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SMALLHOLDER FARMERS' PERCEPTIONS, ATTITUDES, AND MANAGEMENT OF TREES IN FARMED LANDSCAPES IN NORTHEASTERN ETHIOPIA

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Agricultural Knowledge, Learning, Documentation and Policy Project (AKLDP-Ethiopia)

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CSA	Central Statistics Office
CBD	Convention on Biological Diversity
E.C.	Ethiopian Calendar
ETH	Ethiopian National Herbarium
GOE	Government of Ethiopia
GIS	Geographical Information System
GTP	Growth and Transformation Program
MPTs	Multipurpose Trees
NEERP	Northeastern Ethiopia Regional Planning Office
NMSA	National Metrological Services Agency
PAs	Peasant Associations
SPSS	Statistical Package for the Social Sciences
YBP	Years Before Present

EXECUTIVE SUMMARY

A study was conducted in northeastern Ethiopia with the main objective of describing and analyzing the perceptions and attitudes of smallholder farming communities regarding trees on-farm, including their status of integration and management. The research was carried out between March–December 2015. Sixty-five *kebeles* (peasant associations) in 12 *woredas* (rural districts) were selected by multistage sampling in which 623 household heads were selected using stratified random sampling techniques. Qualitative data were generated by conducting semi-structured interviews. The farm plot of each household was equated to an ecological sampling unit for gathering biophysical data. Focus group discussions, guided field walks, and direct observations were also applied to secure additional data. The resulting data were manipulated using suitable analytical software packages (Excel, SPSS) to calculate descriptive statistics, including percentages, means, and standard deviations. Significant differences between means were tested. A total of 520 (83.5%) of smallholder farmers expressed interest in integrating trees into farm plots, but in practice 276 (44.3%) of the total had no single tree in their farm plots. More plant species and corresponding use-values were mentioned by: informants living in South Wollo Administrative Zone than other zones; males than females; the richer smallholder farmers than others; those living in the Weina Dega agroecological zones; and those at better education levels. In total, the local people have cognitive domain for 72 woody plant species growing in smallholder farm plots, representing 61 genera and 40 families of seed plants in which the family Fabaceae predominates, with 15 species. The average number of plants and plant uses mentioned by the various social categories of informants is very small, ranging between 0.23–2.2 and 2.03–3.13, indicating the depletion of tree species in the agroecological landscape and accompanying loss of biodiversity-related knowledge. For convenience, the species can be categorized into three management categories as naturally growing, exotics, and regularly cultivated species. In terms of use-value, firewood, bee forage, and environmental services are crosscutting use-values, whereas food, medicine, construction, timber, charcoal, fodder, fertilizer cash income, and agricultural tools are differential use-values collected from particular plants. Species growing naturally in smallholder farm plots are concerns of tree integration initiatives. Comparison of means showed no significant difference for gender, literacy level, and administrative zones, but significant differences for wealth classes, age, and agroecology ($P<0.05$). There are gaps in the provision of extension services for maintaining trees in smallholders' farm plots. Supporting smallholder farmers' activities of growing trees on their own farm plots through selection of useful species, provision of technical assistance, and resource mobilization would contribute to bringing tree species back to the agricultural landscapes. The effort could be sustained through innovative options like the green water credit system. Land-holding certification is considered a guarantee of tree ownership for smallholder farmers, and it is important going forward to formulate regulations that are encouraging to investment in farm trees, protection of tree ownership, and respect and trust-building around tree-use rights of smallholder farmers.

CHAPTER ONE

1 Introduction

1.1. Background

Smallholder farmers have maintained a variety of tree species in the agricultural landscapes in northeastern Ethiopia for millennia, as trees offer smallholders a range of socioeconomic benefits including food, cash income, medicines, fodder, fuel wood, timber, shade, bird-watching towers, and live fences grown on farm boundaries. These benefits are in addition to the proximate and ultimate ecosystem services that trees on-farm provide to the recovery and maintenance of the integrity of agroecosystems; many smallholders may not recognize this benefit of on-farm trees.

The Growth and Transformation Plan (2010–2015) includes ambitious targets for the agriculture sector, including improved natural resources (forest) conservation and use. The Agriculture Sector Policy Investment Framework (2010–2020) develops this thinking in relation to watershed management, natural resources management, the prevention and reversal of arable land degradation, and the new challenges presented by climate change. Since farmed landscapes are part of watershed systems and sources of natural resources, focusing on trees in farmed landscapes aligns with the aspirations of the two above-mentioned documents through reducing farmland degradation, improving natural resources productivity, and maintaining agricultural biodiversity.

Studying trees in farmed landscapes is all about agroforestry, a form of land use practiced since prehistoric times. The term “agroforestry” is a neologism developed recently from the contraction of “agriculture” and “forest.” As a land management system, it involves the introduction or retention of woody perennials, particularly of *multipurpose tree species* (MPTs), along with agricultural crops and pasture for domestic animals/livestock. Through integration into farmland and harnessing particular features of trees, agroforestry helps to diversify income-sustaining smallholder production for increased socioeconomic and environmental benefits. This land management system serves as a buffer against increasing human and livestock population pressure that demands extra natural resources for the sustenance of both. Some local communities in different parts of the world, such as the West African Sahel, are making the best use of keeping trees in farmed landscapes. Their experiences have subsequently stimulated stakeholders at various levels to pursue the scaling up of local efforts of maintaining trees in farmed landscapes through providing agricultural extension services, including technology transfer and selection of tree species. In Ethiopia, the need to introduce farm forestry and offer technical support to farmers and semi-pastoralists has been clearly stated in Proclamation No. 542/2007 articles 4.4 and 5.4. (GOE, 2007). However, there is no explicit statement included in the proclamation specifically addressing the issue of integrating trees in farmed landscapes or efforts to be made to support smallholder farmers’ initiatives to include tree species on their farm plots. Article 4.4 article bluntly states that in order to introduce farm forestry practices, efforts shall be made to provide the farming and semi-pastoral communities with sufficient amounts of plant seeds and seedlings of tree species that have different economic benefits. Article 5.4 details the accompanying technical support. Responsibilities for giving technical support in the selection and planting of tree and forage plant species and in the conservation of the existing ones that help to prevent soil erosion and serve as land-holding boundary markers are discussed. The proclamation is a source of encouragement for farming communities to undertake tree-planting activities in their farm plots.

Understanding agroforestry as a solution to the problems of farmland degradation through checking soil erosion and loss of soil fertility, serving as sink to greenhouse gases, preventing loss of biodiversity and associated indigenous knowledge, and its promises to alleviate poverty is gaining increasing recognition. It has therefore become one of the green strategy bandwagons that is instrumental to build climate change resilience in farmed landscapes. Moreover, agroforestry’s contribution to the maintenance of cultural heritages, traditional ecological knowledge, and resource management systems associated with the management of trees in farmed landscapes in traditional farming communities over the millennia has made agroforestry a focal point for development and research intervention. This research attempts to build on the existing agroforestry knowledge by documenting the smallholder farmers’ perceptions, attitudes, and management of trees in the farmed landscape in northeastern Ethiopia. It assesses the existing situation of tree integration in farmed landscapes and analyzes trends in tree management, specifically to determine if there are more or fewer trees, as well as the associated indigenous knowledge, today than there were 15 to 25 years ago. The study aims to examine the causes for any change observed in the integration of trees in farmed landscapes.

1.2 Research problems, objectives, questions, and hypotheses

1.2.1 Research problems

On-farm trees are the basis of a wide range of services to smallholder farmers. Moreover, these important agroecosystem components are sources of the traditional knowledge pool and management practices held by local communities as a heritage that is passed down to subsequent generations. However, protection of trees and replanting are not encouraged due to underlying factors, including population pressure, land degradation, the farmer's own perceptions, attitudes, and management, small farm size (one hectare and below), and the generally prevailing inferred tenure insecurity. These factors need be considered when it comes to the problems of evaluating the integration of trees in farmed landscapes.

Land degradation due to continued cultivation and removal of the woody elements that were parts of the farmland, in tandem with climate change effects, is leading to chronic poverty in northeastern parts of Ethiopia. Tree species are threatened by destructive harvesting and the clearing of land for agriculture. Livestock damage, land shortage, drought, and lack of financial resources are the key challenges to in¬tensification of tree cultivation. Moreover, some negative effects posed by woody plants on farmed land, including too much shade (competition for light) to herbaceous crops, competition for space and other resources, allelopathic effects on crops, among other effects, may be sources of discouragement to farmers to incorporate trees in their farm plots.

Trees and shrubs are disappearing fast in anthropogenic landscapes of many countries; this is the case in Ethiopia, particularly in northeastern Ethiopia. Research undertaken in Tigray Region of Ethiopia showed that although farmers knew which agroforestry tree species are considered important for integration in crop fields, very few farmers were observed planting these species on their farms (Hachoofwe, 2008). The author noted that the farmers said they have heard of the benefits through hearsay, but they were very skeptical of the actual benefits. Consequently, the farmers were not willing to adopt the species. This author further noted that trees have become scarce in the agricultural landscape, and that even though many farmers had planted some exotic trees, they had little knowledge about how to manage them and were largely unfamiliar with the benefits they can provide. The author attributed this to the consequences of the species not having been around for long enough for communities to be conversant about the merits and overall use-values of the trees. In order to promote the conser¬vation of these trees on-farm, there is a need to involve farmers and educate and raise awareness about tree species that are to be introduced to an area.

Farmers' involvement in tree/shrub management requires a clear understanding of the households' needs that trees can satisfy and the priority species to satisfy these needs. Tree management practices and challenges that hinder tree planting, protection, and sustained uses must also be understood (Hachoofwe, 2008; Tabuti, 2012; Tefera et al., 2014; Ruelle, 2014). Relating to the expectations of farmers, these researchers also reported that in order to scale up tree planting, farmers should be provided with inputs, including seedlings, tools, and other enablers. Some of the above researchers (Hachoofwe, 2008; Tefera et al., 2014; Ruelle, 2014) clearly indicated that farmers in parts of northern Ethiopia, despite adoring the local indigenous tree species on their farms, showed preferences for exotic tree species, the eucalypts in particular. These species were planted to satisfy their household needs; the farmers are motivated by the economic benefits they derive from planting them. This is more pronounced in the findings of Tefera et al. (2014) and Ruelle (2014), where farmers' preference ranking placed the exotic eucalypts in the first rank, mainly due to the cash income generated from selling the wood for construction and other purposes.

While considering economic, social, and legal aspects very important in developing sound strategies of tree integration in smallholders' farm plots, Kassa et al. (2011) and Abiyu et al. (2015) identified major impediments constraining tree planting: lack of tree tenure security; the culture of free grazing/browsing; political and institutional instability; abrupt and radical changes in rural development policies and strategies; and market distortions due to de facto open access forest resources on the one hand and price control and lengthy permit requirements to sell on-farm wood and wood products on the other hand. Different social categories of farming communities may have different responses to the question of tree integration. Household wealth may determine the rate of involvement in tree integration into, or its removal from, one's farm plots. Marginalized people are highly dependent on woody plants for their subsistence and income generation, but chronic poverty often challenges them in maintaining trees on their farm plots.

One major deterrent to tree planting is tenure insecurity, and policy planning at national and local level has an impact on adoption of trees on-farm. Supportive policies and legislation, and clear, secure land tenure and management rights are some of the enabling conditions for sustainable smallholder tree growing. The current legal framework in Ethiopia related to tenure security among farming households through agricultural land registration and certification is anticipated to have a strong positive effect on the sense of tenure security, which may in turn encourage smallholder farmers to plant trees on their farm plots. This study therefore assesses the current status and practices of tree integration into the agricultural landscape in northeastern Ethiopia, with emphasis on smallholders' farm plots.

1.2.2 Research objectives

Overall objective

The overall objective of the research is to describe the perceptions, attitudes, and management practices of tree integration of smallholder farming communities in northeastern Ethiopia.

Specific objectives

The research has the following specific objectives:

- To document traditional uses and management practices associated with agricultural use of trees in farmed landscapes in different agroecological zones in eastern Amhara and Tigray Regions and emerging trends arising as the result of land certification

- To analyze differences of integration of trees in farmed landscapes along differences of gender and wealth group in different societies and agroecological zones

- To identify smallholder farmers' preferences for tree species, crop combinations, and farm locations used for tree integration

- in place to support smallholder farmers' efforts at tree integration into farmlands in northeastern Ethiopia

- To assess enabling/disabling conditions both current/past and traditional/conventional prevailing in northeastern Ethiopia with regard to integrating trees in smallholders' farmlands.

1.2.3 Research questions

With the increasing scale of tree integration into the farmed landscape, it is possible to make the farming system ecologically stable and biologically diverse with the best human selection of tree species. But farmers' consensus of integrating trees in farmed landscapes is not a straightjacket. Visual observation indicates inequality of tree integration between farmlands arising from differences in idiosyncrasies of individual farmer households, sociological factors, and/or policy bottlenecks. Research into tree-people interactions in farmed landscapes helps to identify the accompanying determinants of tree integration into these managed habitats. This study deals with the perceptions, attitudes, and management of trees in smallholder farming communities in northeastern Ethiopia and tries to answer the following questions.

- What are the perceived roles of different species of trees in farmed landscapes?

- As agriculture intensifies, what are the trends in tree integration in farmed landscapes?

- What role do agriculture extension services play in maintaining and increasing or decreasing the number of trees in farmed landscapes?

- Are there differences in the answers to the three questions above between poor/medium/rich and male/female-headed households?

- Are there any new emerging trends associated with the certification of land holdings?

1.2.4 Research hypotheses

Besides documenting the traditional uses and management practices associated with agricultural use of trees, hypotheses testing was done to check significant differences between social groups in their indigenous plant use knowledge of plant species growing in farmed landscapes. The problems investigated in this study were reorganized so that null and alternative hypotheses drawn up from relevant research questions could be rendered amenable for checking through application of appropriate statistical tests. The following null hypotheses were targeted for testing at $\alpha = 0.05$ level.

- There are no significant differences in the integration of trees in farmed landscapes along differences of gender.

- There are no significant differences in the integration of trees in farmed landscapes along differences of wealth status.

- There is no significant correlation between the age of informants and indigenous plant use knowledge of plant species growing in farmed landscapes.

- There are no significant differences in the integration of trees in farmed landscapes between societies of different administrative zones.

- Smallholder farmers are not keen about planting and managing woody species in their farm plots, home gardens, homestead areas, and in other plots of their own.

- Farmers are not aware of the benefits that they can draw from woody plants growing in their private lands.

CHAPTER TWO

2 Literature Review

2.1 The role of trees in the agricultural landscape

In recent years, food security issues have moved to the central position in the livelihood affairs of the rural poor in particular. Domestic food production is declining in the face of a growing population and a changing climate that is having negative impacts on the agriculture of smallholder farmers. The Woodland Trust (**woodlandtrust.org.uk/farming**; **woodlandcreation@woodlandtrust.org.uk**) reports that woody plants have tremendous benefits on arable farms as they keep soils healthy, service pollinating insects, regulate climate, and provide key resources for human use, as detailed in discussions on the merits and advantages of what is called evergreen agriculture (ICRAF, 2013).

The development of sustainable agriculture depends on supporting and increasing production, while maintaining and improving the condition of the natural environment. This can be done by adopting conservation agriculture, and woody plant integration offers a viable option in the wake of agricultural intensification. Smallholder farmers of northeastern Ethiopia have maintained for millennia a variety of tree species in the agricultural landscape, including in crop fields. These tree species offer a range of socioeconomic benefits (food, cash income, medicine, fodder, bee forage, fuel wood, timber, shades, bird watching towers, live fences, control of runoff, protection of soil through reducing wind speed, improvement of soil fertility, and maintenance a healthy ecological state) as well as providing proximate and ultimate ecosystem services. More woody plants on-farm may indicate the prevalence of protected fertile soil. The prevailing lines of evidence on the role of trees in farming systems and the benefits they provide disclose that thoughtful integration of indigenous trees and shrubs into farming systems can support production and help to deliver benefits at the household, farm, and wider public scales. Research on the type and status of woody plants in farmed landscapes, their benefits, and future potential and prospects is at the heart of the matter, and a timely response is called for, especially in northeastern Ethiopia.

2.2 Woody plants in farmed landscapes of smallholder farmers

Over thousands of years, farmers in Ethiopia, as in other countries, practiced different modes of agriculture in their efforts to fit and adapt to the agroclimatic and socioeconomic conditions in a range of ecosystems and in an originally biodiversity-rich landscape. One of the farming systems they developed through the ages is a mosaic of mixed systems that displays a range of agroforestry practices shaped/molded by their local physical and sociocultural conditions. Woody plants integrated with the agricultural crops of smallholders characterize various forms of traditional agroforestry systems from different countries and is almost a universal occurrence in Ethiopia. The current situation in Ethiopia, however, is a gloomy picture because of the accelerated removal of the woody elements of farmed landscapes. This removal is accelerating in the whole of Ethiopia, but is much more accelerated in northeastern Ethiopia, where most fields are now devoid of these elements. This situation is often cited as the main cause of land degradation as well as food, nutrition, energy, and feed insecurity. The term agroforestry refers to the system of land management involving the simultaneous cultivation of farm crops and trees. It includes the practices covering the roles of trees and levels of interactions in farmed landscapes that range from nutrient flows from forest to farm, and community reliance on fuel, timber, or biomass available within the agricultural landscape.

Trees growing on-farm in rural landscapes include: what are known as "fertilizer trees" for land restoration, soil health, and food security; fruit trees for human nutrition; fodder trees that improve the production of smallholders' livestock; timber and fuel wood trees maintained for shelter and energy; medicinal trees that combat diseases; and trees that produce gums, resins, and latex products. Many of the trees are multipurpose, providing a range of benefits. This is the case in rural areas of developing countries, including Ethiopia (Nawir et al., 2007; Abiyu et al., 2015). The available literature pertaining to trees of farmed landscapes shows that the woody components have the potential to enhance soil fertility, reduce soil erosion, improve water quality, enhance biodiversity, increase aesthetic values of the landscape, and sequester carbon (Jose, 2009). Trees as part of the farming system play the role of maintaining and restoring the physical environment needed in order to sustain agricultural production through restoration of soil nutrients. They also help to sustain rural household livelihoods through the provision of tremendous timber and non-timber tree products. Some trees have an important role in land reclamation and rehabilitation in the most highly degraded areas. Farmers and scientists involved in agroforestry value these systems for their ability to prevent land degradation and enhance ecological restoration of farmlands. Tree cover helps to improve soil fertility, although the rate at which this occurs varies greatly depending on the species and the biophysical conditions for growth. Trees are also increasingly grown to counter soil degradation in sloping areas; this is greatly valued in highland areas like northeastern Ethiopia. In addition to this benefit, farmers select species that at the same time give other benefits including food, fodder, medicine, and other uses, such as cultural and spiritual functions noticeable in many rural societies.

2.3 The trees on-farm movement and the evergreen agriculture drive

There is an increased realization of the values of trees on-farm by many smallholder farmers, researchers, and development agents. The growing realization of the household, economic, and ecological benefits of on-farm trees has gradually led to a hidden campaign for the trees on-farm agenda. Different sectors may, however, promote different strategies and perspectives, because the motivations for the movement and desired goals vary across stakeholders. These range from the rather innocent prescriptions by local smallholder farmers that simply focus on woody plants for the sake of the multiple benefits they offer to households and their livelihood needs to the prescriptions imposed by economic drivers and market promoters. Additionally, formal agroforestry tends to promote formally designed agroforestry packages like alley cropping and the like, mainly with exotic tree species. Agroforestry is currently adored for its worth in capturing carbon and cutting the emissions of greenhouse gases. This is the time for Ethiopia to aggressively embark upon the "trees on-farm movement" as it fits its objective realities and long-term aspirations to improve smallholder agriculture and rural livelihoods. Currently, the traditional agroforestry systems are being enhanced with application of modern formal science. In current terms, this comes within the scope of the evergreen agriculture that is recommended for regreening degraded agricultural landscapes (ICRAF, 2013) such as those observed in northeastern Ethiopia.

2.4 Interaction of smallholder farmers with woody plants in farmed landscapes

Subsistence farmers usually integrate trees, crops, and/or animals in their traditional agroforestry systems, which have varying intensities of perennial woody elements in the farmlands. The traditional land-use mode developed by subsistence farmers has over time become a subject for systematic study and improvement. This land-use mode is now recognized as a viable livelihood option promoted by land-use managers and international development efforts. Thus, agroforestry is a land-use system that involves socially and ecologically acceptable integration of trees with crops and/or animals. Agroforestry systems range from subsistence livestock silvopastoral systems to home gardens, on-farm timber production, and tree crops of all types integrated with other crops and biomass plantations within a wide diversity of biophysical conditions and socioecological characteristics (Zomer et al., 2009). All these variants obviously require interactions of a diverse nature, and that is how farmers learned how to accommodate the useful woody plants in their farms and nearby environments.

Trees support the lives of people, and farming communities want to ensure their presence within the environments they have modified and transformed for cultivating crops. Traditional farmers developed their agroforestry practices by "domesticating the forest" and/or the landscape, and hence most of the woody elements of the system are indigenous (Hillbrand, 2013), with their configuration on the land being unique in response to the local agroclimatic and socioeconomic conditions. Gradually, trees on-farm have turned out to be an important element in meeting the key challenges facing farming communities in their continued efforts to ensure food security for present and future generations while protecting the natural resources base on which they depend. Reports (Stapleton and Garrity, 2011) show that the indigenous nitrogen-fixing tree *Faidherbia albida* (= *Acacia albida*) is increasing unfertilized maize yields in Malawi, Zambia, Tanzania, Ethiopia, and numerous other countries.

2.5 Patterns of tree integration in farmed fields

Farmers usually integrate crops with trees in different patterns in response to local conditions. Trees on-farm are important assets of agricultural biodiversity (Cromwell et al., 1999). Woody plants of farmed landscapes in general (trees and shrubs) can be integrated by being scattered in croplands. This gives the fields a characteristic dotted look, in a unique mosaic manner, with trees and vegetation patches in various locations: on field margins and rocky outcrops; on non-arable land that naturally regenerates on farmlands devoid of crops or grass; around homesteads by households; on farm boundaries demarcating farmlands of different families; intercropped on arable lands or croplands; and on croplands as woodlots (Arnold and Dewees, 1998). Woody plants 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 beds, homesteads, fences, and home gardens. Many tree species can be found growing naturally in a wide range of environmental conditions, and differences could result due to the environment or genetic differences or both. Field experiments on provenance and progeny trials allow for an assessment of genetic variation and consequent selection of provenances, progenies, and/or individual species with particular traits that are considered superior.

2.6 Indigenous knowledge of woody plants and their management on-farm

Smallholder farmers protect many woody plant species in and around their farmland and homesteads, and in turn derive ecological, material, and economic benefits from them. Knowledge of the reciprocal relationships between people and plants in general and smallholder farmers and woody plants of the agricultural landscape in particular is critical for understanding the benefits that one offers to the other. Such knowledge belongs to the indigenous knowledge domain that farming communities maintain and that does not surface very easily. The indigenous local knowledge held by local farmers of trees in farmed landscapes is important alongside modern science to manage, develop, conserve, and use on-farm trees. Indigenous knowledge of plants and their uses is best studied by applying the methods of ethnobotany/ ethnoecology, the science that deals with the study of the relationship between people and the plants they know and use in their environment (Gerique, 2006). Thus, ethnobotanical studies are very much required in order to explicate the socioeconomic and cultural roles and impacts, farmers' criteria for selection, preferences, and adoption of woody species for on-farm maintenance, and market development 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 and/or shared knowledge rather than by individuals, which necessitates undertaking broad surveys. Smallholder farmers, who are also owners and custodians of indigenous knowledge in Ethiopia generally, have good understanding about the multiple uses of trees on-farm. However, the current protection of trees and planting of new ones is not encouraging (Hachoofwe, 2008; Kassa et al., 2011). Farmers fully realize the diminishing trend in woody plants on their farmlands and that this is a clear sign that the land is going through degradation. If efforts are directed towards rehabilitating the woody species with farmer participation, step by step the land can heal, thereby restoring the soil and ultimately regaining its fertility. Agricultural land managed in this manner can continue to be productive and provide the services it has always given to the present and future generations.

2.7 Historical perspectives on tree cultivation and domestication on-farm

Ancient Ethiopia started cultivating crops amidst forests and woodlands, using shifting cultivation and minimum or zero tillage. These practices are rarely found today, and only in a few remote parts of the country. Gradually, farmers started opening up the forests and woodlands to expand their cultivation but left several of the multipurpose woody plants, usually leaving the trees on-farm and the shrub species on field margins and fences of home gardens (Asfaw, 2001). Fields and villages in southern parts of Ethiopia are dotted with trees and shrubs, showing that the adoption of open field cultivation has been made possible while some woody species are allowed to grow. There are experiences that the northern parts of Ethiopia can learn from the trees on-farm, traditional agroforestry, and home garden practices of the southern and southwestern parts of the country.

The mechanism for tree integration into farmlands is in most cases restricted to the small-scale planting of trees and shrubs around homesteads, farmlands, and home gardens. This has been the practice by farmers in Ethiopia since immemorial times. However, formal government tree planting programs are said to have officially started in 1910 (Nawir et al., 2007), though on a limited experimental/ pilot scale. Even then, the above source discloses that the country had no support mechanism for adequately encouraging farmers to plant trees.

The currently heightening desire to promote on-farm trees in northeastern Ethiopia directly links up with the Millennium Development Goals (MDGs) that target supporting rural development processes to reduce rural poverty through profitable farms based on diverse and high-value agricultural commodities, including products derived from forests and trees. The goals also support managing water, land, and forest resources in a sustainable way to maintain the provision of environmental services. They also aim to improve policies and facilitate institutional innovation that balances the short- and long-term needs of both rural and urban populations. This desire further stretches to Ethiopia's second Growth and Transformation Program (GTP II), particularly aspects dealing with increasing agricultural productivity and production combined with sustainability and food security.

2.8 Common woody plants in Ethiopian farmed landscapes

Woody plants of the farmed landscapes in Ethiopia have been part of the farmed commodities as they serve a wide range of economic, sociocultural, and ecological functions within the traditional farming systems. Kassa et al. (2011), in a paper titled "Reading the Landscape," explained that there is a lack of on-farm tree planting practice in Ethiopia despite the fact that tree planting initiatives by the government began as far back as the end of the nineteenth century (more than 100 years ago). This is of course considering formal tree planting initiatives spearheaded by government institutions. Farmers have cared for on-farm trees since immemorial times. Formal tree planting took off in urban areas where the problem of wood shortage was mostly felt, and exotic tree species went on being planted. These authors further observed that on-farm tree planting was not widespread, particularly on plots outside homesteads. This is particularly true of farmers in central and northern Ethiopia. They further tried to explicate and identify the underlying discouraging factors, focusing their attention mainly on the historical trend and current status of tree planting by smallholder farmers. Since around 2003, researchers believed that total annual household income could be increased by at least 30% and land could be saved from degradation by engaging farmers in planting trees on the sections of their lands that are not suitable for crop production. They ascribed the shortfall of trees on farmlands to: the lack of tenure security; a historical background that promoted free grazing; instability;

changes in rural development strategies; and cutting down of trees for wood products.

There are, however, different species of woody plants distributed widely and in different agroecologies, many of them occurring in multiple agroecological zones (highlands, middle lands, and lowlands) of the country. The importance of these plants is being more and more realized in northern Ethiopia as the agricultural landscape continues to lose its woody plant elements. Recent research undertaken in Debark, North Gondar, showed that the indigenous woody species of the agricultural landscape are fast disappearing (Tefera et al., 2014; Ruelle, 2014), including both indigenous and exotic species. Conservation of woody plant diversity within agricultural landscapes is critical to farmers' livelihoods in areas that are losing the woody plants of the farmed lands. Efforts are currently underway to bring them back or to swap them with exotic species (Hachoofwe, 2008).

2.9 Tree-crop integration in Ethiopian farmed fields

Tree-crop integration in the Ethiopian situation needs thorough analysis to put things in proper perspective. 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 (Asfaw, 2001). 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 introduced their crops and managed them together. When the seedlings of the preferred species emerged at the desired locations spontaneously from the soil seed bank, they protected them, and thus they always practiced traditional agroforestry.

Research has shown common methods of woody plant integration in farmed landscapes along with the common species in northern Ethiopia (Hachoofwe, 2008; Tefera et al., 2014; Ruelle, 2014); many of them are also found in other parts of Ethiopia. The woody plant species in the country exhibit many forms and contain different preferred species. One of the common forms and species are indigenous species growing naturally from the soil seed bank that are selectively retained by farmers when clearing the land for cultivation. Species that grow spontaneously from the soil seed bank in Ethiopia include many indigenous *Acacia* tree species, *Ole europaea* ssp. *cuspidata, Cordia africana, Ehretia cymosa, Croton macrostachyus, Ziziphus spina-christi, Balanites aegyptiaca, Moringa stenopetala, Ficus* spp., 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*), among others. Still other exotics growing in the farmed landscapes are *Eucalyptus* spp, exotic *Acacia* spp., *Cupressus lucitanica*; many of these are claimed to be fast growers. For *eucalypts* (*Eucalyptus globulus, E. camaldulensis, E. saligna*), the driving forces are markets and economic incentives (Abiyu et al., 2015) that sometimes end up claiming arable farmlands. *Melia azedarach, Shinus molle, Grevilea robusta, Olea europaea* ssp. *cuspidata, Moringa stenopetala, Moringa oleifera, Ziziphus spina-christi*, and *Ficus* spp. are common in farmlands, roadsides, and borderlands.

Some trees and shrub species are commonly integrated with crops in smallholder farm plots based on farmers' selection of the species for their particular use-values. These are mostly indigenous species scattered in farmed areas, including leguminous trees (e.g., *Millettia ferruginea, Acacia abyssinica*, etc.) and woody crops (*Citrus* spp., *Persea americana, Psidium guajava, Casimiroa edulis*) as well as many live fence species, including many shrubs and thorny plants (*Rosa abyssinica, Rhamnus prinoides, Pterolobium stellatum, Carissa spinarum, Calpurnia aurea, Cajanus cajan, Dovyalis abyssinica, D. cafra, Maythenus* spp., etc.).

2.10 Ethiopian smallholder farmers and woody plants in their farmed landscapes

Smallholder farmers in Ethiopia produce relatively small volumes on relatively small plots of land for domestic consumption. They are generally resource-poor, food and wood insecure, depend on family labor, and belong to the informal economy. They may not even be registered. They are usually excluded from the records, lack social protection, and are often vulnerable to ill-treatment in supply chains.

Ethiopia faces population pressure and other socioeconomic factors, which have put the natural resources of the country under immense pressure. Farm sizes of one hectare or below have led to land degradation. Planting trees on-farm assists in reducing the pressure on the already heavily overburdened resources, though some authors (Rahmato, 2004) have their doubts about the success of the tree planting drive, because they surmise that it will be hampered by the prevailing insecure land tenure system and inadequate incentives to encourage investment on the land and manage it sustainably.

2.11 Attributes of woody plants preferred by Ethiopian smallholder farmers

Smallholder farmers in Ethiopia consider a number of biophysical and socioeconomic attributes of woody species for incorporation into agroforestry practices. For a species to be incorporated into farmlands, it should be one that sheds its leaves before the onset of rain and is easily decomposed to increase soil fertility. Evergreen species are kept around the residence, grazing land, and farm boundary to provide shade, fodder, and other functions. Multiple-use species and species with major uses are preferred by households. *Cordia africana* and *Croton macrostachyus* are tolerated, encouraged, or deliberately grown together with other crop components, while trees like *Eucalyptus camaldulensis* and *Rhamnus prinoides* are grown around homes and farm boundaries. Shade for people, livestock, and coffee is one important criterion for setting species preference. This is in addition to the question of suitability for honey beehive placement, provision of quality bee forage, and ability to increase soil fertility.

On-farm trees and shrubs in Debark (Tefera et al., 2014; Ruelle, 2014) are a mixture of indigenous and exotic species, though the former is by far greater in number of species and mostly naturally regenerated, while the latter consists of very few planted species. Exotic species significantly dominate in density and relative abundance (89%), while each indigenous woody species came up with lower relative abundance values of less than 2%. These studies documented the proliferation of eucalypts, mostly in grazing areas and rain-fed crop fields during the last 28 years (1984–2011), while interviewees regretfully asserted that indigenous woody species sharply declined in the agricultural landscape during the last 20–30 years.

2.12 Role of woody plants in the farmed landscapes of northeastern Ethiopia

Pressure on land for agriculture is high in areas cultivated for a long time, where land unsuitable for agriculture is sometimes used in a desperate effort to grow agricultural crops and where degradation has continued for generations. In one way or the other, highland areas in northeastern Ethiopia have fallen into this category. Vegetation, and particularly woody species, maintained in and around farmlands in northeastern Ethiopia assumes the functions of environmental protection or ecosystem services and economic benefits that can be seen to be similar to those reported for other parts of Ethiopia (Hachoofwe, 2008; Adal, 2014; Tefera et al., 2014; Ruelle, 2014) and elsewhere (Gerique, 2006; Tabuti, 2012; Van Damme and Kindt, 2012). Benefits from woody plants in farmed landscape include: the provision of shelter for crops, humans, and livestock; pollinators for pasture, crops, and other plants; sources of firewood, timber, food, medicine; control of soil erosion; improvement of soil fertility; and maintenance of a healthy ecological state, with climate mitigation and carbon farming/trade.

Woody plants in farmed landscapes function as providers of: fuel wood, fodder, food, and medicine to smallholder farmers; crop and vegetation pollination; C-sequestration; soil erosion control; soil fertility enhancement; restoration of biodiversity and water availability; management of watersheds; increased farm productivity; and indispensable shade during the dry season. However, woody plants growing in farmed landscapes are also blamed for undesirable effects. Some negative effects posed by woody plants on farmed land include: too much shade (competition for light) to herbaceous crops; competition for space and other resources; and allelopathic effects on crops, among others. The need for selecting the right species to be integrated with specific crops has to be undertaken with farmer experts in a participatory tree species selection program in order to identify the preferred species and the ones that do not pose negative effects. The effects of shade trees on biophysical conditions and their interactions with crop productivity are usually well understood by farmers. Smallholder coffee farmers in Central America classify shade trees as “fresh” (suitable for integration with coffee) or “hot” (unsuitable) based on their leaf texture and size, foliage density, crown shape, and root system attributes (Cerdán et al., 2012). The fresh/hot classification is significantly related to positive/negative provision of services. In other parts of the world, including Ethiopia, farmers have their own criteria for identifying trees that are incompatible with some crops.

2.13 Analysis of the gaps in on-farm tree planting in Ethiopia

Kassa et al. (2011) consider lack of tree tenure security, free grazing, political and institutional instability, abrupt and radical changes in rural development policies and strategies, and market distortions due to de facto open-access forest resources on the one hand and price control and lengthy permit requirements to sell on-farm wood and wood products on the other as the major gaps constraining tree planting. They concluded that promotion of tree planting for meeting farmers’ own needs and growing market demands and increasing rural household income needed particular attention, among other issues.

Research undertaken in Tigray Region of Ethiopia showed that although farmers knew agroforestry tree species considered important for integration in crop fields, very few farmers were observed planting these species in their farms (Hachoofwe, 2008). Some of the species (*Sesbania sesban* and *Leucaena leucocephala*) were planted as hedgerow species for fencing and were mainly used for fodder, but very few farmers acknowledged the use of these species for soil fertility improvement despite asserting that they had been told by extension agents about the multiple uses of these species, according to this source. The farmers said they had heard of the benefits through hearsay but were very skeptical of the benefits and were not willing to adopt the species. On the other hand, some trees (*Acacia albida = Faidherbia albida*) were considered resistant to browsing and were able to survive in the free grazing areas as they are not browsed by livestock. This category included *Acacia saligna, Rhamnus prinoides, Eucalyptus globulus, Melia azedarach*, and *Azadirachta indica*.

Farmers tended to be reluctant to plant trees if there were uncertainties as to whether they would continue to have rights of access to their holdings, since tenure insecurity and periodic division of plots make them less concerned about the health of their farms. Because of the absence of guarantees that the land they have enriched will remain in their holdings in the long run, they ignored sustainable traditional land management practices that involve crop rotation, organic soil fertilization, and others. Tenure insecurity is held responsible for the unwillingness of farmers to plant trees except eucalypts, now popular in the countryside, not because farmers are unaware of the negative consequences of planting eucalypts, but because of the prevailing land insecurity. Farmers in Ethiopia remember the bitter experience they went through when, due to the resettlement and villagization policies of the 1980s, rural communities were dislocated, forcing farmers to leave behind their perennial crops, trees, and fertile garden areas that they had painstakingly built over many decades.

2.14 Brief history of on-farm trees in northeastern Ethiopia

Land degradation due to continued cultivation and removal of the woody elements that were parts of the farmland, in tandem with climate change effects, are leading to chronic poverty in northeastern parts of Ethiopia. The history of forest destruction in northern Ethiopia has been documented through charcoal carbon dating that goes as far back as 2,450 Years Before Present (Hurni, 1985) and recently through digital photographic archives (Nyssen et al., 2010). In the northern part of the country, the Semite and Hamite peoples caused deforestation since more than 5,000 Years Before Present while also introducing early agriculture to this part of the country (Hurni, 1985). Pastoral people are said to have moved to the area on the southern side in the second half of the sixteeth century (Assen, 1990) and gradually became agropastoral and agrarian communities, eventually causing deforestation peril. Hence, early settlers continued to use the land extensively but gradually diminished its natural vegetation, and other physical resources were diminished, literally robbing it of its potential. This rampant forest destruction continued unabated from the period of the Zemene Mesafent ("years of the nobles" or "the age of the princes") through the 1980s, when the negative impacts became not only more noticeable but led to nature's severe kickback. The forests had been depleted, leaving landscapes that are dotted with small patches of trees concentrated mostly around areas of worship, while farmlands continued to lose the limited trees that were scattered sparsely and unevenly.

In response to the succession of forests further away from the agricultural areas, households entered a phase of protecting and encouraging tree seedlings that voluntarily sprouted around the living quarters and farm margins and sometimes inside crop fields, although deliberate planting of tree seedlings is said to have started in Ethiopia in 1910 (Nawir et al., 2007; Abiyu et al., 2015). The consequence of this is that tree density started growing in agricultural landscapes, while the forests went on diminishing such that some writers described the situation in a manner that implies the forests (trees) are being brought back from the forest to the villages. This shows that tree planting and protection around farms and living areas went on intensifying as we come to the present.

The introduction of *Eucalyptus* spp. in 1894–1895 by the French railway engineer Mondon-Vidaillet and a British army captain O'Brien, who advised and eventually persuaded Emperor Minilik II (Breitenbach, 1961), came to the rescue of the wood shortage. The planting of this exotic tree appeared to have turned on conservation-oriented trends and enabled partial curbing of the rate of deforestation through the reduction of use pressure on some native woody species. However, the driving force can ideally be linked to the desire for quenching the prevailing hunger for wood products. In fact, a sort of protracted observation went on raising some concerns about the ecological problems associated with the planting of the eucalypts, whose leaves are unpalatable to animals and not easily decomposable. Some have written about the eucalypts' allelopathic effects on crops and other herbaceous plants. However, the benefits that this tree provides in Ethiopia today are tremendous and are thanks to the farsighted decision made to introduce and promote it in non-arable areas within the agricultural landscape. Nevertheless, it needs to be clearly pointed out that it is not the ideal and desirable on-farm agroforestry tree type that best meets the needs of Ethiopian smallholder farmers. Debark farmers, however, rated it as the best tree, mainly on account of its lucrative cash returns (Tefera et al., 2014; Ruelle, 2014) through recently opened exogenous market drives and as a quick fix for covering needs for wood products.

2.15 Woody plant dynamics in farmed landscapes in northern Ethiopia

When the farmed landscape of northern Ethiopia is considered, the picture is worrying, because in many places the land has lost the woody plants, and the soil has been eroded. The agricultural landscape is in a dynamic state mainly because of the continued use of the limited woody plants and the largely destructive nature of the use. Animal droppings are immediately picked for preparation of cow dung cakes for household use and income generation. Furthermore, most indigenous trees of the human environment are replaced by exotic species whose management and silvicultural details are largely unknown to the local farming communities, as are the uses of the products. Recognition of the contribution of indigenous species and associated local knowledge would be better options. Likewise, the influence of the different social strata (gender, education, wealth status) on individuals' behavior with regards to preferences for species and propensity for maintenance of trees on-farm cannot be exploited. There is a dire need to innovate and bring in new experiences and best practices.

The support programs for on-farm tree development are usually not well taken up by farmers when they are focused on exotic species, as the study from Tigray (Hachoofwe, 2008) demonstrated. Shifts in farmer decisions in favor of or against tree crops are also influenced by agricultural policy measures that impact input and output prices for alternative agricultural crops and land uses.

2.16 Government laws provisioning support for maintaining trees on-farm

Government and local policy have impacts on adoption of trees on-farm. Supportive policies and legislation, and clear, secure land tenure and management rights are some of the enabling conditions for sustainable smallholder tree growing. Farmers in Ethiopia have tax incentives that are proportionate to the number of trees they plant (Kassa et al., 2011). This author discloses that the government encourages the private sector to invest in forestry by lifting controls on pricing and marketing of forest products; farmers are now facing few restrictions on selling tree products. This paves the way for an open and competitive market for wood. According to Lemenih and Kassa (2014), the current legal framework in Ethiopia has strong positive effects on re-greening by referring to the Rural Land Administration Proclamation, which they said has improved tenure security among farming households through agricultural land registration and certification. They argued that since tenure insecurity was among the major deterrents to tree planting in the past, land certification improved the sense of tenure security and confidence of growing trees in farmers' own farm plots. They also considered that forest policy, issued in 2007, encourages tree planting as it proposes tax incentives to farmers for planting trees in plantations. On the other hand, they remarked that because of fear that plantations will expand and take over productive agricultural fields, as they are doing in northwest Ethiopia, some regional states discourage farmers from planting eucalyptus. Traditional by-laws relevant to trees on-farm that may exist in all societies, though they may be very useful, have not been studied, documented, and presented for application. This is also a challenge that needs addressing.

2.17 New perspective for the trees on-farm agenda in northeastern Ethiopia

Trees and shrubs are disappearing fast in anthropogenic landscapes of many countries; this is the case in Ethiopia. The worst scenario is found in the northern part of the country. In order to promote conser¬vation on-farm, there is a need to involve farmers. Farmers' involvement in tree/shrub management requires a clear understanding of the households' needs that trees can satisfy, of the priority species to satisfy these needs, as well as of tree management practices and challenges that hinder tree planting, protection, and sustained use. Various studies (Hachoofwe, 2008; Tabuti, 2012; Tefera et al., 2014; Ruelle, 2014) showed that smallholder farmers value tree products for household welfare, including needs of accessing food (edible fruits), generating income, and accessing construction wood and other non-timber products, in addition to their obvious ecological and spiritual roles.

The research showed that tree species are threatened by destructive harvesting and clearing land for agriculture. The key challenges to in¬tensification of tree cultivation are livestock damage, land shortage, drought, and lack of financial resources. Farm¬ers suggested that in order to strengthen tree planting, they should be provided with inputs including seedlings, chemicals, and tools. Researchers found that farmers in northern Ethiopia, even though they like the indigenous tree species on their farms, showed preferences for exotic tree species to satisfy their household needs. The preferences are directly dictated by the economic benefits they derive from the exotic tree species (Hachoofwe, 2008; Tefera et al., 2014; Ruelle, 2014).

In Ethiopia, many pastoralists were observed using the dryland tree Dobera glabra for browse during the dry season and the seed as famine food. Woody plants also provide environmental services that benefit communities in flood control or climate change mitigation and in building resilience in vulnerable regions. The loss of trees/shrubs can therefore cause extensive suffering. Application of ethnobotanical methodology helps in identifying the needs of farmers and the suitability of species to the area in question based on the understanding of farmer perceptions, attitudes, and management practices of trees for use in farmed landscapes. This must be blended with facts that modern formal science knows very well about the adaptation, use, and contents of tree products.

CHAPTER THREE

3 Materials and Methods

3.1 Description of the study area

3.1.1 Study area

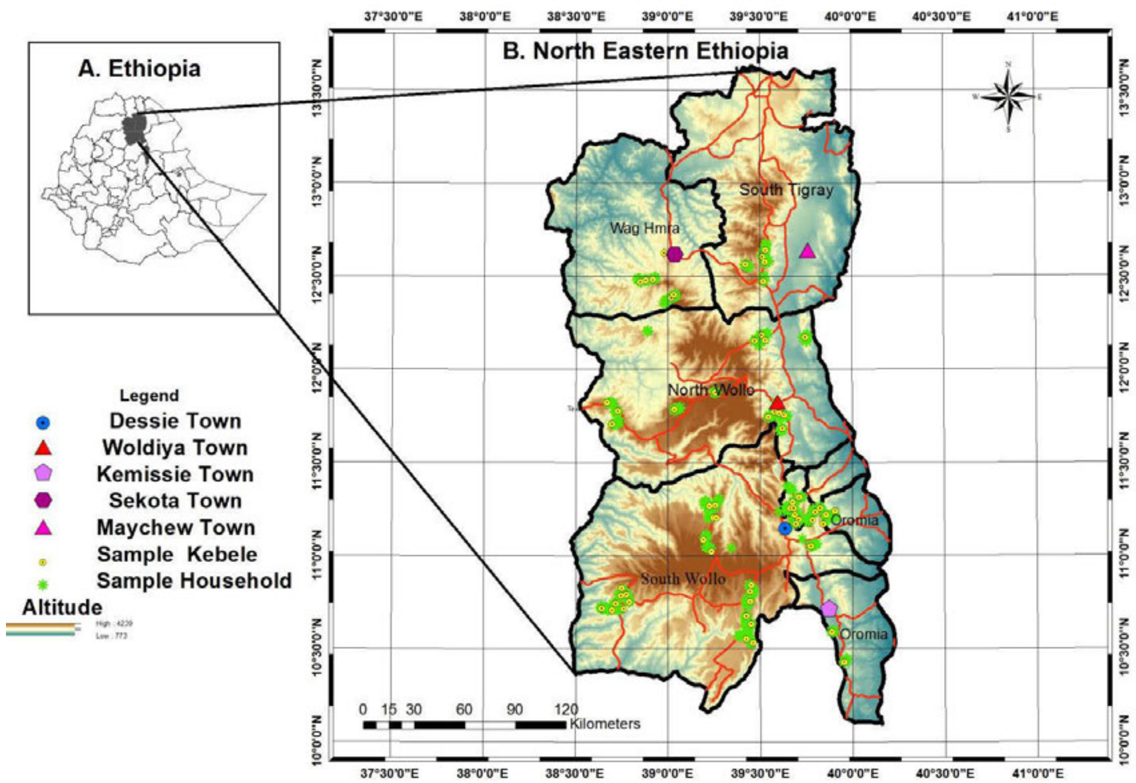
The study area is comprised of four administration zones of the Amhara National Region, namely South Wollo, North Wollo, Wag Hmra, and Oromia Zone and one adjacent administrative zone from Tigray (South Tigray). Northeastern Ethiopia is located within the geographical coordinates of 10° 10'-13° 50'N and 38°30'-40°30'E (see Figure 1). Its total land area as calculated using data from EthioGIS is about 54,401.28 sq. km. It extends in the altitudinal range of roughly from 774 m to 4,239 m across all agroclimatic zones described in Ethiopia except the desert zone, as classified based on ambient heat intensity and moisture regimes.

The area is found at the interface of four cultural groups, including the Amharic language-speaking Amhara people living in South and North Wollo, the Agew people in Wag Hmra, the Oromo people in Oromia Zone, and the Tigrigna-speaking people in South Tigray. They use mixed agriculture as their main livelihood. Settled as far back as 2,450 Years Before Present (Hurni, 1985), their ancestors caused widespread deforestation while practicing early agriculture (Zewde, 1998). Prolonged human settlement and sedentary agriculture have joined hands and left the agricultural landscape without trees or with few trees, exposing the land to soil erosion and leaching, and compromising the fertility of the soil. Paradoxically, the biggest trees so far recorded in Ethiopia are found in patchy natural vegetation of part of this study area, interchanging with trees dotted in nearby farmed lands.

3.1.2 Climate, geology, and soil

The following physiographic description of the study area is made based on an atlas of northeastern Ethiopia (NEERP, 1981 E.C.). The climate of the study area is characterized by diverse agroecological zones. Following Hurni (1998), four of five customary schemes of agroecological zones of Ethiopia except Bereha (desert) occur in the study area. These include High Wurch (extreme cold highland), occurring above 3,700 m.a.s.l. (meters above sea level) (0.4%) and Wurch (cold highland), between 3,200–3,700 m.a.s.l. (4.4%); Dega (cold to cold-humid), between 2,300–3,200 m.a.s.l. (27.4%); Weina Dega (cool to sub-humid), between 1,500–2,300 m.a.s.l. (50.5%) and Kolla (warm to semi-arid), between 500–1,500 m.a.s.l. (17.3%) (see Figure 2).

*Figure 1. Map of the study area showing sampling sites (*kebeles*).*



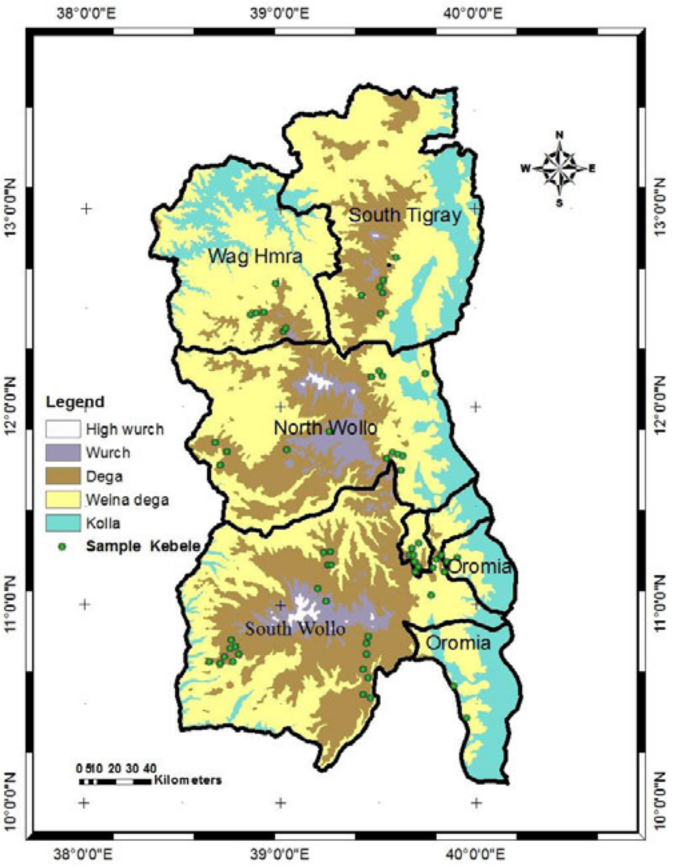


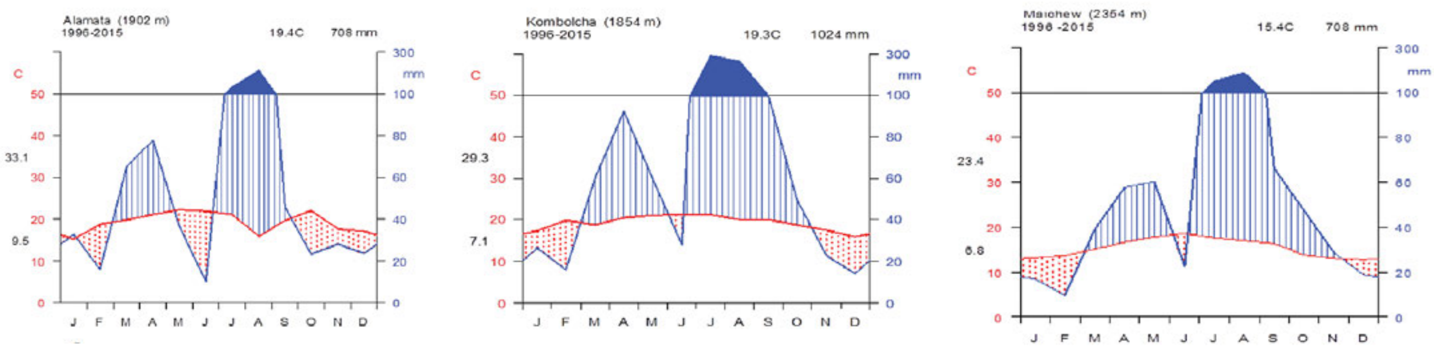
Figure 2. Agroecological distribution of the study area.

The cold highland zones occur in parts of North and South Wollo and South Tigray, and hot arid lowlands occur in eastern parts of North Wollo, Wag Hmra, and South Tigray. A range of variation of temperature and rainfall occur along differences of agroecological zones and/or altitude. Highlands of North and South Wollo lying above 1,500–2,500 m.a.s.l. have annual average temperatures of 15–20°C. Eastern, northwestern, and southwestern parts of North Wollo have an altitudinal range of 500–1,500 m.a.s.l., and the annual average temperature is 20–25°C. In the hot arid climate, the annual average temperature ranges between 25–30°C, and rainfall is below 450 mm. This type of climate is unsuitable for vegetation growth. In the arid climate, the annual average temperature and rainfall is 18–20°C and 410–820 mm respectively and supports bush growth. The tropical zone occurs up to an elevation of 1,750 m.a.s.l. and has an average temperature of 18°C during the winter time. It has an average rainfall of 680–1,200 mm. The types of vegetation found in this zone are grassland and woodland vegetation. The warm temperate climate occurs in the range of 1,750–3,200 m.a.s.l. The lowest monthly average temperature is 10°C, and it is below 10°C for about four months of the year. This climate occurs in areas above 3,500 m.a.s.l. in most parts of North and South Wollo. The cold highland climate is dry during the winter. The annual average rainfall ranges from 800–1,200 mm. Figure 3A–C presents the climate diagrams of Alamata, Kombolcha, and Maichew Meteorological Stations. A bimodal rainfall characterizes the rainfall distribution in the study area in that a big rainy season known as *kiremt* occurs between June and September and a small rainy season locally known as *belg* occurs between February and May. The small rainy season is erratic and highly variable. There is a long dry period from the end of September to February with a short dry spell in June.

Based on the descriptions of the geological structure of Ethiopia, the study area comprises crystalline basement, which is pre-Cambrian and Jurassic in origin. Tertiary extrusive and intrusive basaltic rocks of considerably varying thickness formed as a result of volcanic activity and dramatic uplift of the highlands dominate the geological structure. The volcanic rocks, including rhyolites, trachytes, tuffs, ignimbrites, agglomerates, and basalts, date mainly from the Tertiary (the Trap Series). Cambisols, andosols, lithosols, and black vertisols are the major soil types (Henrickson et al., 1983; Hurni, 1998).

Figure 3A–C. Climate diagram of the study area at three towns (Data source: NMSA, 2015).

A *B* *C*



3.1.3 Natural vegetation

The vegetation of the study area is generally sparse. Particularly in the highlands, where there is more population pressure, the vegetation has been cleared from age-old agricultural conversion and overgrazing. Severe deforestation carried out over a long period of time to meet the demands of the people for wood has restricted the vegetation to a few pocket places in the form of fragments of patchy vegetation. The types of the remnant vegetation of the Wollo Upland floristic region that encompass the present study are mainly Afroalpine, sub-Afroalpine, dry evergreen Afromontane forest, and grassland (Demissew, 1998). The study by Demissew also showed that lower altitudes are covered with *Acacia-Commiphora* woodlands.

3.1.4 Population and socioeconomic activities

The study population was estimated at 1,285,841 individuals in 1,199,737 households (CSA, 2008; see Table 1). The study area is part of the drought-prone region in Ethiopia where historic recurrent drought compromised the lives of thousands of people and has continued to the present.

The smallholder farming communities live by combining traditional rain-fed crop cultivation and animal husbandry, including honey production and other livelihood means. Some years there is not sufficient rainfall. The cultivable flat lands and degraded hillsides dominantly produce grains. The area is now dominated by the cereal culture, and the common food crops are wheat (*Triticum* spp.), barley (*Hordeum vulgare*), Ethiopian oats (*Avena abyssinica*), faba bean (*Vicia faba*), pea (*Pisum sativum*), chickpea (*Cicer arietinum*), chickling vetch (*Lathyrus sativus*), maize (*Zea mays*), *mashilla* (*Sorghum bicolor*), teff (*Eragrostis tef*), different species of oil seeds including *noog* (*Guizotia abyssinica*), safflower (*Carthamus tinctorius*), rape (*Brassica* spp.), linseed (*Linum usitatissimum*), and the Irish potato (*Solanum tuberosum*), among others. Sheep, cattle, goats, donkeys, horses, mules, camels, poultry, and apiculture are also parts of the mixed agricultural system. Traditional weaving, pottery, carpentry, artisanship, trading, labor, and remittances are means of supplementary income for some households.

3.2 Sampling design

3.2.1 Ethical considerations

Initially, compliance was checked with Proclamation No. 482/2006, articles 11:4 and 22:2 providing for access to genetic resources, community knowledge, and community rights (GOE, 2006). The contents of this proclamation are aligned with those of the CBD as they relate and apply to Ethiopia. Thus, ethical clearance was obtained from each administration zone ruling over each *woreda* and *kebele*. The verbal consent of each informant was obtained after explaining the purpose of the research before selecting informants for ethnobotanical data collection using standard procedures.

3.2.2 Selection of study sites

Three rounds of field trips were made to the study area to collect field data. A first reconnaissance visit was made between March 8 and April 7, 2015 to collect general information on the biophysical and socioeconomic conditions of the study area. During the reconnaissance survey, study sites and study subjects (household heads) were selected using a multistage sampling technique. Initially, five administrative zones in northeastern Ethiopia were selected by purposive sampling. The number of study sites, including *woredas* and *kebeles*, was determined commensurate with practical considerations of time and effort. After a reconnaissance survey, 12 of 45 (25%) rural *woredas* and 65 of 653 (10%) (see Table 2) of the total *kebeles* (48, Weina Dega; 16, Dega) were selected by simple random sampling by referring to two agroecological zones, namely cool to sub-humid (Dega) and cold to cold-humid (Weina Dega). PAs (Peasant Associations) in each *woreda* were used to choose informants (of which 144 were taken from the Dega and 479 from the Weina Dega agroecological zones, respectively). The farm plot of each household was equated to an ecological sampling plot for

Table 1. Population of the study area

Geographical area	Population			Number of Households and Household Units		Total
	Total	Male	Female	Households	H. units	
South Tigray	880,717	437,952	442,765	196,383	191,504	2,149,321
North Wollo	1,345,030	677,018	668,012	311,040	301,688	3,302,788
South Wollo	2,217,224	1,102,017	1,115,207	511,409	495,415	5,441,272
Wag Hmra	396,262	199,602	196,660	93,421	90,081	976,026
Oromia Zone	405,550	202,226	203,324	87,484	84,850	983,434
Total	5,244,783	2,618,815	2,625,968	1,199,737	1,163,538	12,852,841

Source: CSA, 2008

noting and recording the diversity and abundance of tree species at three phonological scales of measurement of size, including seedlings, saplings, and trees.

3.2.3 Selection of informants

During the second field trip, August 1–30, 2015, selection of informants was made in each PA using a stratified random sampling technique against gender and wealth group. Stratification enables checking for differences between informants' responses along differences of sociological variables. The wealth group classes applied by the government to rate smallholder farmer households were applied in this study. Likewise, a compromise was made between the recommended practice and practical considerations of time and effort to determine the number of household samples required to investigate for the population. Thus, 623 informants were selected applying the sample determination formula

$$n = \frac{(z_{\frac{\alpha}{2}})^2 pq}{d^2}$$

to the 1,199,737 households (CSA, 2008) living in the five administrative zones of northeastern Ethiopia, where d = 0.04. As the administrative zones were not of equal size, the calculated sample size was distributed to the five administrative zones by proportional allocation as given by

$$n_h = \frac{n \, x N_h}{N}$$

where n = the total number of sample households, N_h = total number of households in the administration zone, and N = the total number of households in the overall study area, northeastern Ethiopia. Considering the cultural division that mostly prescribes gender restriction of women to home affairs and not coming out to talk with guests, 437 males and 189 females informants were selected and taken as sufficient to show gender distinction in response variation in the study population. Likewise, wealth classes (202 poor, 236 middle, and 185 rich farmer households) that voluntatrily took part in the survey were selected after having been considered reasonable by the research team, given the circumstances. This method has been recommended for research that depends somewhat on the relative costs of sampling more units compared with sampling more elements (Israel, 2013).

3.3 Data collection

3.3.1 Ethnobotanical data

Data collection was made during the third-round field trip, October 1–30, 2015. Martin (1995) stated that the first step in gathering quantitative ethnobotanical data is free listing, i.e., delimiting the domain that interests us and asking community members to list the names of plants belonging to the domain. In this study, informants were asked to give a list of tree species growing in their farm plots following Martin (1995), Alexiades (1996), Cotton (1996), and Cunningham (2001). The question asked was, "Would you please list tree species growing in your farm plot and the use-value you are deriving therefrom?" Pre-prepared semi-structured interview guides (see Appendices 1 and 2) and a biodiversity data sheet (see Appendix 3) were used to collect data from informants and

Table 2. Number of sampling **woredas, kebeles,** *and informants*

Adm. zone	No. of rural *woredas*	Sample districts (25%)	Selected *woredas*	No. of *kebeles*			Sample *kebeles* (10%)		Total sample *kebeles*	No. of informants
				W/D	Dega	Total	W/D	Dega		
North Wollo	9	3	Habru, Meket, Raya Kobo	103	60	163	12	3	16	146
Oromia	5	1	Artuma Fursi	20	1	21	2	0	2	20
South Tigray	5	1	Ofla	32	23	55	3	2	5	48
South Wollo	20	5	Borena, Jamma, Kalu, Kutaber, Tehuledere	241	116	357	27	9	36	351
Wag Hmra	6	2	Gazgibla, Dehana	41	16	57	4	2	6	58
Total	45	12		437	216	653	48	16	65	623

corresponding farm plots, respectively. Pictures of tree stands in farm plots were taken using an Olympus Master 2 camera. Secondary data were collected from relevant offices, while focus group discussions were held with selected informants.

3.3.2 Biophysical data

Readings of coordinate pairs and the altitude of each sampled farm plot were taken using GPS Garmin 60. All woody plants found in each sampled farm plot were noted for presence/absence by vernacular names and scientific names where determination was possible. All plant voucher specimens were collected, pressed, dried, identified, and authenticated by reconfirming at the National Herbarium, (ETH), Addis Ababa University and were deposited at Wollo University.

3.4 Data analysis

The field dataset collected from informants and farm plots was edited and presented in quantitative terms for analysis using appropriate descriptive inferential statistical analysis and text analysis. Independent sample t test and ANOVA were carried out to detect significant differences among different means. These differences between means were used to test the various hypotheses. Data entry and simple arithmetic calculations were conducted using Excel 2007 and SPSS version 20. SPSS version 20 was used to compute ANOVA and independent sample t tests for demographic variables of ethnobotanical data.

CHAPTER FOUR

4 Results

4.1 Distribution of informants

Table 3 presents the number of informants consulted for the study against different social categories. A larger number of male informants than females and middle-income farmers than poor and rich farmers were consulted for the study. In terms of agroecology, more informants were included from Weina Dega than from the Dega zones, while in education the majority of informants were illiterate. This disparity makes getting the required equal sample for the study with regards to gender-sensitive cases problematic. More informants from the Weina Dega than from the Dega were consulted because Weina Dega *kebeles* outnumber Dega *kebeles* in the study area, and hence the difference is the result of proportionate sampling. Likewise, since the literacy issue is still at work in the rural community, more illiterate informants turned up than informants from other educational levels.

4.2 The cognitive domains of smallholder farmers

In this study, the cognitive domain and attitude of smallholder farmers towards growing trees in their farm plots was researched. Table 4 presents the different categories of smallholder farmers reporting their interest in growing trees in their farm plots. In general, the proportion of smallholder farmers with a positive attitude to growing trees on their farm plots is appreciably higher than those who were not clearly and unambiguously positive. The result indicated a higher proportion of male, middle-wealth category, and illiterate informants interested in growing trees in farmed landscapes than those in other categories. Middle-age category informants were more interested in growing trees.

Table 3. Distribution of informants in different response categories

Variable	Administrative category						Variable	Administrative category					
	S. Wollo	**N. Wollo**	**Oromia**	**S. Tigray**	**Wag Hmra**	**Total (%)**		**S. Wollo**	**N. Wollo**	**Oromia**	**S. Tigray**	**Wag Hmra**	**Total (%)**
Gender							**Education**						
Male	242	96	17	32	47	434 (69.7)	Write & Read	70	36	5	5	4	120 (19.3)
Female	109	50	3	16	11	189 (30.3)							
Total	351	146	20	48	58	623 (100)	Primary First Cycle (PFC)	70	15	1	10	3	99 (15.9)
Wealth class							Primary Second Cycle (PSC)	33	5	1	3	1	43 (6.9)
Rich	103	43	7	16	16	185 (29.7)	Secondary School (SS)	15	3	0	1	1	20 (3.2)
Middle	137	56	8	15	20	236 (37.9)	Total	351	146	20	48	58	623 (100)
Poor	111	47	5	17	22	202 (32.4)	**Age**						
Total	351	146	20	48	58	623 (100)	20–40	91	21	6	16	13	147 (23.6)
Agroecology							41–60	159	69	11	23	34	296 (47.5)
Dega	81	27	0	18	18	144 (23.1)	61–80	95	53	3	9	11	171 (27.4)
Weina Dega	270	119	20	30	40	479 (76.9)	>81	6	3	0	0	0	9 (1.4)
Total	351	146	20	48	58	623 (100)	Total	351	146	20	48	58	623 (100)

Table 4. Smallholder farmers' interests in growing trees in their farm plots

Variable	Overall	Informant's attitude based on response	
		Yes (%)	No (%)
Total	623	520 (83.5)	103 (16.5)
Gender			
Male	434	361 (57.9)	73 (11.7)
Female	189	159 (25.5)	30 (4.8)
Wealth Class			
Rich	185	155 (24.9)	30 (4.8)
Middle	236	192 (30.8)	44 (7.4)
Poor	202	173 (27.8)	29 (4.7)
Agroecology			
Dega	144	118 (18.9)	26 (4.2)
Weina Dega	479	402 (64.5)	77 (12.4)
Education			
Illiterate	341	271 (43.5)	70 (11.2)
Read and write	120	111 (17.8)	9 (1.4)
PFC	99	85 (13.6)	14 (2.2)
PSC	43	33 (5.3)	10 (1.6)
SS	20	20 (3.2)	0 (0)
Age			
20–40	147	121 (19.4)	26 (4.2)
41–60	296	253 (40.6)	43 (6.9)
61–80	171	138 (22.2)	33 (5.3)
Above 81	9	8 (1.3)	1 (0.2)

In the study, the number of plant species growing in farm plots and plant uses as perceived by smallholder farmers have been retrieved. Table 5 presents the average number of woody plants and the number of uses derived from them in farmed landscapes. The informants mentioned one to several types of uses for which they grow or encourage trees on their farm plots. Fifteen major use-values were mentioned by farmers with different frequencies of mention. These use-values include food, cash crop, firewood, charcoal, timber, house construction, agricultural tools, fodder, fertilizer, live fences, shade, cleansing, medicine, incense, and spiritual values (see Appendix 4).

More plant species and corresponding use-values were mentined by informants living in South Wollo Administration Zone than in other sites, by males than females, by the rich wealth group, by those living in Weina Dega agroecological zones, and by those at a better education level.

Table 5. Number of mentions of plants and plant use-values

Category	Number of informants	Average number of plants mentioned	Average number of plant use-values mentioned
Adm. Zone			
North Wollo	146	1.63	2.63
South Wollo	351	2.20	3.20
Oromia	20	1.85	2.85
South Tigray	48	0.23	1.23
Wag Hmra	58	1.03	2.03
Gender			
Male	434	1.72	2.72
Female	189	1.36	2.36
Wealth class			
Rich	185	1.79	2.79
Middle	236	1.59	2.59
Poor	202	1.49	2.49
Agroecology			
Dega	144	1.17	2.17
Weina Dega	479	1.74	2.74
Age			
20–40	145	1.65	2.65
41–60	300	1.60	2.60
61–80	170	1.57	2.57
Above 81	8	2.13	3.13
Education			
Illiterate	341	1.38	2.38
Read & Write	120	1.58	2.58
PFC	99	2.00	3.00
PSC	43	2.21	3.21
SS	20	2.50	3.50

4.3 Perceptions, attitudes, and management of trees on farm plots

Smallholder farmers were interviewed to determine if there were established farmer criteria to grow or encourage tree seedlings in farm plots. Of the 623 informants, 289 (46.4 %) consider no criteria for tree selection. Three hundred thirty-four (53.6%) informants reported the presence of some kind of criteria for tree species selection. Of the 623 informants, 214 (34.5%) reported that the criteria used for plant selection vary with farm plot, while 409 (65.7%) reported that the criteria do not differ with farm plots. The explanations that some informants gave regarding the variation in plant species selection included proximity to home, tree type, benefit, size of farm plot, and compatibility to crops. Three hundred forty-seven (55.7%) informants reported having a tree or trees on their farm plots, along with the sources of the tree species (see Table 6).

Table 6. Sources of tree species standing in smallholder farmers' plots

Sources	Informants	
	Number	Percentage
Encouraging naturally sprouted seedlings	68	20.0
Seedlings gained through gift or donation	31	9.1
Nursing seeds through own effort	24	7.1
Seedlings purchased from local markets	20	1.2
Transplanting seedlings from marginal areas	2	0.6
A combination of sources	182	53.5

Regarding the layout of trees on their farm plots, the study revealed that the experiences of informants vary. Table 7 presents the layout of trees observed on smallholders' farm plots. Figure 4 shows a tree standing at the center of a smallholder's farm plot.

Table 7. Layout of trees on farm plots

Layout	Informants	
	Number	Percentage
Scattered throughout farm plot	82	23.6
Occuring at selected spots inside farm plots	64	18.4
Standing between farm boundaries	60	17.3
Forming a hedge around the farm margin	27	7.8
A combination of layouts	114	32.9

Figure 4. **Cordia africana** *tree standing at the center of a smallholder's farm plot of teff* **(Eragrostis tef)** *(Photo: Hussien Adal).*

The layout of on-farm trees in northeastern Ethiopia demonstrates that a mosaic of patterns prevails. A high proportion of a combination of layouts indicates that the patterns of trees on the farms are random, spontaneous, and determined by their natural occurrence.

4.4 Trends in tree integration

The informants gave a recounting of the past experiences, covering both positive and negative practices, and explained current trends in tree integration into farmed plots. One hundred eighty-eight (30.2%) of the 623 informants pointed out that there are differences between past and current practices in tree integration, while 435 (69.8%) never referred to such differences. Few major assertions were advanced describing personal perceptions of temporal variations in tree integration. The assertions that were made include: there were more trees, both in type of species and density, in farm plots in the remote past than there are today; there is a gradual increase of trees recently; more trees were lost during the war time; eucalypt trees are detrimental to indigenous trees; and peoples' awareness of the significance of trees is gradually decreasing. Also, the emerging introduction of exotic trees into the farming landscape was mentioned as a new event to show differences in tree integration trends.

The study also disclosed the presence of tree species that had been part of the farmed landscapes, but have disappeared today. Two hundred sixty-one (41.9%) of 623 informants felt that some tree species are disappearing from their locality, while 362 (58.1%) were not aware of any disappearance of trees from farm plots in their vicinity. This may have arisen from the gradual replacement by younger smallholder farmers of the elderly farmers endowed with more knowledge of farming and farmland species. The former may lack information regarding what happened in the remote past and the current environmental changes that have compromised tree species in the area. The types of tree species said to be locally extinct varied from locality to locality. In the Dega agroecological zones, *Olea europaea L. subsp. cuspidata, Hagenia abyssinica, Juniperus procera,* and *Rosa abyssinica* were among those mentioned. In the Weina Dega zone, *Cordia africana, Croton macrostachyus, Olea europaea L. subsp. cuspidata, Acacia tortilis, Acacia etbaca, Rhus glutinosa, Buddleja polystachya,* and *Acacia abyssinica* were reported to have disappeared at least from their locality as far as the plain observation of the informants goes.

The status of perceptions of informants associated with trees forming the basis of their local environmental knowledge, associated concepts, and myths was gathered. One hundred twenty-eight (20.5%) of 623 informants believe that, along with local loss of trees, there is a corresponding local loss of knowledge and practices related to tree use (see Table 8), while 495 (79.5%) do not feel any loss of environmental knowledge occurring associated with loss of trees. This shows that many farmers have not developed awareness of the usefulness of their local indigenous ecological knowledge; this is an area that requires educational intervention. The data further showed that trees of farmed landscapes are important assets. This is a general phenomenon.

When informants were asked to relate the local disappearance of trees in their localities to any circumstance, 128 (36.6%) ascribed local disappearance to one to several reasons, while 395 (63.4%) reluctantly gave any account. Twenty-one (16.4%) of 128 informants related disappearance of trees to various causes (see Table 9), a greater number ascribed it to multiple causes; i.e., combinations of causes listed in Table 9 were mentioned by 47 (36.7%) informants, which is more than those who mentioned a single cause.

Table 8. Local loss of environmental concepts associated with loss of trees

Concepts	Informants who could associate loss of environmental concepts with loss of trees	
	Number	Percentage
Association of trees with spirits	33	25.8
A place for conducting court sessions or for general social gathering	29	25.8
Perceived use-values	11	8.6
Source of rainfall	9	7.0
A combination of losses	42	32.8

Table 9. Causes of disappearance of trees from smallholders' farm plots

Causes	Informants who mentioned tree disappearance causes	
	Number	Percentage
Land management issues (burning, frequent plowing)	21	16.4
Drought	14	10.9
Lack of peoples' awareness	13	10.2
Aging and death of trees	8	6.3
Use pressure	8	6.3
Impacts of invasive species	7	5.5
Camel browsing on treestands in farm plots (Figure 5)	5	3.9
Mismanagement of trees	4	3.1
Competition with crops	1	0.8
Effects of small plot size	1	0.8
Combinations of causes (2 or more of the above indicated)	47	36.7

Figure 5. A straying camel browsing on* Ziziphus spina-christi *growing on-farm after harvest of the crop teff (*Eragrostis tef*) in this case (Photo: Hussien Adal).

The study disclosed that 276 (44.3%) of 623 informants have no experience of growing a single tree on their farm plots. Table 10 presents the arguments of informants justifying their experiences of not having any single tree or trees on their farm plots. A greater proportion of the "no experience" informants presented multiple arguments to explan why they lacked experience of growing trees on their farm plots. It will be necessary to wisely and skillfully refute these reasons in order to convince and engage the "no experience" group in activities of on-farm tree management.

Table 10. Arguments of treeless informants

Argument	Informants' reasons for not having trees	
	Number	Percentage
Shading effect on crops	40	11.5
Lack of awareness	19	5.5
Lack of external support	15	4.3
Impact of sandy soil	13	3.8
Poor seedling establishment	13	3.8
Drought	11	3.2
Small plot size	12	3.5
Pestilence (epidemic diseases and the like)	12	3.5
Frost or cold climate not suitable for tree growth	10	2.9
Impact of free browsing	9	2.6
Lack of tree planting habit	9	2.6
Land subleasing	9	2.6
Distance from home	2	0.6
Old age infirmity	1	0.6
Priority to different land use	1	0.3
Burning	1	0.3
A combination of arguments	169	48.7

Informants trying to justify their not having any single tree on their farm plots (see Figure 6) proposed very interesting solutions for overcoming the difficulties facing integration of trees on their farm plots (see Table 11), and a higher number came up with combined multiple solutions compared to those proposing a single solution.

Table 11. Informants' suggestions for overcoming difficulties of growing trees

Proposed solutions	Informants' suggestions	
	Number	Percentage
Selection of suitable species	35	12.70
Educating people	34	12.30
Appropriate site selection	27	9.70
Policy formulation and enforcement	18	6.50
Sound tree management	16	5.78
Providing external support	15	5.43
Controlling free browsing	12	4.34
Watering seedlings	10	3.60
Tree protection	7	3.20
Encouraging tree nursery establishments	4	1.44
Community participation	1	0.36
Ensuring tree ownership	1	0.36
A combination of solutions	96	34.80

*Figure 6. Smallholder farm plot of teff (*Eragrostis tef*) with no single tree (Photo: Hussien Adal).*

Smallholder farmers' current practices of introducing exotic tree species into their farm plots were recorded through informant interviews. One hundred eighty-two (29.2%) informants replied verifying the presence of some exotic tree species on their farm plots, while 441 (70.8%) replied that they had no experience of growing exotic tree species. The common exotic tree species mentioned and observed in some farm plots were *Eucalyptus globulus, Eucalyptus grandis, Cytisus proliferus, Sesbania sesban, Cupressus lusitanica, Senna multiglandulosa, Grevillea robusta, Cajanus cajan, Shinus molle, Casuarina cunninghamiana, Jacaranda mimusophilia, Mangifera indica*, and *Malus sylvestris*.

4.5 Influence of social categories on local perceptions, attitudes, and tree management

4.5.1 Gender and trees on smallholder farmers' plots

Distinctions in being male or female with regards to growing trees on smallholders' farm plots was retrieved; 208 (33.4%) informants supported the presence of gender distinction while 415 (66.6%) gave no support for the assertion. Comparison of means showed that male households grow relatively more trees on their farm plots than female-headed household do, but no significant mean differences ($P<0.05$) (see Table 12) were observed.

Table 12. Gender differences in growing trees on smallholder farmers' plots

Category	Mean±sd	Significance value		
		t	df	significance
Male	1.72±2.13			
Female	1.36±1.86	2.009	6.21	0.045

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The gender distinction in growing trees on farm plots was ascribed to many different reasons, including that it was too difficult a job for females (21, 9.2%), that it was a job unfamiliar to females (7, 3.7%), that there is a perception of it being the duty of men (7, 3.7%), that it was a work burden (33, 15.9%), that social classification dictates that females' engagement be in indoor activities (13, 6.3%), that female income is low (23, 11.1%), and a combination of the above reasons (96, 46.2%).

4.5.2 Wealth class and trees on smallholder farmers' plots

Distinctions among different wealth classes regarding growing trees on farm plots was retrieved, disclosing that 460 (73.8%) of 623 informants supported the presence of distinction between different wealth groups, while 163 (26.2%) did not give support to the presence of distinction. Upon interviewing to seek explanations regarding whether being a member of a particular wealth category would influence attitude towards growing trees, the informants generally supposed that wealthier smallholder household heads kept relatively more trees on their farm plots, for a number of reasons (see Table 13). Better awareness and access to agricultural extension services were mentioned by 17.7% and 4.6% of informants, but a combination of assumed factors claimed close to 60%. Farm plot size is not attributed to wealth category, since leasing does not consider wealth status.

Table 13. Suppositions for better tree performance of rich household heads

Assumption	Informant considering rich smallholder farmers keep more trees on farm plots	
	Number	Percentage
Better awareness	100	17.7
Better access to agricultural extension services	21	4.6
More demands for fodder/browsing	18	3.9
Extra-large plot size	15	3.3
Sufficient labor force	13	2.8
Subleasing farm plots	11	2.4
Drive of immediate economic needs	8	1.7
A combination of assumptions	274	59.6

ANOVA showed that the distinction among different wealth classes regarding growing trees on farm plots was significant (F = 1.13, P>0.05) (see Table 14).

Table 14. ANOVA results of tree integration among different wealth classes

Category	Mean±sd		Sum of squares	df	Mean sq.	F	Sig.
Rich	1.79±2.3	Between groups	9.58	2	4.791		
Middle	1.49±1.90	Within groups	2620.63	620	4.220		
Poor	1.59±1.98	Total	2630.21	622		1.133	0.3

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.5.3 Age and trees on smallholder farmers' plots

Table 15 presents ANOVA results of differences in growing trees among successive age groups of smallholder farmers. The results of the study showed that older informants integrate more trees, along with possessing relatively more knowledge than younger people, with a significant difference (F = 0.206, P>0.05). This agrees with the general fact regarding age-wise distribution of indigenous botanical and ecological knowledge among rural farming communities. This needs to be focused on in future selection and expansion of woody plants on farmed landscapes; participation of knowledgeable elders becomes critical.

Table 15. ANOVA results of tree integration among successive age groups

Category	Mean±sd		Sum of squares	df	Mean sq.	F	Sig.
20–40	1.65±1.995	Between groups	2.628	3.0	0.876		
41–60	1.6±2.10	Within groups	2627.590	61.9	4.245		
61–80	1.57±1.98	Total	2630.218	622.0		0.206	0.8
Above 81	2.13±2.94						
Total	1.61±2.0						

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.5.4 Education and trees on smallholder farmers' plots

Table 16 presents mean differences of tree integration along differences of literacy level. The results of the study showed that with increasing literacy level there is a corresponding increase in mean number of trees integrated into farm plots, but ANOVA result indicated that the difference is only weakly significant ($F = 3.899$, $P<0.05$).

Table 16. ANOVA results of tree integration among different literacy levels

Category	Mean±sd		Sum of squares	df	Mean sq.	F	Sig.
Illiterate	1.38±1.77	Between groups	64.736	4	16.18		
Write & Read	1.58±2.02	Within groups	2565.482	618	4.15		
Primary First Cycle	2.0±2.4	Total	2630.218	622		3.899	0.04
Primary Second Cycle	2.21±2.8						
Secondary School	2.5±2.1						
Total	1.6						

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.5.5 Agroecology and trees on smallholder farmers' plots

Table 17 presents differences of tree integration on smallholder farmers' plots in terms of agroecology. Comparison of means showed that in the Weina Dega agroecological zone, household heads grow relatively more trees on their farm plots than in the Dega, but the difference is only weakly significant ($P>0.05$).

Table 17. Differences in tree integration based on agroecological variation

Category	Mean±sd	Significance value		
		t	df	sig.
Dega	1.17±2.0			
Weina Dega	1.74±2.03	-2192	621	0.073

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.5.6 Administration zone and trees in smallholder farmers' plots

Table 18 presents ANOVA results of comparisons of means of tree integration in smallholder farmers' plots among administrative zones. The mean number of trees integrated into farm plots varies with administrative zones, but ANOVA has indicated that the difference is not significant ($F = 8.54$, $P<0.05$).

Table 18. ANOVA results of tree integration among administrative zones

Category	Mean±sd		Sum of squares	df	Mean sq.	F	Sig.
North Wollo	1.63±2.97	Between groups	138.28	4	34.50		
Oromia	1.85±2.23	Within groups	2491.93	618	4.03		
South Tigray	0.23±0.928	Total	2630.21	622		8.54	0
South Wollo	2.2±1.4						
Wag Hmra	1.03±1.270						
Total	1.61±2.056						

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.6 Role of agricultural extension services in maintaining trees on farmed landscapes

The study looked at whether there are initiatives/ stakeholders supporting smallholder farmers' efforts on tree integration into their farm plots. Two hundred thirty-five (37.7%) of 623 informants asserted positively, while 388 (62.3%) did not know of any such initiatives or stakeholders providing support for smallholder farmers. Moreover, informants were interviewed to express their interests in cooperating with any would-be initiative/ program working on tree integration into smallholder farmers, to which 502 (80.6%) of 623 informants answered positively while 121 (19.4%) gave no positive response. Both groups were asked to disclose why they said "no" or "yes" to probable cooperation with tree integration initiatives. On the "yes" side, 156 (31%) said they would do so because they are fully aware of the multiple benefits of trees growing on farms, while 59 (11.7%) said they would do so based on the lessons derived from local development agents. Only 5 (0.9%) said they know the contribution of farm trees to improving soil fertility, while 282 (56.2%) informants gave a combination of different assertions. On the other hand, on the "no" side, the informants gave a number of reasons (see Table 19).

4.7 Emerging trends associated with legal issues

Informants were asked to speak about what they feel with regards to the protection of their tree-use rights as expressed in cutting or selling trees growing on their farm plots. Five hundred sixty-seven (91%) of 623 informants responded positively by saying they like to be assured of tree-use rights, while 56 (9%) did not consider this important. Land-holding certification is considered a guarantee of tree ownership of smallholder farmers. Five hundred thirteen (82.3%) agreed that their tree-use rights are protected by government laws, while 110 (17.7%) said they do not currently know the extent of legal protection of tree-use rights. The informants' judgment of the various stakeholders' preoccupation in mainstreaming on-farm trees for improved agricultural productivity and natural resources management was retrieved from their responses. In this case, 226 (36.3%) agreed that there is mainstreaming of on-farm trees by government agencies, while 397 (63.7%) do not have support for mainstreaming of trees on farm plots. Informants recognizing steps taken to mainstreaming trees on smallholders' farm plots support their assertion based on their inference of local government efforts. Twenty-three (10%) informants said they have observed seedlings distributed from community nurseries for planting, 143 (63.2%) were given education to raise their awareness of integrating trees into their farms, 6 (2.2%) strongly argue that there is local government follow-up and assessment of tree planting on farm plots, and 54 (23.8%) gave a combination of the above evidence.

4.8 Composition of woody species in farmed landscapes in northeastern Ethiopia

Observation and counts of smallholder farmers' plots for woody plants standing inside their farms revealed that 278 (44.6%) of 623 informants had no trees while 345 (55.4%) had one or more tree species growing in the farm plots. In total, 72 woody plant species representing 61 genera and 40 families were recorded in this study. In terms of habit, 49 (68%) are trees and 23 (32%) are shrubs. Of the total, 15 (20.8%) species belong to the family *Fabaceae*, 5 species to *Rosaceae*, 4 species each to *Anacardiaceae* and *Euphorbiaceae*, 3 species each to *Myrtaceae* and *Rutaceae*, 2 species each belong to *Boraginaceae, Celastraceae, Cuppresaceae, Loganiaceae*, and 31 families are represented by a single species. Ten plant species are cultivated as cash crops in fields accessible to irrigation schemes while 14 species are introduced for agroforestry purposes. The remaining majority (48 species) naturally occur in the farm plots, either developing from seeds available in the seed

Table 19. Reasons of informants on the "no" side

Reasons	Informants on the "no" side	
	Number	Percentage
Negative shade effect on crops	29	23.9
Skepticism on success of the survival of on-farm plantings	23	18.2
Difficulties of small plot size	15	12.3
Lack of awareness	11	10.0
Not doing it well due to old age	6	4.9
Lack of established tree planting culture on farm plots	5	4.1
Poor seedling establishment arising from poor soil condition	4	3.3
No encouragement from local government	3	2.5
Distance from home	2	1.6
A combination of the above reasons	23	19.0

bed or from seeds dispersed to the farm plots through various natural dispersal mechanisms. The latter groups of plant species and other locally extinct species not mentioned here are disappearing from the agricultural landscape and therefore require intervention to bring them back to the farm plots in desirable numbers.

In terms of use, firewood, bee forage, shade, and ecological services are cross-cutting use-values drawn from all species recorded in the study. See Figure 7 for an example of trees planted to be used as livestock fodder. Up to 10 use-values are obtained from one or another species (see Appendix 4).

Figure 7. **Cytisus proliferus** *grown on maize (***Zea mays***) farm for livestock fodder (Photo: Hussien Adal).*

CHAPTER FIVE

5 Discussion

5.1 Distribution of informants

The effort made to include an equal number of females and male informants for the study has failed. It is always the case in a rural community to find more male-headed households than female-headed households, due to the prevailing cultural disapproval of females working in the field and generally appearing in public. Immigration of literate individuals to the towns and cities keeps the number of educated people in the rural area below the number of illiterate individuals. This is a very common phenomenon in developing countries, and government actions to increase the educated population of rural areas is an ongoing process, as seen currently in the expansion of schools into remote rural villages. With more and more education, the situation will continue to improve, but it will persist for some time to come.

5.2 The cognitive domains of northeastern Ethiopian smallholder farmers

Trees in farmed landscapes in northeastern Ethiopia provide a range of goods and services, including food, fodder, climate change mitigation, biodiversity conservation, and water quality options. Farmers and farming communities have a significant role to play in the preservation and conservation of these resources, the ecosystems, and the associated indigenous knowledge. In this regard, smallholder farmers of northeastern Ethiopia have considerable roles to play in optimizing and ensuring the continuous flow of the resources and ecosystem services that accrue from farmland trees.

Generally, the study has revealed that smallholder farmers in northeastern Ethiopia have positive attitudes about the integration of trees into their farm plots, mainly due to the benefits that these on-farm trees provide to sustain their life. However, the number of farm plots without trees is almost as high as the number of farm plots with trees due to the low level of tree integration and purposeful management observed. The level of cognitive domain of household heads regarding trees in the agricultural landscape varies with social categories. The list of uses mentioned by our informants when compared with those reported in many other studies elsewhere (Gerique, 2006; Jose, 2009; Tabuti, 2012) and in Ethiopia (Hachoofwe, 2008; Adal, 2014; Tefera et al., 2014) revealed a high degree of correspondence. This implies that the cognitive domains for on-farm woody species are more or less similar in rural communities found in different parts of Ethiopia and other countries where livelihoods depend on plants.

Relatively more records of trees on smallholders' farm plots in the Weina Dega agroecological zone than in the Dega zone explains the influence of agroecology on smallholders' perceptions, attitudes, and management of trees in farmed landscapes. Agroecological settings with rich agrobiodiversity that include trees growing in farm plots contribute to sustainable livelihood security at the local, national, and global levels. Identification of differences in perceptions, attitudes, and management among different social groups with regards to tree integration helps to develop mechanisms of support for specific groups of smallholder farmers (low-income farmers, female farmers, etc.).

5.3 Status of tree integration and management on-farm

In order to integrate trees on farms, farmers apply a number of criteria, including fast growth, utility, compatibility, multipurpose use-value, drought resistance, and access to seedlings. Most of these are similar to reports by earlier researchers (Cerdán et al., 2012; Van Damme and Kindt, 2012). The decreasing trend in indigenous tree integration on farms alluded to by informants is a phenomenon reported by Hachoofwe (2008) based on a study conducted in Tigray. The same trend prevails, as reports (Negash and Achalu, 2008) demonstrated, for southern Ethiopia and in the northwest (Tefera et al., 2014; Ruelle, 2014, Abiyu et al., 2015). Landscape re-greening through adopting the emerging evergreen agriculture (ICRAF, 2013) is a strategy that combines relatively short-term livelihood gains, commonly realized in conservation agriculture, with longer-term but sustained crop productivity and environmental resilience achieved by inclusion of leguminous and fruit trees. Increasing evidence shows that evergreen agricultural practices are a key element in regenerating the long-term quality of the land and can be the basis for a more resilient climate-smart agriculture that comes with science-based solutions that promise to help smallholders protect and enrich soils, increase food production, adapt to climate change, and reduce greenhouse gas emissions in areas like northeastern Ethiopia.

The new trend rightly brought up by farmers concerning the increasing level of exotic trees planted on farmlands had also been observed in an earlier study in Tigray (Hachoofwe, 2008). Abiyu et al. (2015) consider that trees are planted by smallholder farmers in Ethiopia either for biomass or as a major source of income. Since many of the exotic woody species are important for farmer households, considering them in tree nursery establishment and promotion is vital. In earlier studies that addressed some of these aspects, it was shown that many of the indigenous species recovered have been recorded as multipurpose woody plants used as food, medicine, and a variety of purposes by the respective communities (Adal, 2014; Lulekal, 2014). Trees of farmed landscapes are depicted by informants as important assets. This is a general phenomenon that prevails in other countries as well (Cromwell et al., 1999). Many species that are among those frequently reported to be the common multipurpose woody components of the agricultural landscapes in highland Ethiopia (Negash and Achalu, 2008; Hachoofwe, 2008; Tefera et al., 2014; Ruelle, 2014) were recorded in this study.

Fourteen (about 19%) species are exotics introduced into farm plots through the agroforestry packages and as a hedgerow for their multipurpose values by the agricultural development drives, including fodder values and merits as live fence or woodlot species.

5.4 Composition of woody species in the farmed landscapes

The analyses showed that the family Fabaceae was the dominant taxon group and accounted for 15 of the 72 woody plant species in this study. The relatively heavy load of leguminous species (about 21%), known as fertilizer trees, and found among the woody components, underlines the importance of farmland woody species. They are important not only for economic and other utility purposes but also on account of the remedy that they offer to the degraded and degrading landscapes of northeastern Ethiopia. Their presence also implies that the farmers in one way or the other do realize their important roles in the fields, at home, and in the market place. These fertilizer trees growing on-farm in rural landscapes are managed for land restoration, soil health, and food security. The trees encountered are also sources of fruits for human nutrition; fodder that improves the production of smallholders' livestock products; timber and fuel wood trees maintained for shelter and energy; medicinal trees that combat diseases; and trees that yield gums, resins, or latex products. Many of these trees are multipurpose, providing a range of benefits in rural areas of developing countries as typically reported, including by Nawir et al. (2007) and Abiyu et al. (2015). Significant yield increases of maize and sorghum when intercropped with fertilizer woody species have been reported for the Sahel region, West Africa, Malawi, and other countries (ICRAF, 2013).

The woody taxa of the study area are categorized as belonging to one of three management categories, i.e., naturally growing, introduced or exotic, and deliberately cultivated species. The heavy load of the leguminous species observed in this study spells a high level of utility and ecosystem services. Tree integration concerns should address naturally growing species, which have in earnest received less appreciation by smallholder farmers. This opens an important platform for awareness raising and deeper study of the local indigenous knowledge of the woody species preferred by smallholder farmers. Such background information is important for re-greening the agricultural landscape of the study area, which can then be considered by adjacent areas.

5.5 Possible solutions to the observed gaps and the way forward

The key suggestions provided by informants (suitable tree species, public education, good setting, policy, tree management, external support, tree protection (including by controlling free browsing), watering seedlings, community participation, tree ownership rights) are worth taking up as a way forward in order to mitigate the situation. These solutions are well focused on most of the problems discussed earlier (Nawir et al., 2007; Hachoofwe, 2008; Kassa et al., 2011) and the usual options offered as possible solutions. These suggestions are focused on the major gaps, and addressing them would resolve many problems. Other innovative options such as the green water credit approach (Fleskens and Chilima, 2013) could also be considered. According to the conservation-objective-devoid land allocation theory of von Thunen cited by Abiyu et al. (2015), farmers allocate land to the use that gives the highest land rent but fails to capture the biodiversity and use-value criteria that farmers care for. In view of the geographical, climatic, and social characteristics of northeastern Ethiopia discussed above, the trend that is developing around Lake Tana Catchment (Abiyu et al., 2015), which is actually similar to that reported in Tefera et al. (2014) and Ruelle (2014), is not what one would wish to have happen in the present study area, where food and animal feed security issues have to be made the centerpiece strategies of tree integration plans. In this regard, Abiyu et al. (2015) asserted that the comparative advantages of tree planting should be seen against the food security targets of any local area. What is more, it has to be seen in the light of sustainable agricultural production and improved quality of life. Now is the time for Ethiopia to aggressively embark upon the "trees on-farm movement" as it fits its objective realities and long-term aspirations. If efforts could be directed towards rehabilitating the woody species with farmer participation, step by step the land could heal, thereby restoring the soil and ultimately regaining its fertility. Agricultural land managed in this manner can continue to be productive and provide the services it has always given to the present and future generations.

Varying degrees of perceptions and attitudes of smallholder farmers occur together with tree management practices in farmed landscapes of northeastern Ethiopia. Generally, smallholder farmers have a positive attitude towards integration of trees in the agricultural landscapes, but the level of cognitive domain of households for trees varied across social categories and decreased along the age gradient. Local extinction of trees, as well as the causes of extinction and local perceptions of the role of trees, varied from locality to locality. No experiences of smallholder farmers' preferences for tree species, crop combinations, and farm locations were reported for tree integration into farm plots. Farmers' conviction of the presence or absence of local support mechanisms, as well as their determination of cooperating with a potential tree integration initiative in the future, is on the borderline, implying that there is a need to develop a strong means by which to address the tree integration interests of smallholder farmers. The emerging land certification endeavor has been a source of confidence for farmers to engage in integrating trees into their farm plots, but more enabling, legally binding enforcement mechanisms may be necessary to assure farmers of tree-use rights. Concern for tree integration into smallholder farmers' plots has so far been an area of little engagement, if not a very much neglected one. Tree integration into smallholder farm plots should, therefore, be in the mainstreaming agenda, including issues dealing with mechanisms of tree ownership and use rights.

Intensification of tree management will need to address the different chal¬lenges that smallholder farmers and researchers are likely to face. Many woody species that people in the de¬veloping world depend upon are threatened by factors such as over-exploitation or habitat conversion and are thus disappear¬ing. Rural and marginalized people, especially women, are highly dependent on woody plants for their subsistence and income generation. There is a dire need to innovate and bring in new experiences and best practices to overcome the challenges.

One such experience that could be tried in Ethiopia is the green water credit concept, which smallholder farmers can implement as practiced in other countries (see Fleskens and Chilima, 2013); for example, in Malawi. Green water is the water held in soil and available to plants in situ. It can be managed by smallholder farmers and other rural community members. The approach is based on analysis that the most cost-effective way of building resilience to increasing water scarcity caused by land degradation and climate change is to increase water storage in farmers' fields. Future prospects go beyond the usual goods and services to generate additional revenue from innovative areas like the green water harvest (Fleskens and Chilima, 2013) and the currently much-discussed carbon trade initiative (Jose, 2009).

The part of the study area that falls in the arid zone is an ideal site for introducing agroforestry practices to solve the problems of deforestation, land degradation, and poverty alleviation. The presence of three different cultural groups creates further opportunities to study how different cultural groups manage trees in farmed landscapes and opportunities to pave the future roadmap.

CHAPTER SIX

6 Conclusion

Integration of trees into smallholders' farm plots is valuable, provided it is done with best selection of tree species and helps to meet the real needs of the smallholder farmers. It appears that there is need to give due attention to the selection of useful tree species based on well-established selection criteria that consider local environmental conditions, farmers' interests, and the economic, ecological, social, and spiritual significance of tree species. The trees growing on smallholder farmers' plots recorded in this study are mainly from natural sources or seedlings obtained for free through gifts. However, the farmers' efforts in this regard are not negligible. Equally important in the efforts of tree integration in smallholders' farm plots, besides selection of best species, is the selection of appropriate sites within the farm plots in which the trees can fit. In this study, no uniformity has been observed among smallholder farmers in site selection and choice of layout of trees.

Informants cognizant of the disappearance of trees and associated knowledge from the agricultural landscape are relatively fewer, indicating a trend of gradual loss of both species and knowledge attached with the species. Moreover, assessment of current activities to bring trees back to their natural origin, i.e., to the farm plots, has pointed out the emphasis given to the propagation of exotics, as noticed from the efforts of local nurseries. Also, there is recognition of the influence of drought and war hazards on the presence of trees in farmed landscapes, alongside the deforestation process of natural forests. Environmental knowledge connected to survival of trees on local farms held by young farmers is less than it is in the elderly informants. This is identified from the little judgment younger farmers have regarding the local disappearance of particular tree species. Trees spotted in smallholders' farm plots are by and large remnants of past human pressure.

Local extinction of trees as well as local perception of the role of trees varied from locality to locality. Disturbance of the abode of spirits, loss of places that could be used in running court services for settling issues, and changing rainfall patterns (vegetation attracts rainfall, according to the local people) are among the bad effects of loss of trees that go beyond the socioeconomic losses from farms as mentioned by the informants. The majority of informants reluctantly mentioned the factors responsible for the actual loss of trees from their farm plots. Those who dare mentioned it attributed the losses to both human factors and natural causes. The former factors can be avoided provided that tree integration in the smallholders' farms is in the mainstreaming agenda. Lack of personal motivation to grow trees on their farm plots can also be avoided if incentives can be provided for farmers. Thus, the suggestions made to overcome difficulties of keeping trees in smallholders' farm plots have implications for the way forward. There are wide possibilities of working with smallholder farmers in the mission of tree integration.

The role of agricultural extension services in the maintenance of trees on smallholder farms cannot be overemphasized. Although some informants knew of some supportive initiatives/stakeholder mechanisms, the majority of informants did not recognize the existence of such support mechanisms for tree integration. This finding indicates that the matter has not been given the kind of attention it deserves in this era of climate change tribulation. Smallholder farmers welcome stakeholders working on tree integration, stemming from the knowledge they have gained of the multi-faceted benefits and services drawn from trees grown on farm plots. Indeed, some farmers appeared to diverge from this line of thinking, not because they have no interest in cooperating with stakeholders, but because of their past experience that promises may not translate into actions. Their skepticism of observing practical steps ever being handed out at the farmers' gates in the form of tree support programs is high. They do wish, however, that such programs would be put forward so that they could work synergistically with them.

The legal atmosphere for issues of tree integration is not a bottleneck as such, since an emerging land certification initiative has lessened the problem of doubts over ownership rights to trees grown in one's farm plots. Furthermore, Proclamation Number 542/2007, passed to provide for the development, conservation, and utilization of forests, supports the integration of trees into farmed landscapes. But implementation of the Proclamation at the grassroots level seems not encouraging. Local development plans lack emphasis on farm plot tree integration. Also, information about legal provisions on the protection of individual ownership rights to trees growing on one's farms appeared not adequately communicated to smallholder farmers. None of the informants mentioned the presence of a government proclamation or legal mechanism regulating the interaction of trees on their farm plots or their right of utilization of tree resources.

Based on the informants' responses, it is possible to say that tree integration into smallholder farm plots is not on the mainstreaming agenda so far. Despite this generalization, there are piecemeal activities of handing out advice to local farmers, along with the normal agricultural and rural development packages in the agricultural extension and technology transfer schemes.

Concerns of tree integration have so far been an area of little engagement, if not a very much neglected development area.

The study has recorded 72 woody plants, many of them belonging to the family Fabaceae, existing at one of three management categories, i.e., naturally growing, introduced exotic, and deliberately cultivated species. The naturally growing species require little effort to maintain in the agricultural landscapes, because they are self-propagating. Accepting their inclusion and regulating or encouraging their growth through sound management practices such as fencing, pruning, lopping, pollarding, and cutting as well as replanting and transferring seedlings to appropriate locations within the farm plots can be adequate measures of tree integration. The exotics are among the species stock introduced to the farm plots at different occasions through the Ministry of Agriculture linked with promotion of agroforestry practices in the country. Smallholder farmers can draw multiple benefits from these species. Beyond a number of other uses of each species, the multipurpose species offer varying degrees of use-values, including improving the fertility of the soil, provision of livestock fodder, and conservation of soil and water. Sources of these exotic agroforestry species for smallholder farmers often are community nurseries established in each *woreda* under the supervision of local Agriculture and Rural Development Offices to promote local agroforestry practices.

The third management category of tree species recorded from the smallholder farm plots are cultivated species planted in irrigated fields and around water spots. These trees are given great attention as they are regarded as cash crops fetching household income to fill cash flow gaps. Their integration on the farms is demand-driven and regulated by the market chain. Since their influence on the household economy is very well established, integration of these species is adequately taken care of by smallholder farmers themselves, because they want supplementary household income. Tree integration concerns should, therefore, emphasize naturally growing species, which have received less appreciation by smallholder farmers. An option to consider would be to try to build a science-based trees on-farm initiative constructed on the existing traditional agroforestry of smallholders that is attuned to and harmonized with the time-tested perceptions, attitudes, and management practices of local indigenous knowledge.

CHAPTER SEVEN

Recommendations

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

- Smallholder farmers' activities of tree integration on their farm plots should be guided through a well-designed local management plan and should include making effective use of indigenous knowledge and skills through the participation of knowledgeable elders from the local community.

- Trees to be considered for integration should be identified through participatory tree selection involving male and female farmers and researchers. The trees should be indigenous species growing naturally in the local environment. Since many exotic woody species already growing on some farm plots are very important for farmer households, their inclusion in local-area tree nursery establishments needs to be based on evaluation through ranking and comparison in areas where they have proven to be successful. Since it has been found that on-farm tree development programs focused on exotic species are usually not taken up well by farmers, more emphasis should be given to indigenous woody species of the area that are appreciated by local inhabitants. In both cases, however, copious inclusion of leguminous species would be of much help to the people and the land.

- Knowledgeable elders of local communities need to participate in establishing tree nurseries and promotion activities, given their useful time-tested knowledge about farmland trees and their management.

- It will be necessary to wisely and skilfully refute the reasons provided by farmers for not growing trees in order to convince and engage the "no experience" group in on-farm tree management activities.

- Smallholder farmers' awareness of the overall values of tree integration should be raised. In such awareness-raising drives, lessons on the usefulness of the local indigenous botanical and ecological knowledge and management practices should be included, since this research has shown that farmers have not developed the necessary minimum awareness package.

- Tree integration efforts should be guided, drawing scientific principles and knowledge from relevant fields of study, including ethnobotany, agroforestry, horticulture, and other related disciplines.

- Careful assistance should be given to farmers in their efforts to identify suitable sites for tree integration (inside crop fields, home gardens, farm margins, and other suitable locations).

- Location-specific selection (trees for inside fields, home gardens, homesteads, margins, tree lots, etc.) should be made, keeping in mind community preferences and the 72 species identified in this study, in order to maximize the benefits to the farming communities, the degraded and degrading landscapes, and the rest of the population.

- Smallholder farmers' efforts of tree integration should be supported with adequate logistics, technical assistance, and conditional provision of land adjacent to crop fields for effective tree integration on a competitive basis. Successful farmers need to be rewarded in various ways, including financial rewards, the provision of additional plots of land for integrating trees on-farm, payment and sponsorship for training other farmers (farmer-farmer trainings), material provision, etc. Rewards should be focused on the needs and priorities of farmers in the local area.

- Smallholder farmers' confidence that they will benefit from tree resources on their farm plots should be developed through creation of transparent and legally binding enforcement mechanisms that can improve the practices of and benefits to farmers.

- Innovative initiatives, such as the green water credit system, should be introduced. Through fund generation, these initiatives can be sustained for years to come. Gradually, carbon trade can be injected into such schemes.

- Continued extensive studies that apply both qualitative and quantitative ethnobotanical methods should be undertaken to optimize lessons learnt from local indigenous experts, lessons that can then be plowed back into local tree integration activities.

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Appendix 1. Semi-structured interview schedule with smallholder farmers (English version)

Farmer's Name ___________ Gender ___ Age ___ Religion _________ Wealth Class ______
National Region _________ Adm. Zone __________ Woreda/District ______ Kebele/PA ______
Agro climatic zone ___ Plot Size ___ GPS readings: Easting ___ Northing ___ Altitude ___

1. Do you like to have trees on your farm plots?

2. If you have trees on your farm plots, please list in their vernacular names. 1/ 2/ 3/ 4/

3. Is there any use-value you are drawing from trees on your farm plot? Please list. 1/ 2/ 3/ 4/

4. On what merit did you select each type of tree grown on your farm plot. 1/ 2/

5. Does the criterion differ with crop type and/or plot type?

6. Would you please explain why the selection criteria vary?

7. The trees grown on your farm plots are A) encouraged on the spot from naturally germinated seeds B) transplants of seedlings from elsewhere C) nursed from seeds on own efforts D) planted from seedlings purchased from local market E) planted from seedlings gained through gift or donation

8. Please tell me the layout of trees on your farm plots. A) Spontaneously scattered throughout B) between farm boundaries C) forming hedge around the farm margin D) at selected spots inside the farm plot

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

10. If yes, would you please mention the difference

11. Are there trees which have disappeared from local farm plots today?
    If yes, please mention the names of these trees. 1/ 2/ 3/

12. Would you describe any environmental knowledge, concept and myth lost along with the loss of trees?
    1/ 2/ 3/

13. What do you think are the reasons for the loss of these trees? 1/ 2/ 3/

14. If you don't have trees on your farm plot, why is it so? 1/ 2/ 3/

15. What could be the solutions to keep trees on your farm plot? 1/ 2/ 3/

16. Are there exotic trees on your farm plot? Would you please list them in their local names?
    1/ 2/

17. Is there a distinction in being a female or male with regards to growing trees on farm plots?

18. If yes, what is the difference?

19. Has wealth group category any influence on growing trees on farm plots?

20. If yes, what is the difference?

21. Would you please name an initiative/stakeholder that hitherto supported your efforts?

22. Were you volunteer to cooperate with had there been an initiative/program assisting smallholders' in tree integration into the farm plots?

23. If yes/ no, what is your justification; 1/ 2/ 3/

24. Do you have an ownership right to use trees growing on your farm plot?

25. Is your right legally protected?

26. Is there mainstreaming of on-farm trees on the government side, at local or national level?

27. If yes, what are the efforts made so far to promote tree integration into smallholder farms?
1/ 2/ 3/

Appendix 2. Biodiversity data sheet for diversity and density of tree species in farm plots

Farmer's Name _________________ Gender ____ Age ____ Edu. Level ____ Religion ____
Wealth Class ____ National Region ____ Adm. Zone ____ District ____ PA ____
Agro climatic zone ____ Plot Size ____ GPS readings: Easting ____ Northing ____ Altitude ____

No.	Local /scientific name	Number of seedlings (< 1.5 m)	Number of saplings (1.5 m and 3 m)	Number of mature plants (>3 m)	Number of living stumps	Number of dead stumps

Appendix 3. List of woody plant species recorded from smallholders' farm plots

Key: H, Habit; F, Food; M, Medicine; Co, Construction; T, Timber; Ch, Charcoal; Fd, Fodder; Fe, Fertilizer; C, Cash; Agt, Agricultural tool; P, Provenance

C.No.	Local name	Scientific name	Family name	H	F	M	Co	T	Ch	Fd	Fe	C	Agt	P
50	Nech girar	*Acacia abyssinica* Hochst. ex Benth	Fabaceae	T			x		x	x	x			
19	Doret	*Acacia etbaca* Schweinf.	Fabaceae	T			x			x	x	x	x	
43	Yeferen girar	*Acacia melanoxylon* R. Br.	Fabaceae	T			x		x	x	x			Exotic
29	Tikur girar	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	T		x	x		x	x	x	x		
49	Wachu girar	*Acacia seyal* Del.	Fabaceae	T					x				x	
8	Korera	*Acacia tortilis* (Forssk.) Hayne	Fabaceae	T						x	x		x	
	Sesy	*Albizia schimperiana* Oliv.	Fabaceae	T			x							
30	Bedano	*Balanites aegyptiaca* (L.) Del.	Balinataceae	T										
48	Azamir	*Bersama abyssinica* Fresen.	Melianthaceae	T							x			
36	Anfar	*Buddleja polystachya* Fresen.	Loganiaceae	T			x					x	x	
25	Sinayel	*Cadia purpurea* (Picc.) Ait.	Fabaceae	S			x							
23	Yergib ater	*Cajanus cajan* (L.) Millsp.	Fabaceae	S	x					x	x			Exotic
51	Digta	*Calpurnia aurea* (Ait.) Benth	Fabaceae	S			x				x			
22	Agam	*Carissa spinarum* L.	Apocyanaceae	S										
70	Shewshewe	*Casuarina cunninghamiana* Miq.	Casuarinaceae	T			x							Exotic
52	Chat	*Catha edulis* (Vahl) Forssk ex Endl	Celastraceae	S								x		Cultivated
65	Lomie	*Citrus aurantifolium* (L.) Brum f.	Rutaceae	T								x		Cultivated
61	Tringo	*Citrus medica* L.	Rutaceae	T										Cultivated
60	Birtukan	*Citrus sinensis* (L.) Osb	Rutaceae	T	x							x		Cultivated
59	Bunna	*Coffea arabica* L.	Rubiaceae	T								x		Cultivated
54	Feteqa	*Combretum molle* R. Br. ex G. Don	Combretaceae	T										
5	Wanza	*Cordia africana* Lam.	Boraginaceae	T			x	x	x			x		
7	Bisana	*Croton macrostachyus* Del.	Ephorbiaceae	T							x			
15	Yeferengetid	*Cupressus lusitanica* Mill.	Cuppressacea	T			x	x				x		Exotic
	Treelucent Eng	*Cytisus proliferus* L.f.	Fabaceae	S						x	x			Exotic
13	Kitkita	*Dodonaea angustifolia* L. f.	Sapindaceae	S							x			
35	Wulkifa	*Dombeya torrida* (J. F. Gmel.) P. Bamps	Sterculiaceae	T			x							
54	Koshim	*Dovyalis abyssinica* (A. Rich.) Warb.	Flacourtiaceae	T	x									
67	Hulaga	*Ehretia cymonsa* Thon	Boraginaceae	S	x								x	
57	Sembo	*Ekebergia capensis* Sparrm.	Meliaceae	T	x		x	x						
4	Nechbahirzaf	*Eucalyptus globulus* Labill.	Myrtaceae	T				x				x		Exotic
3	Key-biharzaf	*Eucalyptus grandis* Maiden.	Myrtaceae	T			x	x				x		Exotic

C.No.	Local name	Scientific name	Family name	H	F	M	Co	T	Ch	Fd	Fe	C	Agt	P
21	Dedeho	*Euclea racemosa* Murr.	Ebenaceae	T							x			
28	Kulkual	*Euphorbia ampliphylla* Pax	Euphorbiaceae	T										
20	Kinchib	*Euphorbia tirucalii* L.	Euphorbiaceae	T										
46	Shola	*Ficus sur* Forssk	Moraceae	T	x			x		x				
53	Gravilia	*Grevillea robusta* R. Br.	Proteaceae	T							x	x		
66	Haroresa	*Grewia bicolor* Juss.	Tiliaceae	S										
2	Sefa	*Grewia mollis* A. Juss	Tiliaceae	S			x						x	
11	Koso	*Hagenia abyssinica* (Bruce) J. F. Gmel.	Rosaceae	T		x	x		x			x		
10	Amja	*Hypericum revolutum* Vahl	Hypericaceae	S										
32		*Jacaranda mimosifolia* D. Don	Bignoniaceae	T							x	x		Exotic
26		*Jatropha curcas* L.	Euphorbiaceae	S										Exotic
15		*Juniperus procera* L.	Cuppressaceae	T			x	x				x		
37	Apple	*Malus sylvestris* Mill.	Rosaceae	T	x							x		Cultivated
62	Mango	*Mangifera indica* L.	Anacardiaceae	T	x							x		Cultivated
42	Kombel (Atat)	*Maytenus arbutifolia* (A. Rich.) Wilczeck	Celastraceae	S										
12	Kechemo	*Myrsine africana* L.	Myrsinaceae	S										
73	Neem	*Melia azedarach* L.	Meliaceae	T		x								
72	Shiferaw	*Moringa stenopetala* L.	Moringaceae		x	x								
	Asquar	*Nuxia congesta* R. Br. ex. Fresen	Loganiaceae	T										
6	Woira	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Cif	Oleaceae	T				x	x			x	x	
1	Beles	*Opuntia ficus-indica* (L.) Miller	Cactaceae	S	x							x		
74	Filfle	*Parkinsonia aculeata* L.	Fabaceae	T						x				
63	Solie	*Pittosporum viridiflorum Sims*	Pittosporaceae	T	x								x	
75	Tikur inchet	*Prunus africana (Hook.f.) Kalkm.*	Rosaceae				x	x						
45	Kok	*Prunus persica* (L.) Batsch	Rosaceae	T										Cultivated
58	Zeytun	*Psidium guajava* L.	Myrtaceae	T	x									Cultivated
31	Kentefa	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	S										
38	Gesho	*Rhamnus prinoides* L'Herit.	Rhamnaceae	S		x						x		Cultivated
14	Imbis, Talo	*Rhus glutinosa* A. Rich.	Anacardaceae	T			x				x		x	
64	Debobisha	*Rhus natalensis* Krauss	Anacardiaceae	T										

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17	Kega	*Rosa abyssinica* Lindley	Rosaceae	S	x									
6	Enbacho	*Rumex nervosus* Vahl	Polygonaceae	S										
40	Akaya	*Salix subserrata* Wild	Salicaceae											
39	Kundoberbere	*Schinus molle* L.	Anacardiaceae	T		x								Exotic
33	Yeferenj digta	*Senna multiglandulosa* (Jacq.) Irwin & Barneby	Fabaceae	S										Exotic
34	Meno	*Sesbania sesban* (L.) Merr.	Fabaceae	S						x	x			Exotic
76	Kakiba	*Sideroxylon oxyacanthum* Baill.	Sapotaceae	S										
77	Woiba	*Terminalia brownii Fresen.*	Combretaceae			x								
47	Girawa	*Vernonia amygdalina* Del.	Astraceae	T			x							
18	Kurkura	*Ziziphus spina-christi* (L.) Desf.	Rhamnaceae	T			x					x	x	