ADDIS ABABA UNIVERSITY
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MSc. THESIS

Tree Species Diversity, Structure and Management Practices on Smallholders Farmer's Landscapes in Elfeta District, West Shoa Zone, Oromia Regional State, Ethiopia

By
Taressa Chawaka

A Thesis Submitted To The Department Of Zoological Science, School Of Graduate Studies In Partial Fulfillment Of The Requirements For The Degree Of Master Science In Biology

Advisor: Dr. Bikila Warkineh

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DECLARATION

I hereby declare that this MSc. thesis is my original work and all sources of material used for this thesis have been duly acknowledged.

Name: Taressa Chawaka Urgesa

Signature: _____

Date: _____

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This is to certify that the thesis entitled "**Tree Species Diversity, Structure and Management Practices On Smallholder Farmer's Landscapes In Elfeta District, West Shoa Zone, Oromia Regional State, Ethiopia**" submitted in partial fulfillment of the requirements for the degree of Master science in Biology. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the Department for open defense.

Name of Advisor	Signature	Date
Bikila Workineh (Ph.D.)	_____	_____

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We, the undersigned, members of the Board of Examiners of the final open defense by Teressa Chewaka have read and evaluated his thesis entitled "**Tree Species Diversity, Structure And Management Practices On Smallholder Farmer's Landscapes In Elfeta District, West Shoa Zone, Oromia Regional State, Ethiopia",** and examined the candidate's oral presentation. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the master degree with corrections.

Name of the Chairperson	Signature	Date
_____	_____	_____
Name of Advisor	Signature	Date
Bikila Warkineh (PhD)	_____	_____
Name of External Examiner	Signature	Date
_____	_____	_____

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LIST OF ACRONYMS

AIK	Associated indigenous knowledge
BD	Biodiversity
CSA	Central Statistical Agency
DBH	Diameter at breast height
EWANRO	Elfeta Woreda Agricultural and Natural Resource Office
FGD	Focus Group Discussion
GTP	Goals and Transformation Program
HHs	House Holds
Ha	Hectare
IVI	Important value index
KI	Key informant
MPTs	Multipurpose tree species
FMNR	Farmer to Management of Natural Resources
N-F	Nitrogen Fixation

ABSTRACT

The study was conducted in the smallholder farmer's landscape of Elfeta District, West Shoa Zone, and Oromia Regional State, Ethiopia. The objective of this study was to assess the tree species composition, structure, diversity, management practices and their socioeconomic importances. Three kebeles representing three different elevations highland, midland and lowland agro-ecology were selected. A total of 21 households were randomly selected to collect socioeconomic data and other information. Data on tree species diversity in crop fields was collected by categorizing households as rich, medium and poor. Tree species inventory was carried out on 21 plots (each, 50mx100m) in the smallholder's farmer's landscape. For tree species ≥ 5cm DBH, measurements of DBH and tree height were taken. A total of 78 tree species belonging to 48 families were recorded in the farmlands of the study area. 322 individuals tree species were identified in the three study areas, of which 165 were found at lowland (Etisakoye kebele), 103 species in midland (Ambelta Godeti kebele) and 54 species in highland (Harotufticha kebele) farmers landscape. The study indicated that the tree species diversity indices and species richness were higher at lowland than midland and highland agro-ecological zones. On the other hand, farmers at the study site also have developed experiences of tree species preferences for different purposes. According to the respondents, the main purposes of preference or retaining tree species on their farmland were for soil fertility, firewood, timber production, fencing, animal fodder, fruit, income generation, house construction, charcoal production and other purposes. Even if the diversity of tree species is better in the study, they need a series of management to save and sustain for the future generations to overcome the socio-economic and environmental problems.

***Keywords**:* - Important value index, Shannon diversity index, Species evenness, Species richness, Tree species diversity,

CHAPTER ONE

1. INTRODUCTION

1.1. Background the of study

Tree species are biologically exist on the smallholder farmland and/or planted by farmers. Farmers retain, protect plant and encourage trees species on farming landscapes to enhance socio-economic benefits, including provisions of food, cash income, medicines, fodder, fuel wood, timber, shade, bird-watching towers, and live fences grown on-farm boundaries (Arnold & Dewees, 1995). The retention of trees and shrubs in agricultural landscapes depends on local ecological knowledge regarding the use and conservation of species, the values of plants within subsistence and market economic systems, soil, spiritual feelings, and traditions associated with plants, as well as changes in socio-cultural structures (Neba, 2009)

According to Garrity and Verchot (2008), the conservation of plant species in the agricultural landscapes of the smallholder farmers is received as growing attention and priority in Africa. However, the ability of agro-ecosystems in biodiversity conservation varies greatly depending on the land management, land use, and environmental and socio-economic conditions of an area (Tolera Motuma *et al*., 2008 and Negash Mamo *et al.,* 2012). For example, in Southern and Southwest Ethiopia home garden and agricultural forest landscapes has higher number of tree species than the cereal-based agricultural landscape common to Central and Northern Ethiopia (Duguma Lalisa and Hager,2010; Tefera Bekele *et al*., 2014).

In Ethiopia, tree species of the farmed landscapes have been part of the farmed benefit as they serve a wide range of economic, socio-cultural, and ecological functions within the traditional farming systems (Kassa Habtemariam *et al*., 2011). Trees diversity in the farmed landscape also enhances the ecological quality of the landscape arrangement and provides habitat and stepping stones for the dispersal of plant and animal species (Perfecto &Vandermeer, 2002; Schroth *et al.,* 2004). Thus, tree species diversity can contribute to ecosystem productivity as well as sustainability under conditions of diversity in species traits and environmental aspect in agricultural landscapes (Kindt *et al.,* 2004).

Ethiopia is one of the globally exemplary centers of plant diversity, endemism and plant domestication with its diverse climates, altitudes, topography, soil conditions, natural vegetation

and cultures (Edwards and Ensermu Kelbessa, 1999; Teketay Demel, 2001; Hurni, 2007). However, the diverse natural vegetation and biodiversity have been and still are under intense pressure, especially in the highlands of Ethiopia, as a result of the long history of human settlement and cultivation, persistent deforestation, over-grazing and growing agricultural intensification (Tadesse Getahun, 2001; Lemenih Mulugeta and Telila Habte *et al.*,2015). As explained by FAO (2010), forest resources in Ethiopia have been declining and the biodiversity and other forest-based ecosystem services are clearly eroding (Kindu Mengistie *et al*., 2015, 2016).

Recent research carried out in Debark, North Gondar, showed that the indigenous tree species of the agricultural landscape are fast disappearing (Ruelle, 2014), including exotic species. The altitude, soil conditions, slope and household activities also affect the role of the agricultural landscape in biodiversity conservation (Nair, 1993; Mengistu Fentahun, 2008; Yirdaw Eshetu *et al.,* 2015). Agricultural intensification through the growth of improved seeds, inorganic fertilizers, and pesticides is also increasing the environmental degradation, which in turn leads to a decline in agricultural productivity and agro-biodiversity (Hadgu *et al.,* 2009). Landscape and agricultural production transformations caused by the rapid expansion of exotic tree species and economically important cash or food crops are threatening the traditional farming systems, which are more biodiversity-friendly (Achalu Nigusie, 2004; Abebe Tesfaye, 2005 and Dessie Gessesse, 2007).

Generally, the variation in tree species composition and diversity among different locations and land uses indicated that more studies are needed across diverse, ecological and socioeconomic settings to inclusively understand the role of agro ecosystem in plant diversity preservation. Still in Elfeta Woreda, research done and information on farmland tree species diversity and their socio-economic importance were not discovered attentively. Therefore, the researcher initiated to 1) document tree species diversity on the smallholder of farmland landscape and analysis their management practice, 2) to assesses the socio-economic importance of tree species 3)to analyze the effect of agricultural expansion on these tree species diversity on farmed landscapes in case of Elfeta Woreda, west shoa of Oromia, Ethiopia.

1.2. Research problems

Trees give a wide range of services to smallholder farmers. For thousands of years, farmers in Ethiopia practiced different modes of agricultural system. One of the farming systems they developed through the ages were a mixed systems that indicates a range of agro forestry practices related to their local physical and socio-cultural conditions. The research conducted by Mohammed Assen & Zemede Asfaw (2015) showed that, tree plants integrated with the agricultural crops of smallholders characterize various forms of traditional agroforestry systems in different countries and is almost a universal occurrence in Ethiopia . Among the traditional agroforestry systems, farmland agroforestry practice is one of part of the farmed land useful thing in Ethiopia which have been concerned with socio-economic, socio-cultural and ecological functions within the traditional farming systems (Kassa Habtemariam *et al*., 2011).

Due to their socio-economic and ecological value, farmlands agroforestry are reducing by several factors, including human population pressure, excessive droughts, desertification and farming systems arranged towards cash crops that good to motivate monocultures (Gonzalez, 2001 and Augusseau *et al*., 2006). On the other hand, some negative impact posed by tree plants on farmed land like too much shade to herbaceous crops, competition for space and other resources, allelopathic effects on crops , may be discourage farmers to incorporate trees in their farm lands.

Tree species on the smallholder landscape faced so many threats and are disappearing fast due to human effects on landscapes of many countries; this is the case in Ethiopia, particularly in Elfeta woreda. The most direct threats to all these trees are clearing by humans, i.e. anthropocentric activities. For example, according to (Gibbons and Boak, 2002; Aguilar and Condit, 2001), the legal and illegal deforestation of scattered trees is widespread in every landscapes of worldwide.

In order to increase the conservation of on-farm trees, there is a need to involve farmers and educate and create awareness about tree species that are to be introduced to the farmland. Tree management requires farmer's involvement for a clear understanding about the result come from the tree species. Research developed by (Hachoofwe, 2008; Tabuti, 2012) explained that, tree

management practices and challenges that impede tree planting, protection, and sustained uses must also be understood.

However, still now there were no data in the study area which could help in analyzing and recommending proper management actions to sustain the farmland agroforestry system for the benefit of the people. Therefore, the present study was aimed at assessing the composition, structure, diversity of trees, management practices and socio-economic benefit and factors affect the management of tree species of farmland agroforestry in Elfeta woreda.

1.3. Objectives of the study

1.3.1. General objective

- The overall objective of the research is to describe the tree species diversity, socio-economic importance, and management practices of tree species on smallholder farming communities in Elfeta woreda of west shoa, Oromia regional state.

1.3.2. Specific objectives

The research has the following specific objectives:

- Identify the farmland agroforestry tree species composition in the study area.
- To investigate the structure of tree species in the study area.
- Compute the farmland agroforestry tree species diversity in the study area.
- Assess farmer's management practice of farmland tree species in the study area.
- To analyze the smallholder farmers' preferences and the purpose of preferring tree species.
- Assess the socio-economic factors that affect sustainability of tree species diversity in the study area.

1.4. Research questions

In order to achieve the above objectives, the following research questions were used:

- What is the farmland agroforestry tree species composition in the study area?
- How does the population of tree species structured in the study area?
- How diverse is the farmland agroforestry of the study area in terms of tree species?
- Is there any management practice for tree species diversity in the study area?
- How and why local farmers preferred and retain the tree species on the farmland?
- Do socio-economic factors affect the sustainability of tree species diversity on farmland?

1.5. Significance of the study

This research will contribute to identify the tree species composition, structure and diversity in agroforestry farmland systems in the study area. It will help the people of the study area to be aware more about the importance of tree species and give attention to manage the threatened tree plants. In addition, the documentation of the tree species can be part of the information source for those who want to conduct further research on tree species diversity on farmland and the development of awareness in society.

1.6. Limitation of the Study

Because of time and finance the study was only focused on the selected kebeles of the Elfeta Woreda. On the other hand, to collect data from the study area, the researcher faced the following challenges which means due to the pandemic disease (Covid-19) the researcher couldn't move throughout the study area to gather information from the informants and households because physical contacts were very difficult to carry out a discussion with the smallholder farmers.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 The role of trees in the agricultural landscape

Ethiopia's economy is specially based on agriculture which supports 83 % of the population rain-based grain, specially teff, maize and wheat as well as livestock, mainly cattle, sheep and goats (Deressa Temesgen *et al*.2009). Through farmer to management of natural resource (FMNR) and active tree planting on farms, the widespread growth of trees on agricultural land can play an important role in enhancing tree diversity and cover at landscape scale. This can mitigate and reduce deforestation and land degradation with large potential for soil organic carbon and nitrogen sequestration (Bewket, 2002 and Gelaw Aweke *et al*., 2014).

Campbell *et al.(* 1991) explained that most farmers use trees specially for their traditional activities such as the provision of fruit, fodder, wood, shade, meeting places, medicines, soil improvement role and also use tree for flood regulation, disease regulation and pest regulation, pollination; also used to provide cultural services such as spiritual aspects, recreation, and cultural diversity, spiritual and religious values.

In fact, many farmers in Ethiopia, including those who have not practiced any form of intensive tree planting, implement FMNR to indigenous species scattered on farm, and fruits, but also for ecosystem services such as shade and soil improve (Poschen,1986). In most cases, farmers themselves are aware of the contribution of trees as a protector against poor yields, food shortages, fuel scarcity and as a source of medicinal treatment (Kasolo & Temu, 2008). These values are especially important to the low income peasant farmers where there is need for diversification of farm products (Masiga & Ruhweza, 2007).

2.2 .Environmental importance of tree species on the farmland

As it defined by Tim (2007), different agroforestry systems and practices are designed to reduce the risks and increase the sustainability of large-scale agriculture. If we compare agroforestry land use system with sole cropping system with respect to nutrient input and accumulation, agroforestry is the best one. Trees increase nutrient input by adding nutrient to the soil through N-fixation, nutrient pump from deeper soil horizons and dead root as organic matter

(Bellow, 2004). Therefore, smallholder farmers which are unable to get chemical fertilizer can improve their crop production (Tim, 2007).

In mixed-farming systems where trees and crops grow in combination, various types of interactions exist between the associates which can also improve the soil quality. Nair (1993) reported that trees on croplands are useful to improve soil fertility due to their organic inputs with nutrient recycling through mineralization.

2.3. Socio-economic importance of tree species on the smallholder landscape

In several rural areas, trees play an important role in household food security. Forests and trees provide farmers food and fuel, and they also provide cash income particularly for the poor, and they provide insurance against drought and crop failure. According to Tesfaye Abebe (2005), farm trees of diverse species serve different socio-economic and ecological functions. Farmers have historically protected, planted and managed trees on their land in order to get different advantageous. Agroforestry trees can reduce dependence of the livelihood on the forest by providing different goods such as fuel wood, construction material etc for the local community. Wickens *et al.* (1985) estimated that 75% of the tree species (7,000-10,000) of tropical Africa are used as browse and this fodder trees contribute in several ways to the food security of households: that means they can contribute to domestic livestock production which in turn influences milk and meat supply; in addition, fodder given to animals used to produce manure for organic fertilizer. Additionally, tree provides increased firewood production as well as reduces soil erosion (Lana *et al.,* 1990).

2.4. Crop integration with trees in Ethiopian smallholder farmed landscape

Asfaw Zemede (2001) said that for most of Ethiopia, observation makes it clear that the crops are integrated with the natural trees that were retained at the time of converting forests and woodlands to farmlands. Farmers usually retain between 1–20 trees of selected species per hectare and minimize impact on the crops through occasional lopping and pollarding of trees (Poschen,1986). Examples of this practice include *Cordia africana* intercropping with maize in sub-humid zones , *Faidherbia*-based agroforestry in *teff-wheat* zones (Poschen,1986) and a diverse range of *Acacia* species such as *A. Tortilis* and *A. senegalin* fields in low savanna regions (DegefuTulu *et al.,* 2011). It is also common for farmers to carefully plant and manages trees on

their farms, such as fast growing timber predominantly using *Eucalyptus spp*. or fruit orchards (Deininger and Jin, 2006). In earlier years, farmers never cleared forests and woodlands completely. Instead, they identified a suitable place for cultivating crops and then removed most of the wild plants, retaining some of the multipurpose species at some spots in the farm, and integrate their crops and managed them together. When the seedlings of the preferred species emerged at the desired location, they protected them, and thus they always practiced traditional agroforestry. Research has shown common methods of tree plant integration in farmed landscapes along with the common species in northern Ethiopia (Hachoofwe, 2008; Tefera Bekele *et al.,* 2014; Ruelle, 2014) and many of them are also found in other parts of Ethiopia. The tree species in the country shows many forms and contain different preferred species. One of the common forms and species are indigenous species growing naturally from the soil seed bank in Ethiopia include many indigenous *Acacia* tree species, *Ole europaea* **ssp**. *cuspidata*, *Cordiaafricana*, *Ehretiacymosa*, *Croton macrostachyus*, *Ziziphusspina-christi, Balanitesaegyptiaca*, *Moringastenopetala*, *Ficusspp*., and many others, depending on the agroecology and location. Other species are those promoted by modern agriculture and by traditional farmers, including mostly leguminous trees, both indigenous species (e.g.,*Acacia abyssinica*, *Acacia tortilis*, *Acacia seyal*, *Faidherbia albida*, *Sesbania sesban*, *Sena spp., Tamarindus indica, Erythrina brucei*) and exotic species (e.g., *Leucaena leucocephala, Cajanus cajan, Eucalyptus spp., Cytisus proliferus, Acacia saligna*). Still other exotics growing in the farmed landscapes are *Eucalyptus spp*, exotic *Acacia spp.,Cupressus lucitanica*; many of these are intended to be fast growers. For eucalypts (*Eucalyptus globulus*, *E. camaldulensis, E. saligna*), the running forces are markets and economic incentives (Abiyu Abrham *et al*., 2015) that sometimes end up claiming suitable farmlands.

2.5. Patterns of tree integration in farmed fields

Most of time, farmers integrate crops with trees in different patterns in response to local conditions. Tree species of farmed landscapes in general can be introduced by being scattered in croplands. This gives the fields a characteristic of dotted look, in mosaic manner, with trees and vegetation covers in various locations, on field margins; on non-arable land that naturally reforms on farmlands lacking of crops or grass; around homesteads by households; on farm

border demarcating farmlands of different families, in crop on arable lands (Arnold and Dewees, 1998). Tree species are found in different areas, zones, habitats, and the like, being generally scattered in the field, field margins, grazing areas, stream banks and dry river , homesteads, fences, and home gardens.

2.6. Indigenous knowledge of Tree species and their management on-farm land

Smallholder farmers maintain many tree species in and around their farmland and homesteads, and in turn derive ecological, material, and economic benefits from them. The indigenous knowledge held by local farmers of trees in farmed landscapes is cornerstone for modern science to manage, develop, conserve, and use on-farm trees. Research reported by Gerique (2006) identified that Indigenous knowledge of trees and their uses is best studied by using the methods of ethnobotany, the science that deals with the relationship between people and the plants they know and use in their environment. Thus, ethnobotanical focus studies are very much required to explain the socioeconomic and cultural roles and impacts, to select good trees, preferences, and growth of tree species on-farm maintenance, and market purpose and expansion (Van Damme and Kindt, 2012).

Indigenous local knowledge required for proper understanding, care, and use is mostly held by the community as a whole as their common shared knowledge rather than by individuals, which initiates undertaking wide surveys. Smallholder farmers, who are also owners and upholders of indigenous knowledge in Ethiopia generally, have good understanding about the multiple uses of trees on-farm. However, the current protection, conservation of trees and replacing of new ones is not encouraging (Hachoofwe, 2008; Kassa Habtemariam *et al.,* 2011).

2.7. Historical perspectives on tree cultivation and domestication on-farm

In Ethiopia, the integration of trees into agriculture come out some 7000 years ago and has developed during later millennia into number of noticeable indigenous agroforestry systems (Getahun Addis, 1974, Kanshie, 2002). Also Getahun explained that in ancient times, the cultivation of domesticated and wild fruit trees was concentrated in monasteries and used as major source of food for the nuns, monks, hermits and warriors. The historical development of gardening in Ethiopia also followed the human settlement history which is supported by Pankhurst (1993) and much older in northern Ethiopia than in the southern Ethiopia.

On the other hand, it has said to be that farmers started opening up the forests and woodlands to expand their cultivation but left many of the useful tree species, usually leaving the trees on-farm and the shrub species on field margins (Asfaw Zemede, 2001). The way of tree introduction into farmlands is in most cases restricted to the small-scale planting of trees around homesteads, farmlands, and home gardens. This has been practiced by farmers in Ethiopia since ancient times. However, formal government tree planting programs have been started in 1910 (Nawir *et al*., 2007).

Currently, the research reported by Brown (*et al*., 2012) stated that agricultural land in Ethiopia is estimated to cover 52.62 ha (46% of the country's total area) and give support for the livelihoods of 83% of the population, form 80% of export incoming and 73% of the raw materials in agricultural based industries (Bishaw Badege *et al.,* 2013).

2.8. Socio-economic factors affecting tree species diversity in farmland

The number of tree species and number of individual trees in farmland is varies due to socio-economic factors. Species composition and their densities in agricultural land are the result of local natural aspects as well as human influences. A host of biological, socio-economic and policy factors influence farmer conservation of tree density in agricultural land (Boffa, 1999).

In fact, the presence of the tree species in agricultural field depends on the farmers who manage the land and their tree species in agricultural field which gives support to resource-poor farmers (Gardon *et al.,* 2003). The household's resources, mainly land size have an impact on tree species diversity management. For instance, farmers with small land holding cannot have a large stock of trees since the purpose of the land is primarily used to produce crops for consumption. In other way Scherr (1995) explained that Large land holders, could produce a large volume of tree. Tesfaye Abebe (2005) also shows that size of the farm affect tree species richness of farms and agricultural practices in this farm also brings the degradation of species diversity. Even though agricultural activities cause a decrease of species diversity in the cultivated lands, other species are confined to show better development in the agricultural areas. Species composition is influenced by farmers' expectations from trees because many plant contribute to the rural population products like Leafy vegetables, fruits, fire wood, medicines

etc. These products are also useful sources of income through harvesting, processing and commercialization activities (Nikiema *et al*., 2005).

The agroforestry system shows how farmers value and manage plant resources in their territory. It contributes to the conservation of plant genetic resources and to biodiversity conservation. Number of species kept in the crop fields is witness to the productive uses of species diversity conservation. Species composition in the farmland is influenced by ecological and economic factors in the area of socio -cultural environment (Boffa, 1999). In this category, two major groups of variables can be clearly separated; local environment and household environment. Among the local environment, commercialization and access to market, reliance on off-farm income, access to inputs and access to off-farm resources are believed to influence species diversity of farms. Commercialization and access to market often causes a decline in the diversity of species. On the other hand, farmers believed to make amends their lack of access to markets and resources by producing their consumption from home production (Shaxson and Tauer, 1992).

Farmers with little access to resources, particularly land, may focus on the production of few ingredient food crops or trade-off home production of crops with off-farm waged work, depending on their individual comparative advantage. And also, protection of trees and replanting are not encouraged in farmland due to factors like population pressure, land degradation, the farmer's own perceptions, attitudes, and management, small farm size (low hectare. These factors should be considered when it comes to the problems of evaluating the introduction of trees in farmed landscape (Mohammed Assen & Zemede Asfaw, 2015).

2.9. Tree species management practices and its preference on farmland

Juma *et al* (2001) said that by following up the initial results with more conventional scientific analysis, participatory research methods revealed important findings about local knowledge of the different sources of nutrients available to farmers. The basic idea of participatory research is that farmers and professional researchers have different knowledge and skills and by working together the two groups, may achieve better results than by working alone (Hoffmann *et al*., 2007). Participatory approaches have proved effective in generating

using new technologies for change of natural resources adaptive and applied research programmes (Sutherland, 1998).

Farmers grow trees for different purposes and no particular tree species can be regarded as being best for all requirement of the household. The choice of trees for agricultural system depends on the purpose of the farmer whether to grow them for individual or industrial use (Sanjeev *et al*., 2012). The trees that are important for soil fertility improvement may not be preferred by farmers that need fuel-wood and forage. However, farmers have planting trees in a specific case; they nearly always work several functions simultaneously. Trees planted for fodder may fixing-nitrogen and improve nitrogen availability in the soil (Schroth and Sinclair, 2003).

Generally, the selection of tree involves identifying and prioritizing farmers‟ needs in tree management and preferences for soil fertility enhancement. Furthermore, by taking the knowledge of local environmental condition into consideration, a participatory approach helps to identify tree species for selection that can meet both social and environmental needs (German *et al.,* 2006).

It is difficult to conserve biodiversity and natural resource in the place where population growth is very high (McNeely, 2004). However, it has been proven that indigenous people still living in the traditional manner have managed natural resources with sustainability by respecting to some what the rules of the ecosystems. The agroforestry farmland system is one of the examples where natural resources have been quite well managed under traditional land use practices. The selective retention of tree species in agricultural landscapes is a traditional agroforestry practice in the smallholder sector of much of Africa (Boffa, 2000).

The good management practice of farmlands is to initiate the advantages supplied by the trees, while reducing the disadvantages. This can be done through various management techniques, including selection of tree species with desirable outcomes, proper tree spacing (scattered, in line), tree management (pruning, lopping, controlled harvesting, etc.), selection of associated crops and livestock management (Verheij, 2003).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in Elfeta woreda, west shoa zone, Oromia regional state, Ethiopia. Elfeta district is located between 8−**9°N** Latitude and **37°−38°**E Longitude at an altitude ranging from 1800−3268m.a.s.l and **112** km away from the West of Addis Ababa(**EWANRO, 2015**) . It is bounded by Chobi Woreda in the North, Jeldu Woreda in the East, Dendi woreda in the South and AmboWoreda in the west. The specific study areas in the district are Haro Tufticha, Ambelta Gudeti and Itisa Koye kebeles.

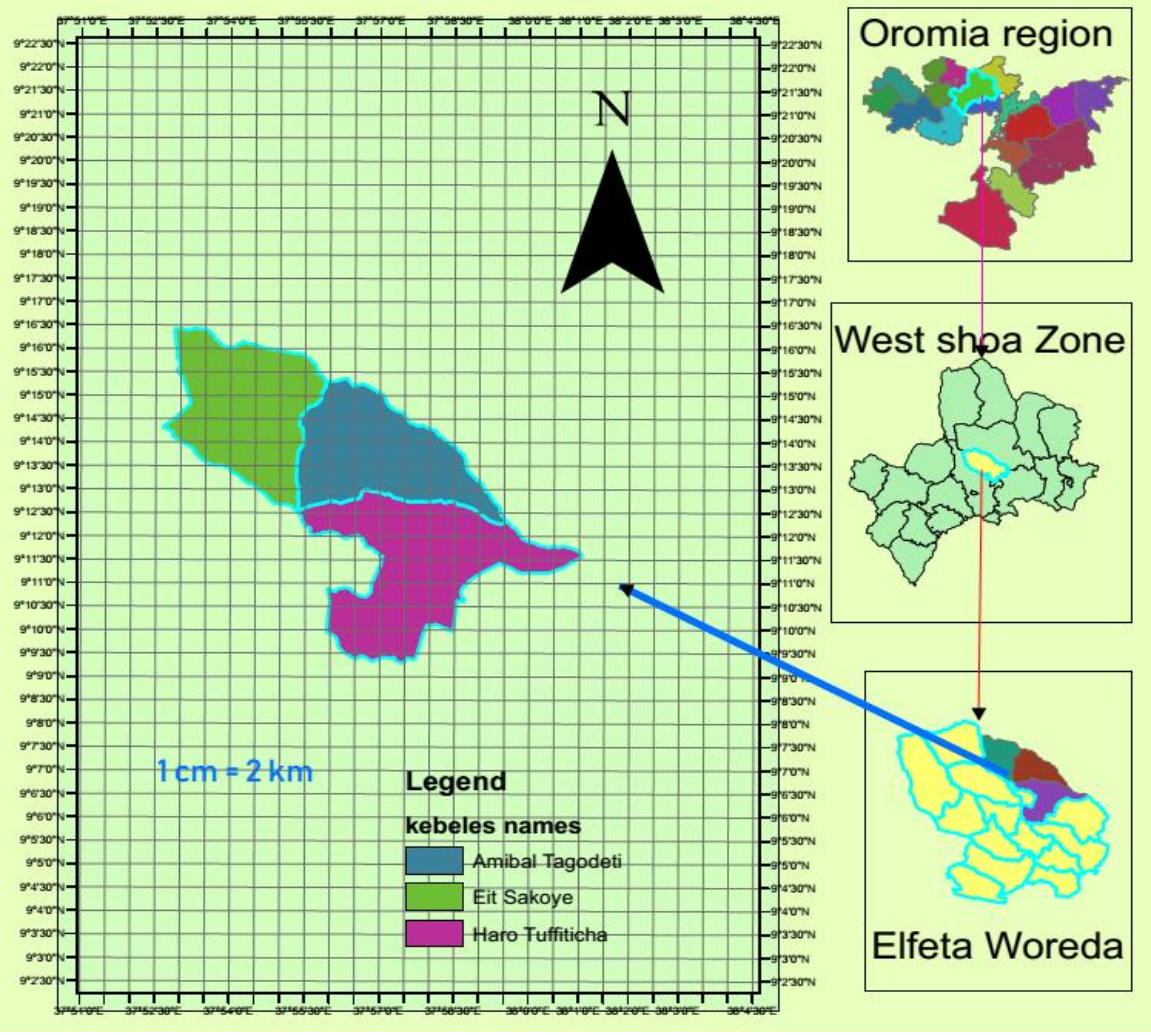


Figure 1. Map of Oromia regional state showing West Shoa and the study district

As **EWRA (2018**) revealed, the total area of Elfeta District is estimated to be about 44,518ha. Out of the total area of Elfeta district, 25,807ha is used for cultivation, 1.53 ha is used for water bodies, 787 ha is used for forest cover, 8150.5 ha is used for grazing land, 1.5 ha is not used for any development purpose and 9770ha is used for other purpose like road, religion organizations, residential area .

The major soil textures found in the district are Red soil (60%), Black soil (20%), Sandy soil (15%) and the land of these areas exclusively used for agriculture.

3.1.2. Climate and agro-ecology

The climate of Elfeta Woreda is characterized by relatively medium temperature throughout the year with minor seasonal variations. The minimum and maximum temperatures of the study area are about **11^0C** and **23^oC** respectively with the average temperature of 17^0C, where as the minimum and the maximum annual rainfall ranges between 500mm −1172mm, with a long period of summer rain from May to September (**EANRO, 2015**)

The people in the study area categorized the land into three agro-ecological zones: namely high land (45%), midland (40%) and low land (15%). Three *kebele* were selected purposively Haro Tufticha from highland, Ambelta Godeti from midland and Itisa Koye from lowland.

3.1.3. Population and socio-economic activities

Based on the figures published by CSA (2007), this woreda has an estimated total population of 95,611, of whom 47,877 were men and 47,734 were women. About 8323 were urban dwellers and 87,288 were rural dwellers. The majority of the population were Protestant(75%); While 20% of the population practiced Ethiopian Orthodox Christianity, and 5% practiced traditional religions(Wakefata or Waka tokicha in Afan Oromo). Ethnically, the population of the Woreda were consists of Oromo ethnic groups.

The livelihoods of most farmers depend on crop production and livestock rearing. The major land use types of the study areas are cultivated land, grazing land, Forestland, shrubland and Homegarden land. The agricultural activities carried out in the study areas are cereal crops like Wheat (*Triticum aestivum)*, Barley (*Hordeneum vulgare*), *Teff* (*Eragrostis abyssinica*),

sorghum (*Sorghum bicolor*), maize (*Zea mays*), Nug(*Guizotia abyssinica*), sunflower (*Carthamus tinctorius*), Enset(*Ensete ventricosum*)and. A variety of vegetables such as onion (*Allium cepa, Allium ascalonicum*), garlic(*Allium sativum*), tomato (*Lycopersicon esculentum*), chili (*Capiscum annuum*), carrot (*Daucus carota*), and cabbages(*Brassica oleracea*), Pomato(*Solamum tuberosum*), pulse crops such as Pea(*Pisum sativum*), Bean(*Phaseolus spp*) and chickpea(*Cicer arietinum*); cash crops like Gesho*(Rhamnus prinoides)* and coffee(*Coffea arabica*), fruit plants such as Orange(*Citrus sinensis*), Tirngo(*Citrus grandis*) Banana(*Musa acuminate*), Leom(*Citrus aurantifolia*), Papaya(*Carica papaya* L.), Avocado (*Persea americana*), Apple(*Malus domestica*), Mango(*Mangifera indica*) and stem eaten plant like sugar canes(*Sacharum officinarum*) are grown (**EWANRO, 2015**).

Figure 2. Some agricultural activities of Etisakoye *kebele* (photo taken by Teressa, 2020**)**

3.2. Methods

3.2.1. Research design

3.2.1.1. Selection of study sites

Three rounds of field trips were made to the study area to collect data. The first reconnaissance visit was carried out in January 2020, the second and the third trips were implemented in June 2020 and October 2020 respectively to collect general information on the biophysical and socioeconomic conditions of the study area. During the reconnaissance survey, study sites including rural *kebeles* were determined using random sampling technique by referring to the three agro ecological zones, namely highland (*Baddaa*), midland (*Badda Daree*) and lowland (*Gammoojjii*) based on their altitudinal occurrence. One *Kebele* was selected purposively from each of the agro-ecology based on the tree coverage.

Table 1. The Study *kebeles* and their respective agro-ecological zones

Kebeles	**Agro-ecologis**	**Elevation**
Haaro tufticha	Highland	1800m
Hambelta gudeti	Midland	2500m
Etisa koye	Lowland	3268m

Figure 3. Photo shows agro-ecological category of the study sites (photo taken by Teressa. 2020)

3.2.1.2. Key informants and household selection

On the second field trip, June 1–30, 2020, selection of informants and interviewing process were made in each *kebeles*. The Key informants (KI) are persons who have knowledge about the historical background of tree species diversity in the area, tree conservation practices, changes in local conditions and village households who have continuously lived for more than 20 years in the villages. To select key informants, village tour was made with *kebele* council.

During the village tour, four individual farmers were asked to give the names of key informants. At each village, out of 5 key informants suggested from each *Kebeles*, six top ranking

were selected to categorize HHs into wealth classes. The purpose of selecting KIs was to categorize villagers by wealth class and to provide information on agroforestry management and historical development of on farm trees. To classify households (HHs) in each village into different social classes, wealth ranking was carried out by using the method used by Crowley (1997). Key informants were used to classify all individual HH's in each selected villages into three main wealth categories (rich, medium, poor) based on the criteria of farm size, number of cattle, money deposited in the bank, availability of house in town etc.

Finally, 21 households (HHs) were selected to assess tree species diversity and their socio-economic importance.

Table 2. Number of sampled kebeles, and households by wealth class.

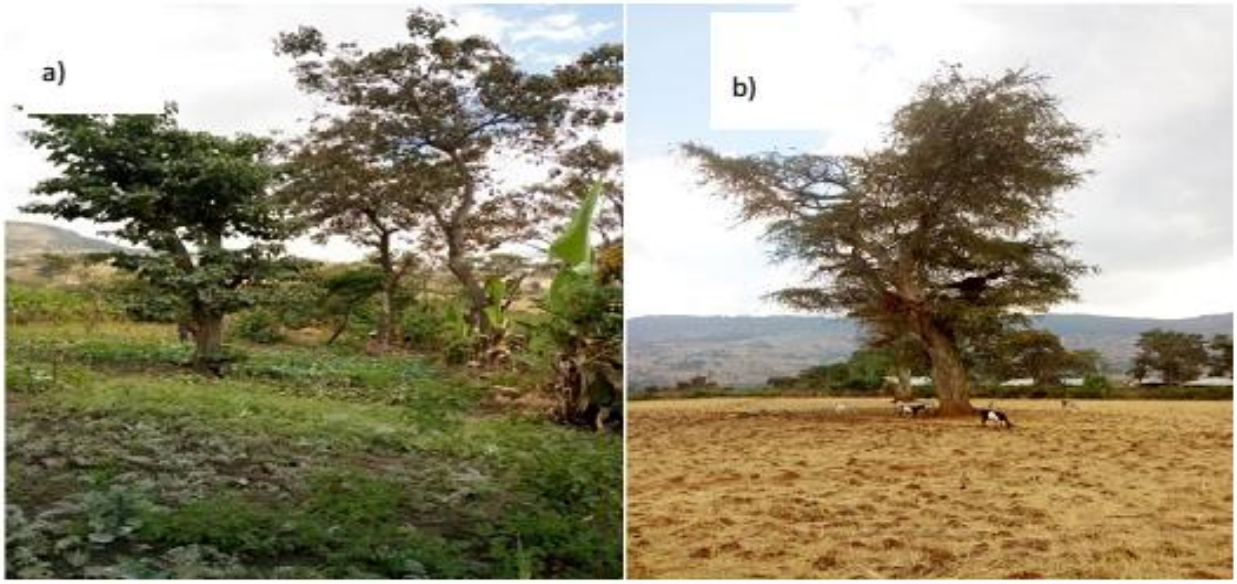
Sample Kebeles	**No. of HHs by Wealth class**			
	Poor	**Medium**	**Rich**	**Total**
Itisa Koye	2	3	2	7
Haro Tufticha	2	3	2	7
Ambelta Godeti	2	3	2	7
Total	6	9	6	21

Data on socioeconomic uses of tree species were collected through interview using semi-structured questionnaire and focus group discussions on 21 households. Secondary information related to the study areas was collected from previous studies, District Office of Bureau of Agriculture and other published sources.

3.2.1.3. Tree species inventory

Before starting field survey, reconnaissance survey was carried out in the selected *kebeles* to get first-hand information about the study area. In the present study, a tree is an independent woody plant that grows from a single main stem. Inventory of tree species were carried out on farms of sampled households. Due to species richness calculations, all tree on the farms were recorded according to the concept used by Tesfaye (2005). But in counting the individuals of each tree species, those trees with a minimum Diameter at Breast Height (DBH) > 5cm at 1.3 m height from the ground were included, and their diameter was measured by diameter tape. Inventory of homegarden trees, trees on farmland and on grazing lands were inventoried by taking 3 land use system as a quadrat sample from a HH farm based on the idea used by Nikiema (2005). From each three kebeles, 7 agricultural farm plots having total 21 sample plot of three a quadrat size each with 50m × 100m=5000m^2(0.5ha) land use system like homegarden , grazing land and farmland were used. Farm size was estimated by farmers in their local measurement unit, called "hand(chikile)", which is 2hand=1m.

The parameters taken during the inventory were number of tree species and DBH to estimate number of stems per farm or hectare, and the basal area per farm or hectare of the sampled household's farm area, respectively. Samples of all trees species encountered in the plots were recorded by their local names with the owners of the land involvement.



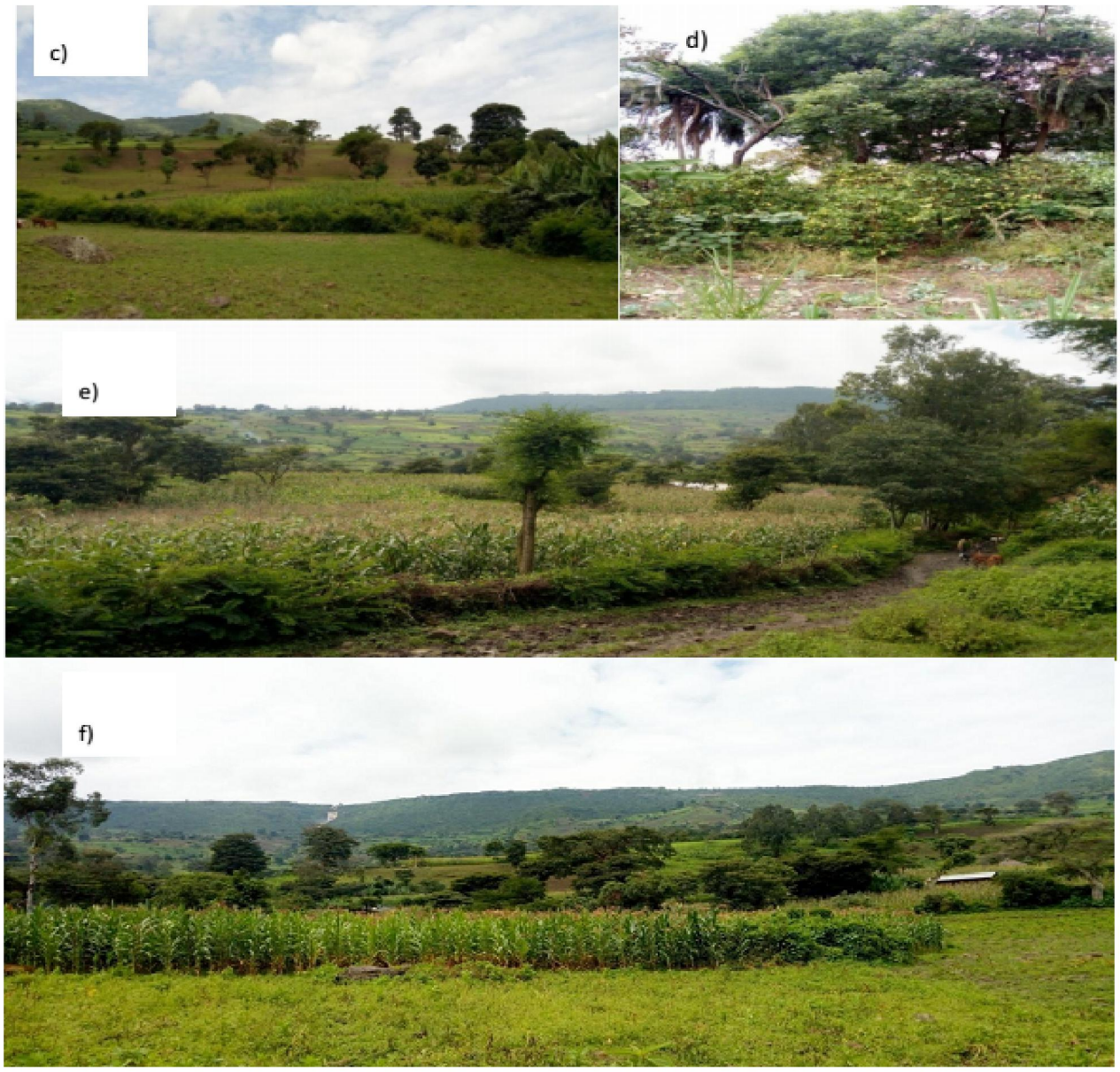


Figure 4.Typical tree species observed in the small holder farmer's landscape of the study area of Elfeta woreda(photo taken y Teressa, 2020)

a) Vegetables under *Cordia africana* ***b)*** *Faidherbia albida* in teff and used as fodder for goat **c)***Ficus vasta, Croton macrostachyus, Ficus thonnengii* and *Faidherbia albida with maize and teff soil* ***d)*** *Coffea arabica* planted under *Ekebergia capensis* and *Phoeenix reclinata* ***e)*** *Cordia Africana and Faidherbia albida with maize* ***f)*** *Faidherbia albida, Cordia Africana, Ficus vasta, Eucalyptus globules, Maesa lanceolata and other tree species in home garden.*

3.3. Data collection methods

As mentioned above, data collection was made during the second and third-round field trip, June – October 2020. Data was collected from household by interviewing them at their farmland area, key informant interviews about the information of household and farmland trees, focus group discussion from each *Kebeles* (combination of household and key informants) and direct field observation (Fig.5). The criteria of selecting of sample districts and HHS were based on agro ecology and potential of traditional agroforestry practices. The household's semi-structured interviews were conducted to separate socio-economic values of on farm trees, preferred useful tree species, awareness of the farmers about on farm tree management and challenges they faced to treat these trees. Biophysical information (DBH), height and numbers of tree species in different land use systems were used. Height and DBH of tree species were measured by using diameter tape. In this case, local names, number of all live individuals and DBH of all tree species with DBH ≥5 cm and height ≥1.3 m only were recorded

For better communication with the respondents, questionnaires were translated into the local language (Afan Oromo) and presented to them, to evaluate clearly their understandings and knowledge.

Figure 5. Households interviewing and focus group discussion (Photo taken by Teress, 2020)

3.4. Data analysis

Tree species having DBH ≥5 cm, height ≥ 1.3m were used in the analysis of relative dominance of a species in an area. Their abundance, DBH, basal area, relative density, relative frequency and importance value index (IVI) were used in the description of tree species. Species diversity and evenness were measured using the Shannon-Wiener diversity index. To assess the similarity between tree samples of the study area, the Sorensen coefficient of similarity index was used.

The data collected through the questionnaire, interviews, species richness, diversity, structures were analyzed using Microsoft excel version 2007.

3.4.1. Structural Analysis

3.4.1.1. Basal area

Basal area is the cross-sectional area of tree stems at breast height. Basal area was calculated for each tree species with diameter ≥ 5 cm as:

$$BA = \frac{\pi(DBH)}{4} \quad \text{Where,} \quad \pi = 3.14$$

BA = basal area (m^2)

DBH = diameter at breast height (cm)

3.4.1.2. Importance value index (IVI)

The IVI indicates the importance of individual tree species in the farmland and was calculated by using three components (Kent & Coker 1992) as follows;

$$\text{Frequency} = \frac{Area\ of\ the\ plot\ in\ which\ species\ are\ occured}{Total\ number\ of\ quadrats\ studied} \text{x}100\%$$

$$\text{Relative frequency} = \frac{Frequency\ of\ a\ species}{Sum\ of\ frequency\ of\ all\ species} \text{ X } 100\%$$

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{Total\ number\ of\ individuals\ of\ all\ species} \text{ X } 100\%$$

$$\text{Relative dominance} = \frac{Total\ basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species} \text{X } 100\%$$

IVI = Relative density + Relative frequency + Relative dominance

3.4.2. Species Diversity analysis

To analyses species diversity, two components are important: richness and evenness. The species richness refers to the number of species per farm while evenness refers to their relative abundance. To determine species richness of each farm, species index, which is the total number of tree species on a farm, were calculated (Kent and Coker, 1992).

3.4.2.1. Shannon-Wiener index of diversity

The Shannon-Wiener index is the most widely used type of diversity index to calculate species diversity (Kent and Coker, 1992).

$$\text{Shannon-Weiner Diversity Index (H')} = -\sum_{i=1}^{S} P_i \ln P_i$$

Where, Pi= abundance of individuals found in the i^{th} species or the number of individuals of one species/total number of individuals in the samples.

lnpi =natural logarithm of pi S= the number of species i= 1, 2, 3…s

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).

The evenness of a population was calculated by (Krebs1999);

$$\text{Species Evenness (E)} = \frac{H'}{H\max} = \frac{H'}{\ln S} \quad \text{with } H\max = \ln S$$

Where, H' = Shannon's diversity index; S = Number of species pooled in all study site

H max = ln(s) is the natural logarithm of the total number of species evenness

Kent and Coker (1992) summarized that if the value of E increase, the evenness of the species also increase in their distribution within the sample. E has values between 0 and 1, where 1 represents a situation in which all species are equally abundant.

3.4.3. Similarity Analysis

Similarity indices measure the degree to which the species composition of different systems is alike. Based on the analysis of the data from the three *kebeles*, similarity index (Ss) was calculated with the following formula (Kent and Coker, 1992):

$$S_s = \left(\frac{2a}{2a+b+c} \right) x100$$

Where Ss= Sorensen similarity coefficient

a = number of species common to both samples

b = number of species in sample 1

c = number of species in sample 2

The coefficient is multiplied by 100 to give a percentage.

CHAPTER FOUR
4. RESULTS

4.1 Tree species composition

A total of 78 different tree species belonging to 48 families were recorded from the three *kebeles* of the smallholder farmlands of the Elfeta Woreda (appendix 1). Among the total 322 individuals identified in the three study areas, maximum species number(165) were recorded at lowland(Etisakoye *kebele),* 103 species from midland(Ambelta Godeti *kebele*) and 54 species from highland(Harotufticha *kebele*) farmers landscape were collected (appendix 2,3,4). In terms of tree species distribution across sites, 20 tree species were common to the three *kebeles,* 15 species were different to Ambelta and Etisa koye *kebeles,* 20 species were common to Etisa and Harotufticha *kebele* and 22 species were similar with Harotufticha and Ambeltagodeti *kebele*(Figure 6).

Out of 48 families collected, Fabaceae was the most dominant, represented by 10 species, followed by Rutaceae with 6, Moraceae with 5 and Rosaceae with 4 species (appendix 1).

Out of the total species identified from the study area, 142 tree species were collected from the Home garden, followed by grazing land (95) and farmland (85).

A total of 142 tree species recorded in home garden were characterized by a higher numbers of tree species than other land use types. This finding result is the same with the study of Motuma et al.(2008) and Abiot and Gonfa (2015) who reported that higher number of tree species were present in home gardens than most of the other land use types. Less tree species were identified from crop field of study area. This indicates that the trees were sparsely distributed in the field.

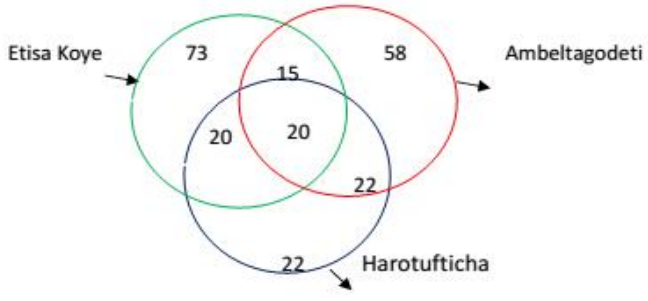


Figure 6. Species richness and number of species overlap between the three study sites.

4.2. Structure of Tree species

4.2.1. Basal area

Basal area (BA) is the cross-sectional area of all of the stems in a stand at breast height and calculated from the diameter at breast height (DBH) of the individual tree species. The basal area in the highland, midland and lowland agro-ecology of the smallholder farmland agroforestry of Elfeta district were 0.821m^2/ha, 2.66m^2/ha and 3.1m^2/ha, respectively (Appendix3, 4 & 5).

4.2.2. Importance Value Index

In the three agro-ecological zones, the Importance Value Index of all tree species were analyzed. However, top five important tree species were briefly discussed here in terms of their importance value index (Table 3). Accordingly, *Eucalyptus globulus*, *Juniperus procera*, *Grevillea robusta*, *Podocarpus falcatus* and *Hagenia abyssinca* were the top five ranked tree species by their IVI respectively in the highland farm landscape agroforestry.

In the midland agroforestry, Cordia *Africana, Juniperus procera, Faidherbia albida, Grewia ferruginea and Ficus vasta* were top five ranked tree species by their IVI respectively.

Cordia africana Faidherbia albida, *Ficus vasta*, *Croton macrostachyus* and *Ricinus communis* were the top five ranked tree species by their IVI respectively at lowland farm landscape agroforestry .

IVI is used to determine the overall importance of each species in the community structure. This is supported by the research of Simon and Girma (2004) which explained that species those have the greatest importance value are the primary dominant of specified trees. Therefore, to evaluate the importance of each species, the IVI was estimated for the tree species recorded in the farmland agroforestry practices in the three agro-ecological farmland agroforestry (Appendices 3,4 & 5).

Table 3. The top five tree species with the highest IVI values in the three agro-ecological farm landscape agroforestry of Elfeta *Kebeles*

Agro-ecology	Scientific name	Rel. freq.%	Rel. dens%	Rel. dom%	IVI
Highland	*Eucalyptus globulus*	11.32	11.11	6.09	28.52
	Juniperus procera	3.774	3.704	14.25	21.728
	Grevillea robusta	7.547	7.407	6.09	21.044
	Podocarpus falcatus	7.547	9.259	3.41	20.216
	Hagenia abyssinca	5.66	5.556	4.629	15.845
Midland	*Cordia Africana*	6.0606	5.825	1.88	13.766
	Juniperus procera	4.0404	3.883	4.398	12.321
	Faidherbia albida	4.0404	3.883	4.248	12.171
	Grewia ferruginea	2.0202	1.942	5.376	9.3382
	Ficus vasta	2.0202	1.942	4.985	8.9472
Lowland	*Cordia africana*	4.4304	4.848	1.613	10.891
	Faidherbia albida	2.5316	2.424	5.697	10.653
	Ficus vasta	3.1646	3.03	3.645	9.8396
	Croton macrostachyus	5.0633	2.424	0.903	8.3903
	Ricinus communis	5.6962	1.212	1.226	8.1342

4.3. Diversity of tree species

The values of diversity index at the highland, midland and lowland farmland agroforestry were 2.221, 2.967, 3.199 where as species evenness were 0.718, 0.730, 0.745 respectively (Table 4). Similarly, the value of tree species richness at highland, midland altitude and lowland altitudes farmland agroforestry were 22, 58 and 73 respectively. The values of diversity indices of trees in the lowland farmland agroforestry were greater than the midland and highland agroforestry. This may be due to the high number of species richness in the lowland agro-ecological farmland agroforestry than midland and highland agroforestry. The species richness also showed the variation between the three agro-ecological farmland agroforestry. This may be due to agro-ecological characteristics, altitudinal variation, socio-cultural and farmer's management strategy.

The study reported by Hodel *et al*. (1999) stated, besides altitude and temperature, soil quality is an agro-ecological factor that brings variation of plant diversity. Also Dossa *et al*. (2013) stated that there is a decline in tree species richness with increasing altitude because of a greater role of environmental filtering at higher elevations.

Table 4. Species richness, diversity, and evenness of tree species in study sites.

Selected *Kebeles*	Species richness	Species diversity (H')	Species evenness
Eltisa koye	73	3.199	0.745
Ambelta Godeti	58	2.967	0.730
Haro Tufticha	22	2.221	0.718

4.4. Similarity index between Kebeles

Sorenson's index of similarity of Etisakoye and Ambeltagodeti *kebeles* showed the highest similarity (46.9%) followed by Ambeltagodeti and Harotufticha *kebele* (36.06%) because these kebeles were nearest to each other and also had somewhat similar soil texture and climatic condition. Etisakoye and Harotufticha *kebele* had lowest similarity index (29.6%) as compared with other *kebeles* (Table 5).

Table 5. Sorenson species index of similarity (%) along three *kebeles.*

Kebeles	Etisakoye(%)	Ambeltagodeti(%)	Harotufticha(%)
Etisakoye	-	46.9	29.6
Ambeltagodeti	-	-	36.06
Harotufticha	-	-	-

4.5. Tree species preference

To assess farmers' species preferences, respondents were asked to rank the five most important tree species among the species they retain or planted. From the highland, midland and lowland of Elfeta woreda, the most tree species preferred by farmers' were *Eucalyptus globulus, Coffee arabica, Cordia africana* respectively based on their socio-economic importance (Table 6).

The local farmers retain the tree species based on their ability to enhance annual crop yield, possessing easily decomposing leaf, compatibility with crops and other uses for services like timber, fuel-wood, fodder and housing materials, etc. A study reported by Chakraborty *et al.* (2015) shows that farmers prefer species that easily decompose to increase the soil fertility and give quick return, species with high growth rate, multipurpose usage, fruit species and timber species.

Table 6. Top five tree species preferred to retained or planted on farmland by farmers at the three agro-ecological zones.

Agro-ecology species	Tree species	Retained species	Planted
Highland	*Eucalyptus globulus*	-	√
	Juniperus procera	-	√
	Grevillea robusta	-	√
	Erythrina brucei	√	√
	Hagenia abyssinca	-	√
Midland	*Coffee arabica*	-	√
	Cordia africana	√	√
	Teclea nobilis	-	√
	Rhamnus prinoides	√	√
	Ficus vasta	√	-
Lowland	*Cordia africana*	√	√
	Coffee arabica	-	√
	Ficus vasta	√	-
	Rhamnus prinoides	√	√
	Faidherbia albida	√	-

4.6. Management practice of tree species on smallholder farmland

Tree species give a wide range of service for the households. In the study area, the respondent's major benefits from tree species in the farmland were for construction (25%), followed by fuel-wood (23%), income generation (16%), Food (13%), soil fertility (9%), Shade (7 %), Medicine (5%) and other purposes (Fig. 7).

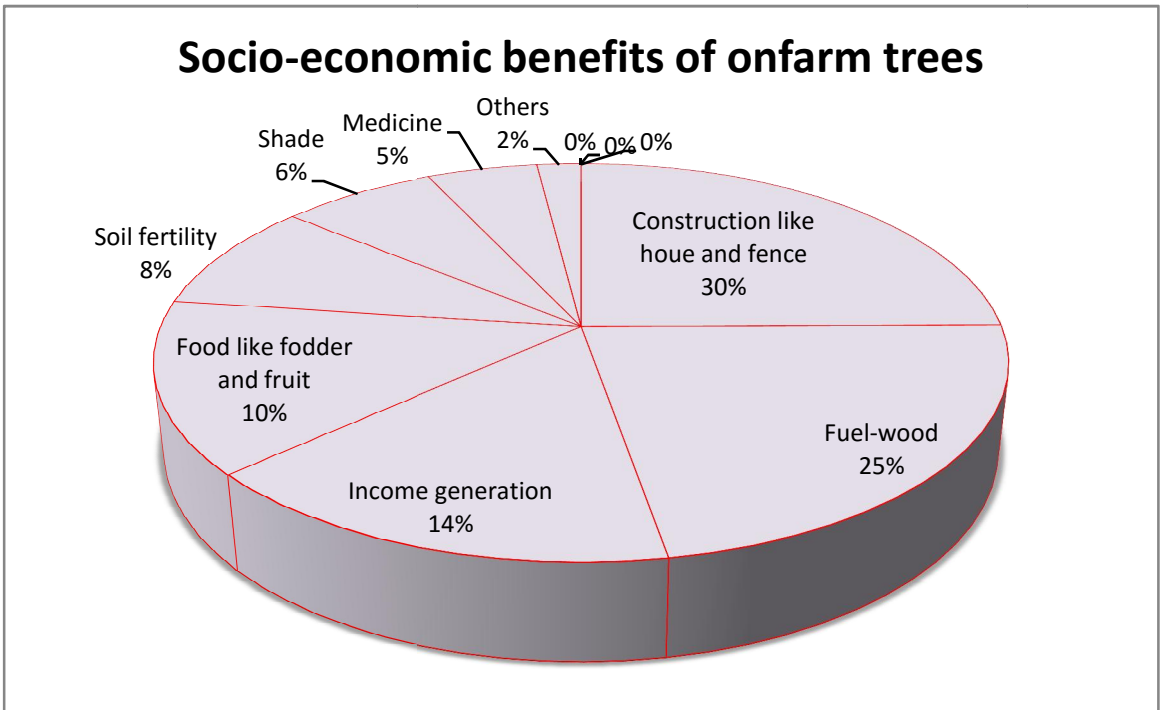


Figure 7. Farmer's reasons for retaining or planting tree species on their farmland.

From figure 7 we can conclude that the respondents manage tree species in the smallholder farmland agroforestry mostly for construction and for fuel-wood purposes. These two services were covering more than the other services provided (55%). This is because in rural areas no electricity and no other options exist for constructions except tree species. Leonidas (2015) reported that the farmers in rural areas use tree species mostly for fuel-wood and building poles as main products.

The present study is supported by Abebe Tesfaye(2005) who reported that on-farm trees can be used for different purposes like firewood, timber, construction, farm implements and fodder, food, medicine, and they also play beneficial ecological roles such as erosion control and soil fertility improvement. On the other hand Tefera Bekele *et al.* (2014) also reported that tree plants on farmland are used for multiple purposes such as fodder; construction materials, farm tools and equipment; sources of income, soil fertility; furniture and bee forage at Debark district in the northern highlands of Ethiopia.

4.7. Crop integration with tree in the smallholder farmed landscape

Crops are integrated with the natural trees that were retained at the time of converting forests to farmlands and/or integrated with the tree they plant. The informants said that not all trees are comfortable for all crop integration. Farmers usually retain specific trees of selected species per hectare to make tree sparsely distributed in the crops. For example *Cordia africana, Ficus vasta, Faidherbia albida, Acacia abyssinica and Croton macrostachyus were* intercropping with maize, sorghum, Barley, Teff and wheat at the midland and lowland of the study area. But, at the highland area there were no more crop integration with tree except somewhere, because these area were mostly dominated with *Eucalyptus globules* and *Juniperus procera* which do not suitable for crops.

Figure 8. Crop integration with tree species in small holder farmers landscape (photo taken by Teresa, 2020).

4.8. Socio-economic factor that affect sustainability of tree species on farmland

Most of HH in the study area responded that tree species in the farmland agroforestry had shown a decreasing condition starting from the recent time. The most declining tree species were *Acacia abyssinica (laaftoo), F. albida (Garbii), O. europaea L (Ejersa). P. falcatus (Birbirsa)*, P. *africana (Gurraa), E. capensis (Somboo), Ficus sycomorus (odaa)* and *F. vasta (Qilxuu)*. According to Focus Group Discussion (FGD), the major reason for the loss of these species were the land holding for agricultural productivity due to land scarcity and increasing of human population. In addition to agricultural expansion, the main reason still now is, removing these species for purpose of construction, timber, and charcoal and having poor regeneration action. On the other hand, the respondents mentioned that even if the people in the study area have had the awareness of replacing the used tree, they would have no interest to replant the removed tree due to land use scarcity.

Figure 9. Some farmland tree species decreasing due to agricultural expansion (photo taken by Teressa, 2020).

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion and Conclusion

Even if Elfeta weroda is among the deforested parts of West Shoa Zone in Oromia Regional State, small holder farmland agroforestry tree species still exist in various challenges. The study identified a total of 78 tree species belonging to 48 families in the three agro-ecological farmland agroforestry of the study sites.

However, the differences exist in the structure, diversity and composition of tree species in the small holder farmland agroforestry among the agro-ecological zones. Lowland small holder farmland agroforestry supports higher number of tree species with higher diversity indices than the other two agroforestry because soil texture and climatic condition of the area were more comfortable for trees than the other.

The farmers in the study area select and retain tree species in their farmland because of their advantages for socio-economic and ecological contribution such as fuel-wood, timber, shade, fodder, soil conservation and other benefits. However, tree species on the small holder farmland mostly decreasing due to the increment of socio-economic and ecological use of these trees. According to idea of the respondents from the study area, they use these trees because no other options exist for purposes of construction and fuel-wood due to no electricity in the rural area of the study area.

5.2. Recommendations

Based on the major conclusions of the research, the following recommendations were made:

- Even if the diversity of tree species is better in the study, it needs a series improved management and the stakeholders of the area like agricultural sector of the woreda specifically field worker(Dihe) should involve to save its sustainability for the future to over-come the socio-economic and environmental problems such as fuel-wood, construction materials, soil erosion and climate change through giving training for all

households about tree management, growing and importance of trees to create awareness in farmers.

- The trees should be indigenous species growing naturally in the local environment. Because of exotic tree species like *Eucalyptus* in the highland of the area mostly affecting the soil fertility of farm plots and it is better if the farmers will focuses on indigenous trees.
- Knowledgeable elders of local communities and government body should participate in establishing tree promotion activities and their conservation.
- Specific actions could be taken by government to those species which have seriously decreasing from the farmland even from the area to ensure their regeneration and to save the species extinction through direct sowing and preserving.
- Careful assistance should be given to farmers by educated person (Dihe) in their efforts to identify suitable sites for tree integration (inside crop fields, home gardens, farm margins, and other suitable locations).
- Smallholder farmers' efforts of tree integration and management should be supported with adequate technical assistance and encouragement by government. Successful farmers need to be rewarded in terms of financial rewards, the provision of additional plots of land to increase their awareness of tree conservation
- This study was about tree species diversity on farm landscape of the three kebeles and did not include the left *kebeles* and also not includes natural forest and other many natural resources. Therefore, it is recommended that further studies should be needed by educated person to fill the above mentioned gaps.

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7. APPENDICES

Appendix 1. List of different tree species recorded from different land use of the three *kebeles* of the study site (collected by Teressa, 2020)

No of Family	***Species present***	***No of species under family***	***Local name in Afan Oromo***
Boraginaceae	*Cordia africana* Lam.	1	Waddeessa
Euphorbiaceae	*Croton macrostachyus* Hochst. ex.A.Rich.	3	Bakkanniisa
	Ricinus communis L.		Qobboo
	Euphorbia candelabrum Kotschy		Adaamii
Fabaceae	*Acacia abyssinica* Hochst. ex Benth.	10	Laaftoo
	Albizia schimperiana Oliv		Imalaa
	Albizia sp.		Gaafatoo
	Pterolobium stellatum		Harangamaa adii
	Dichrostachys cinerea		Harsaamessa
	Calpurnia aurea (Lam.) Benth.		Ceekaa
	Erythrina brucei Schweinf.		Waleensuu
	Faidherbia albida Del.		Garbii
	Millettia ferruginea Hochst.		Sootalloo
	Albizia gummifera J.F.Gmel.		Muka-Arbaa
Icacianaceae	*Apodytes dimidiata E. Mey ex Arn.*	1	Calalaqaa
Melianthaceae	*Bersama abyssinica Fresen.*	1	Lolchiisaa
Buddlejaceae	*Buddleja polystachya Fresen.*	**1**	Anfaara adii
Apocynaceae	*Carissa spinarum L.*	2	Hagamsa
	Acokanthera schimberia (Engl.)Boehni		Qaraaruu
Ulmaceae	*Celtis africana Brum. F.*	1	Mata- qoma
Rubiaceae	*Coffea arabica L.*	2	Buna
	Rytigynia neglecta		Mixoo
Sterculiaceae	*Dombeya torrida D. goetzenii.*	1	Daannisa
Meliaceae	*Ekebergia capensis Sparrm.*	1	Somboo
Myrtaceae	*Eucalyptus globulus Habill.*	2	Baar-gamoo

	Syzygium guineense (Wild) D.C.		Goosuu
Ebenaceae	*Euclea racemosa L.*	1	Mi'eessaa
Moraceae	*Ficus sp.*	5	Qilimxoo
	Ficus sur Forsk.		Harbuu
	Ficus thonningii Bl.		Dambii
	Ficus vasta Forsk.		Qilxuu
	Ficus sycomorus L.		Odaa
Tiliaceae	*Grewia ferruginea Hochst. Ex. A. Rich*	2	Dhoqonuu
	Grewia bicolor		Harooressa
Proteaceae	*Grevillea robusta A. Cunn. ex R. Br.*	1	Giraviliyaa
Acanthaceae	*Justicia schimperiana T.anders.*	1	Dhummuugaa
Myrsinaceae	*Maesa lanceolata*	1	Abbayyii
Celastraceae	*Maytenus obscura (A. rich) Cuf.*	1	Kombolcha
Oleaceae	*Olea europaea L.*	1	Ejersa
Arecaceae	*Phoenix reclinata Jack.*	1	Meexxii
Podocarpaceae	*Podocarpus falcatus (Thunb.) C. N. Page.*	1	Birbirsa
Verbenaceae	*Premna schimperi Engl.*	1	Urgeessaa
Rosaceae	*Prunus africana (Hook.) Kalkm.*	4	Gurraa
	Malus domestica		Appilii
	Hagenia abyssinca		Heexoo
	Rubua steudneri Schweinf.		Goraa
Rhamnaceae	*Rhamnus prinoides L. Herit.*	1	Geeshoo
Anacardiaceae	*Rhus glutinosa A.Rich.*	3	Xaaxessaa
	Rhus vulgaris Meikle.		Daboobessaa
	Mangifera indica L		Maangoo
Polygonaceae	*Rumex nervosus Vahl.*	1	Dhangaggoo
Salicaceae	*Salix subserrata wild*	1	Alaltuu
Asteraceae	*Vernonia amygdalina Del.*	2	Eebicha
	Faurea speciosa Welw.		Dabaqqaa

Lauraceae	*Persea americana Mill*	1	Avokaadoo
Phytolaccaceae	*Phytolacca dodecandra L Herit.*	1	Andoodee
Rutaceae	*Citrus sinesis Del.*	6	Hadheessa
	Teclea nobilis (L.) Osb.		Burtukaana
	Citrus aurantifolia (Christm.) Swingle		Loomii
	Claus enaanisata		Ulumayii
	Citrus grandis (L.) Osb.		Turungoo
	Citrus aurantium		Qomxaaxxee
Caricaceae	*Carica papaya L.*	1	Pappayaa
Mimosoideae	*Entada abyssinica*	1	Hambaltaa
Cupressaceae	*Juniperus procera*	1	Gattiraa
Araliaceae	*Cussonia arborea A. Rich.*	1	Gatamaa
Sapindaceae	*Dodonaea angustirolia L.*	1	Ittacha
Agavaceae	*Dracaena afromontana R. Br. ex G.Don*	1	Rukeessa
Flacourtiaceae	*Dovyalis abyssinica A. Rich.*	1	Koshommii
Musaceare	*Musa acuminata*	1	Muuzii
Capparidacae	*Capparis tomentosa*	1	Harangamaa gurraacha
Poaceae	*Saccharum officinarum*	1	Shankoora
Olacaceae	*Ximenia americana*	1	Hudhaa
Bignoniaceae	*Stereosprmum kunthianum*	1	Botoroo
Juncaceae	*Juncus effusus*	1	Shanbaqqoo
Oliniaceae	*Olinia rochetiana A.Juss.*	1	Soolee
Simarobiaceae	*Brucea antidysenterica J.F. Mill.*	1	Qomanyoo
Sapotaceae	*Mimusops kummel*	1	Qolaadii
48	78		

Appendix 2. Structural parameter measurement of tree species in lowland *Kebele*

Tree species	No. Of stems	DBH (cm)	Basal area /plot(m²)	Freq	R. Freq%	R . Den %	R. Dom %	IVI
Cordia africana	8	8	0.05	7	4.4304	4.848	1.613	10.891
Croton macrostachyus	4	6	0.028	3	5.0633	2.424	0.903	8.3903
Ricinus communis	2	7	0.038	2	5.6962	1.212	1.226	8.1342
Euphorbia candelabrum	2	10	0.0785	2	1.2658	1.212	2.532	5.0098
Acacia abyssinica	4	9	0.063	4	2.5316	2.424	2.032	6.9876
Albizia schimperiana	1	8	0.05	1	0.6329	0.606	1.613	2.8519
Albizia sp.	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Pterolobium stellatum	1	6	0.028	1	0.6329	0.606	0.903	2.1419
Dichrostachys cinerea	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Calpurnia aurea	3	7	0.038	2	1.2658	1.818	1.226	4.3098
Faidherbia albida	4	15	0.1766	4	2.5316	2.424	5.697	10.653
Millettia ferruginea	2	6	0.028	1	0.6329	1.212	0.903	2.7479
Albizia gummifera	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Apodytes dimidiata	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Bersama abyssinica	1	8	0.05	1	0.6329	0.606	1.613	2.8519
Buddleja polystachya	4	5	0.0196	3	1.8987	2.424	0.632	4.9547
Carissa spinarum L.	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Acokanthera schimberia	2	5	0.0196	1	0.6329	1.212	0.632	2.4769
Celtis africana Brum.	3	6	0.028	2	1.2658	1.818	0.903	3.9868
Coffea arabica	6	5	0.0196	6	3.7975	3.636	0.632	8.0655
Rytigynia neglecta	1	6	0.028	1	0.6329	0.606	0.903	2.1419
Dombeya torrida	3	7	0.038	3	1.8987	1.818	1.226	4.9427
Ekebergia capensis	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Eucalyptus globulus	1	8	0.05	1	0.6329	0.606	1.613	2.8519
Syzygium guineense	3	6	0.028	2	1.2658	1.818	0.903	3.9868
Euclea racemosa	3	5.5	0.0237	3	1.8987	1.818	0.765	4.4817
Ficus sp.	3	11	0.095	2	1.2658	1.818	3.065	6.1488
Ficus sur	2	12	0.113	1	0.6329	1.212	3.645	5.4899
Ficus thonningii	1	13	0.1326	1	0.6329	0.606	4.277	5.5159
Ficus vasta	5	12	0.113	5	3.1646	3.03	3.645	9.8396
Ficus sycomorus	2	13.5	0.143	2	1.2658	1.212	4.613	7.0908
Grewia ferruginea	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Grewia bicolor	2	9	0.063	1	0.6329	1.212	2.032	3.8769
Grevillea robusta	3	8	0.05	3	1.8987	1.818	1.613	5.3297
Justicia schimperiana	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Maesa lanceolata	2	6	0.028	1	0.6329	1.212	0.903	2.7479
Maytenus obscura	1	5.5	0.0237	1	0.6329	0.606	0.765	2.0039
Olea europaea	2	7	0.038	2	1.2658	1.212	1.226	3.7038

Phoenix reclinata	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Podocarpus falcatus	3	6	0.028	3	1.8987	1.818	0.903	4.6197
Premna schimperi	3	6.5	0.033	3	1.8987	1.818	1.065	4.7817
Prunus africana	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Malus domestica	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
Rubua steudneri	2	7	0.038	2	1.2658	1.212	1.226	3.7038
Rhamnus prinoides	3	6	0.028	2	1.2658	1.818	0.903	3.9868
Rhus glutinosa	1	9	0.063	1	0.6329	0.606	2.032	3.2709
Rhus vulgaris	3	8	0.05	2	1.2658	1.818	1.613	4.6968
Rumex nervosus	1	6	0.028	1	0.6329	0.606	0.903	2.1419
Salix subserrata	2	5.6	0.0246	2	1.2658	1.212	0.794	3.2718
Vernonia amygdalina	2	5	0.0196	1	0.6329	1.212	0.632	2.4769
Faurea speciosa	2	6.5	0.033	2	1.2658	1.212	1.065	3.5428
Persea americana	1	8	0.05	1	0.6329	0.606	1.613	2.8519
Phytolacca dodecandra	2	5.5	0.0237	2	1.2658	1.212	0.765	3.2428
Citrus sinesis	1	6	0.028	1	0.6329	0.606	0.903	2.1419
Teclea nobilis	2	6.5	0.033	2	1.2658	1.212	1.065	3.5428
Citrus aurantifolia	2	5.6	0.0246	1	0.6329	1.212	0.794	2.6389
Claus enaanisata	2	5.8	0.0264	2	1.2658	1.212	0.852	3.3298
Citrus grandis	1	6.5	0.033	1	0.6329	0.606	1.065	2.3039
Citrus aurantium	2	6	0.028	2	1.2658	1.212	0.903	3.3808
Carica papaya	1	5.3	0.022	1	0.6329	0.606	0.71	1.9489
Entada abyssinica	2	8	0.05	1	0.6329	1.212	1.613	3.4579
Juniperus procera	4	12.2	0.117	3	1.8987	2.424	3.774	8.0967
Cussonia arborea	2	7	0.038	2	1.2658	1.212	1.226	3.7038
D.angustirolia	1	6	0.028	1	0.6329	0.606	0.903	2.1419
D.afromontana	2	5	0.0196	2	1.2658	1.212	0.632	3.1098
D.abyssinica	1	6.1	0.029	1	0.6329	0.606	0.935	2.1739
C.tomentosa	3	5.7	0.0255	2	1.2658	1.818	0.823	3.9068
X.americana	3	5	0.0196	3	1.8987	1.818	0.632	4.3487
St.kunthianum	1	5.4	0.0228	1	0.6329	0.606	0.735	1.9739
Juncus effusus	3	9	0.063	3	1.8987	1.818	2.032	5.7487
O. rochetiana	2	6.3	0.0311	2	1.2658	1.212	1.003	3.4808
B.antidysenterica	1	5.8	0.0264	1	0.6329	0.606	0.852	2.0909
M.kummel	1	6.7	0.0352	1	0.6329	0.606	1.135	2.3739
73	165		3.1	158				298.65

Appendix 3. Structural parameter measurement of tree species in midland *Kebele*

Tree species	No.Of stems	DBH (cm)	Basal area/plot (m^2)	Freq	R. Freq%	R . Den%	R. Dom %	IVI
Cordia africana	6	8	0.05	6	6.0606	5.825	1.88	13.766
Croton macrostachyus	2	6	0.028	1	1.0101	1.942	1.053	4.0051
Ricinus communis	1	7	0.038	1	1.0101	0.971	1.429	3.4101
Euphorbia candelabrum	1	10	0.0785	1	1.0101	0.971	2.951	4.9321
Acacia abyssinica	3	9	0.063	2	2.0202	2.913	2.368	7.3012
Albizia schimperiana	1	8	0.05	1	1.0101	0.971	1.88	3.8611
Pterolobium stellatum	2	6	0.028	2	2.0202	1.942	1.053	5.0152
Dichrostachys cinerea	1	5	0.0196	1	1.0101	0.971	0.737	2.7181
Calpurnia aurea	2	7	0.038	2	2.0202	1.942	1.429	5.3912
Erythrina brucei	1	7	0.038	1	1.0101	0.971	1.429	3.4101
Faidherbia albida	4	12	0.113	4	4.0404	3.883	4.248	12.171
Millettia ferruginea	2	6	0.028	2	2.0202	1.942	1.053	5.0152
Bersama abyssinica	1	8	0.05	1	1.0101	0.971	1.88	3.8611
Buddleja polystachya	1	5	0.0196	1	1.0101	0.971	0.737	2.7181
Carissa spinarum L.	2	6	0.028	2	2.0202	1.942	1.053	5.0152
Celtis africana Brum.	1	6	0.028	1	1.0101	0.971	1.053	3.0341
Coffea arabica	2	5	0.0196	2	2.0202	1.942	0.737	4.6992
Ekebergia capensis	2	6	0.028	2	2.0202	1.942	1.053	5.0152
Eucalyptus globulus	3	8	0.05	3	3.0303	2.913	1.88	7.8233
Ficus sp.	1	5.5	0.0237	1	1.0101	0.971	0.891	2.8721
Ficus sur	2	11	0.095	2	2.0202	1.942	3.571	7.5332
Ficus thonningii	1	12	0.113	1	1.0101	0.971	4.248	6.2291
Ficus vasta	2	13	0.1326	2	2.0202	1.942	4.985	8.9472
Ficus sycomorus	1	15	0.1766	1	1.0101	0.971	6.639	8.6201
Grewia ferruginea	2	13.5	0.143	2	2.0202	1.942	5.376	9.3382
Grevillea robusta	3	8	0.05	3	3.0303	2.913	1.88	7.8233
Justicia schimperiana	2	5	0.0196	2	2.0202	1.942	0.737	4.6992
Maesa lanceolata	1	6	0.028	1	1.0101	0.971	1.053	3.0341
Maytenus obscura	1	5.5	0.0237	1	1.0101	0.971	0.891	2.8721
Olea europaea	2	7	0.038	2	2.0202	1.942	1.429	5.3912
Phoenix reclinata	1	5	0.0196	1	1.0101	0.971	0.737	2.7181
Podocarpus falcatus	3	6	0.028	3	3.0303	2.913	1.053	6.9963
Premna schimperi	2	6.5	0.033	2	2.0202	1.942	1.241	5.2032
Prunus africana	1	6	0.028	1	1.0101	0.971	1.053	3.0341

Malus domestica	1	5	0.0196	1	1.0101	0.971	0.737	2.7181
Hagenia abyssinca	2	7	0.038	1	1.0101	1.942	1.429	4.3811
Rubua steudneri	1	7	0.038	1	1.0101	0.971	1.429	3.4101
Rhamnus prinoides	3	6	0.028	3	3.0303	2.913	1.053	6.9963
Rhus vulgaris	1	8	0.05	1	1.0101	0.971	1.88	3.8611
Mangifera indica	1	7	0.038	1	1.0101	0.971	1.429	3.4101
Salix subserrata	2	5.6	0.0246	2	2.0202	1.942	0.925	4.8872
Vernonia amygdalina	2	5	0.0196	2	2.0202	1.942	0.737	4.6992
Persea americana	2	8	0.05	2	2.0202	1.942	1.88	5.8422
Phytolacca dodecandra	2	5.5	0.0237	2	2.0202	1.942	0.891	4.8532
Teclea nobilis	3	6.5	0.033	3	3.0303	2.913	1.241	7.1843
Citrus aurantifolia	1	5.6	0.0246	2	2.0202	0.971	0.925	3.9162
Claus enaanisata	2	5.8	0.0264	1	1.0101	1.942	0.992	3.9441
Citrus grandis	2	6.5	0.033	1	1.0101	1.942	1.241	4.1931
Citrus aurantium	1	6	0.028	1	1.0101	0.971	1.053	3.0341
Carica papaya	1	5.3	0.022	1	1.0101	0.971	0.827	2.8081
Juniperus procera	4	12.2	0.117	4	4.0404	3.883	4.398	12.321
M. acuminata	1	10	0.0785	1	1.0101	0.971	2.951	4.9321
C.tomentosa	1	5.7	0.0255	1	1.0101	0.971	0.959	2.9401
S.officinarum	2	8.2	0.052	2	2.0202	1.942	1.955	5.9172
St.kunthianum	1	5.4	0.023	1	1.0101	0.971	0.865	2.8461
Juncus effusus	2	9	0.063	2	2.0202	1.942	2.368	6.3302
O. rochetiana	1	6.3	0.031	1	1.0101	0.971	1.165	3.1461
B.antidysenterica	1	5.8	0.0264	1	1.0101	0.971	0.992	2.9731
58	103		2.66	99				300.02

Appendix 4. Structural parameter measurement of tree species in highland *Kebele*

Tree species	No.Of stems	DBH (cm)	Basal area /plot(m^2)	Freq	R. Freq%	R . Den%	R. Dom%	IVI
Cordia africana	3	8	0.05	3	5.66	5.556	6.09	17.306
Croton macrostachyus	2	6	0.028	2	3.774	3.704	3.41	10.888
Erythrina brucei	3	7	0.038	2	3.774	5.556	4.629	13.959
Apodytes dimidiata	2	6	0.028	3	5.66	3.704	3.41	12.774
Buddleja polystachya	3	5	0.0196	3	5.66	5.556	2.387	13.603
Celtis africana Brum.	2	6	0.028	2	3.774	3.704	3.41	10.888
Coffea arabica	1	5	0.0196	1	1.887	1.852	2.387	6.126
Ekebergia capensis	2	6	0.028	2	3.774	3.704	3.41	10.888
Eucalyptus globulus	6	8	0.05	6	11.32	11.11	6.09	28.52

Grevillea robusta	4	8	0.05	4	7.547	7.407	6.09	21.044
Justicia schimperiana	3	5	0.0196	3	5.66	5.556	2.387	13.603
Maesa lanceolata	2	6	0.028	2	3.774	3.704	3.41	10.888
Olea europaea	1	7	0.038	1	1.887	1.852	4.629	8.368
Podocarpus falcatus	5	6	0.028	4	7.547	9.259	3.41	20.216
Prunus africana	2	6	0.028	2	3.774	3.704	3.41	10.888
Hagenia abyssinca	3	7	0.038	3	5.66	5.556	4.629	15.845
Rhamnus prinoides	2	6	0.028	2	3.774	3.704	3.41	10.888
Rhus vulgaris	2	8	0.05	2	3.774	3.704	6.09	13.568
Salix subserrata	1	5.6	0.0246	1	1.887	1.852	2.996	6.735
Vernonia amygdalina	2	5	0.0196	2	3.774	3.704	2.387	9.865
Juniperus procera	2	12.2	0.117	2	3.774	3.704	14.25	21.728
Juncus effusus	1	9	0.063	1	1.887	1.852	7.674	11.413
22	54		0.821	53				300

Appendix 5. List of tree species on smallholder farmer's landscape with their respective socio-economic importance.

Key: Sh, Shade, F, Feed; M, Medicine; Co, Construction; T, Timber; Ch, Charcoal; Fd, Fodder; CI, cultural identity; Fe,Fence; Agt, Agricultural tool; S=soil fertility; I=Income; E=Erosion control

No	Scientific name	Sh	F	M	Co	T	Ch	Fd	CI	Fe	Agt	S	I	E
1	*Cordia africana*	√	√		√	√						√	√	√
2	*Cr.macrostachyus*	√		√	√	√	√		√		√		√	√
3	*Ricinus communis*			√							√		√	
4	*E.candelabrum*		√	√						√				√
5	*Acacia abyssinica*	√		√	√	√	√		√	√			√	√
6	*Al.schimperiana*	√			√	√	√	√		√	√	√	√	√
7	*Albizia sp.*					√								
8	*P.stellatum*									√				
9	*D.cinerea*					√				√				
10	*Calpurnia aurea*				√	√				√				
11	*Er. brucei*									√				
12	*F. albida*	√			√	√	√	√	√	√			√	
13	*M.ferruginea*	√		√	√	√	√	√		√	√			√
14	*Al. gummifera*	√			√	√	√			√			√	√
15	*Ap. dimidiata*	√			√	√				√				√
16	*B.abyssinica*	√				√				√		√		√
17	*B.polystachya*	√				√				√				
18	*C. spinarum L.*		√	√	√	√				√				√

19	*A.schimberia*				√	√				√	√			√
20	*C. africana Brum.*				√	√				√	√		√	√
21	*Coffea arabica*	√	√	√		√			√			√	√	√
22	*R.neglecta*					√				√				√
23	*Dombeya torrida*	√												√
24	*Ek.capensis*	√			√	√	√	√		√	√			√
25	*E. globulus*				√	√	√	√	√	√		√	√	√
26	*S.guineense*	√		√	√	√	√		√	√	√		√	√
27	*Euclea racemosa*	√	√		√	√	√	√		√	√	√		√
28	*Ficus sp.*	√	√		√	√	√	√		√	√	√		√
29	*Ficus sur*	√	√		√	√	√	√	√	√	√	√	√	√
30	*Ficus thonningii*	√	√		√	√	√	√		√		√		√
31	*Ficus vasta*	√	√		√	√	√	√	√	√	√	√	√	√
32	*Ficus sycomorus*	√	√			√	√	√	√	√		√	√	√
33	*G.ferruginea*	√	√		√	√	√	√	√	√			√	√
34	*Grewia bicolor*	√		√	√	√		√	√	√	√		√	√
35	*Grevillea robusta*	√			√	√				√				√
36	*J.schimperiana*	√		√		√				√				√
37	*M. lanceolata*	√		√	√	√		√	√	√				√
38	*M. obscura*	√			√	√		√		√				√
39	*O. europaea*	√			√	√		√	√	√	√		√	√
40	*Ph. reclinata*	√	√		√	√	√	√		√	√		√	√
41	*P.falcatus*	√	√		√	√	√	√		√	√	√	√	√
42	*P. schimperi*	√		√	√	√		√	√	√	√	√	√	√
43	*Pr.africana*	√			√	√	√			√	√		√	√
44	*Malus domestica*	√	√			√							√	√
45	*H.abyssinca*			√						√				
46	*R. steudneri*		√							√				√
47	*Rh.prinoides*	√	√	√									√	
48	*Rhus glutinosa*	√	√		√	√		√		√				√
49	*Rhus vulgaris*	√			√	√				√				√
50	*M. indica L*	√	√										√	√
51	*Rumex nervosus*	√	√		√	√				√				√
52	*Salix subserrata*	√			√	√		√		√				√
53	*V.amygdalina*	√		√		√		√		√		√		√
54	*F. speciosa*	√			√	√	√	√		√			√	√
55	*P. americana*	√	√	√									√	√
56	*Ph.dodecandra*	√		√						√				√
57	*Citrus sinesis*	√			√	√				√	√			√
58	*Teclea nobilis*	√	√	√									√	√

59	*C.aurantifolia*	√	√	√									√	√
60	*Claus enaanisata*	√		√	√	√		√	√	√	√			√
61	*Citrus grandis*	√	√										√	√
62	*Citrus aurantium*	√	√										√	√
63	*Carica papaya*	√	√										√	√
64	*Entada abyssinica*	√				√	√							√
65	*Juniperus procera*	√			√	√	√			√	√		√	√
66	*Cussonia arborea*	√				√								√
67	*D.angustirolia*	√		√	√	√		√		√				√
68	*D.afromontana*	√				√	√	√						√
69	*D.abyssinica*		√							√				
70	*M. acuminata*	√	√					√					√	√
71	*C.tomentosa*	√		√						√				√
72	*S.officinarum*		√					√		√			√	
73	*X.americana*	√	√	√	√	√				√				√
74	*St.kunthianum*	√				√				√	√			√
75	*Juncus effusus*	√			√			√		√				√
76	*O. rochetiana*	√			√	√				√				√
77	*B.antidysenterica*			√		√								√
78	*M.kummel*	√	√		√	√				√	√			√

Figure 10. Some trees retain in the farmland for the purpose of cultural identification in Elfeta woreda (photo taken by Teressa, 2020)

Specifically in ancient time, the Oromo people in this area did not cut any branches of these trees because at autumn season they slaughter the bull to these trees and call their God/waka tokicha in oromic/ for the coming of fine rain.

Figure 11.Additional photo representing tree species in crop field (photo taken by Teressa, 2020).

Appendix 6. Semi-structured interview schedule with smallholder farmers

First of all, I would like to thank you to be interested for responding the questions!

Part I. Household information

A) Farmer's Name _____

B) Gender _____ Age_____sex_____

C) Marital Status: Single☐ Married ☐ Divorced ☐ Widowed ☐

D) Religion _____ Wealth Class _____

E) Region _____ Adm. Zone _____ Woreda_____ Kebele_____

F) Agro climatic zone _____ Plot Size _____

Part II. **Household resources**

1. Do you have your own land? 1. Yes 2. No

If yes, what is the size of your land in (cimdii= In Afan Oromo) (1 cimdii = ¼ ha)?

_____

2. Do you feel that there is shortage of land in this village? 1. Yes 2. No

If yes, what could be the possible reason?

_____

_____

3. Do you like to have trees on your farm plots? 1, yes 2. No

If yes, please list in their vernacular names.

1._____ 2_____ 3._____4_____

4. Is there any value you get from trees on your farm land? Please list.

_____

_____

5. Where do these trees came from? A. naturally occurring on the land B. planted c. both

_____

6. Are there differences between past and present in maintaining trees on farm plots in your locality?

If yes, would you please mention the difference?

_____

_____

7. Are there trees which have disappeared or disappearing from local farm plots today?

If yes, please mention the names of these trees.

_____

_____

8. How do you see the sustainability of tree species during the last decade in your farm land?

1. Increasing 2. Decreasing

If your response is increasing/decreasing reason out

- **Reasons for increase**: 1= increased market value; 2= increased fuel wood demand, 3=declination of soil fertility 4= increased fodder demand; 5= increased construction wood demand; 6= increased demand for lumber; 7= adequate seed/seedlings supply, 9=others
- **Reasons for decrease**: 1= decreased market value; 2= decreased fuel wood demand 3= decreased fodder demand; 4= decreased demand for construction wood; 5= decreased demand for lumber; 6= land shortage; 7= seed/seedlings shortage; 9= other specify

Part III. Tree management

9. Have you ever managed tree species in your farm that grows naturally/planted? 1. Yes 2. No

If your response is yes what purpose you managed these trees?

- **Key source** for purpose: 1=for fuel wood, 2=for soil improvement, 3= for timber, 4=for animal fodder, 5=for shade 6=for construction, 7= For cultural identity, 8=for others

10 Which types of plant is more found in your cultivated land

1. Artificially planted tree 2. Naturally regenerated tree in cultivated land 3. Both

11. Which tree species most preferable for you in the order of their importance?

1st----------

2nd----------

3rd----------

12. If you don't have trees on your farm plot, why is it so?

_____

13. What could be the possible solutions to keep trees on your farm plot?

_____

_____