Ambaltaa/Doosheet	Indigenous
Erythrina abyssinica Lam. ex DC	Fabaceae	Beeroo	Indigenous
Erythrina brucei Schweinf.	Fabaceae	Waleensuu	Indigenous
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Baargamoo diimaa	Exotic
Euphorbia abyssinica J. F. Gmel.	Euphorbiaceae	Adaamii	Indigenous
Euphorbia tirucalli L.	Euphorbiaceae	Aannoo/Cadaa	Indigenous
Faurea rochetiana (A.Rich.) Chiov. ex Pic.Serm.	Proteaceae	Gaarrii	Indigenous
Ficus ovata Vahl	Moraceae	Qilinxoo	Indigenous
Ficus sur Forssk.	Moraceae	Harbuu	Indigenous
Ficus sycomorus L.	Moraceae	Odaa	Indigenous
Ficus thonningii Blume	Moraceae	Dambii	Indigenous
Ficus vasta Forssk.	Moraceae	Qilxuu	Indigenous
Gardenia ternifolia Schum. & Thonn.	Rubiaceae	Gaambeella	Indigenous
Grevillea robusta A. Cunn. ex R. Br.	Proteaceae	Giraaviiliyaa	Exotic
Grewia bicolor Juss.	Tiliaceae	Harooressa/Safaa	Indigenous
Grewia ferruginea Hochst. ex A.Rich.	Tiliaceae	Dhoqonuu	Indigenous
Jacaranda mimosifolia D. Don	Bignoniaceae	Jaakaraandaa	Exotic
Jatropha curcas Linn.	Euphorbiaceae	Jaatiroovaa/Qobboo	Exotic
Justicia schimperiana (Hochst. ex Nees) T.Anderson.	Acanthaceae	Dhummuugaa	Indigenous
Leucaena pallida Britton & Rose	Fabaceae	Lukiinaa	Exotic
Maesa lanceolata Forssk.	Myrsinaceae	Abbayyii	Indigenous
Mangifera indica L.	Anacardiaceae	Maangoo	Exotic
Maytenus arbutifolia (Hochst. ex A.Rich.)	Celastraceae	Kombolcha	Indigenous

Melia azedarach L.	Meliaceae	Niimii/Miimmii	Exotic
Millettia ferruginea (Hochst.)	Fabaceae	Sootalloo	Indigenous
Morus alba L.	Moraceae	Injoorrii Faranjii/Goraa	Exotic
Ocimum lamiifolium Hochst. ex Benth.	Lamiaceae	Ancabbii	Indigenous
Olea europaea L.	Oleaceae	Ejersa	Indigenous
Olinia rochetiana Juss.	Oliniaceae	Digaajjaa	Indigenous
Persea americana Mill.	Lauraceae	Avokaadoo	Exotic
Piliostigma thonningii (Schumach.)	Fabaceae	Liilluu/Yeqollaa Waanzaa	Indigenous
Pittosporum viridiflorum Sims.	Pittosporaceae	Soolee	Indigenous
Premna schimperi Engl.	Verbenaceae	Urgeessaa	Indigenous
Prunus persica (L.)	Rosaceae	Kookii	Exotic
Psidium guajava Linn.	Myrtaceae	Zayituunaa	Exotic
Rhus vulgaris Meikle	Anacardiaceae	Xaaxessaa	Indigenous
Ricinus communis L.	Euphorbiaceae	Qobboo	Indigenous
Sapium ellipticum (Hochst.) Pax	Euphorbiaceae	Bosoqa	Indigenous
Schrebera alata (Hochst.) Welw.	Oleaceae	Qasammee	Indigenous
Sesbania sesban (Linn.) Merr.	Fabaceae	Sasbaaniyaa	Indigenous
Spathodea nilotica Seem.	Bignoniaceae	Ispaatoodaa	Exotic
Stereospermum kunthianum Cham.	Bignoniaceae	Botoroo/Waashintee	Indigenous
Syzygium guineense (Willd.) DC. Subsp. afromontanum F.White	Myrtaceae	Baddeessaa	Indigenous
Syzygium guineense (Willd.) DC. Subsp. guineense	Myrtaceae	Goosuu	Indigenous
Terminalia laxiflora Engl. & Diels.	Combretaceae	Warakkee	Indigenous
Vangueria apiculata K. Schum.	Rubiaceae	Buruurii	Indigenous
Vepris nobilis (Delile) Mziray	Rutaceae	Hadheessa	Indigenous
Vernonia amygdalina Del.	Asteraceae	Eebicha	Indigenous
Vernonia auriculifera Hiern.	Asteraceae	Reejjii	Indigenous