Addis Ababa University

College of Natural and Computational Sciences

Department of zoological sciences

Msc. Thesis on:

Tree Diversity on Small Holder's Agricultural Landscape in Gambella Woreda of Anuak Zone in Gambella Region, Ethiopia

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august, 2024

Addis Ababa, Ethiopia

Tree Diversity on Small Holder's Agricultural Landscape in Gambella Woreda of Gambella Region, Ethiopia

A Thesis Submitted to the School of Graduate Studies
Addis Ababa University

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Biology

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August, 2024
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APPROVAL SHEET

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE

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As members of the Board of Examiners of the Master of Sciences (M.Sc.) thesis report open defense examination, we have read and evaluated this thesis prepared by Mrs. Kokebnesh Korma Elala entitled "Tree Diversity on Small Holder's Agricultural Land Scape in Gambella woreda of Gambella Region, Ethiopia". We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Biology.

Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the Council of Graduate Studies (CGS) through the Departmental Graduate Committee (DGC) of the candidate's major department. I hereby certify that I have read this thesis prepared under my direction and recommend that it be accepted as fulfilling the thesis requirement.

__________________ __________________ ____________________

Name of Advisor Signature Date

DEDICATION

I dedicate this thesis document to my father, Korma Elala and my mother, Adanech Sime for giving me warmth and love and for their dedicated conviction in my life.

DECLARATION

I, Kokebnesh Korma, do declare that this thesis report entitled “Tree Diversity on Small Holder's Agricultural Land Scape in Gambella woreda of Gambella Region, Ethiopia” is my original work and it has not been documented and submitted earlier by others for any academic issue. All information in this report is well acknowledged.

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ACKNOWLEDGEMENTS

I want to express my gratitude to my advisor,Dr Bikila Warkineh for his invaluable፣ guidance, support, and encouragement throughout my research journey. His sagacious counsel, constructive feedback, and unflagging patience have been instrumental in the completion of this thesis.

I extend my appreciation to the women farmers in the Sample Kebeles (Abol kebele, Abol ker kebele, Opagna kebele, Pinkiu kebele and Siri kebegle) and agricultural office employers,whose participation in this study has provided me with a profound understanding of the tree species diversity and the conservation practices.

Finally, I want to thank my friends and colleagues for their support, resources, and motivation that have helped me complete this thesis.

Title;Tree Diversity on Small Holder's Agricultural Landscape in Gambella Woreda of Gambella Region, Ethiopia

ABSTRACT

This study assessed the diversity of trees found in the agricultural landscape of Gambella Woreda in Gambella Region, Ethiopia. A total of 50 households were randomly selected for tree diversity assessments. Semi-structured Interviews, direct observation and focus group discussions were employed to collect socioeconomic data. Complete enumeration of tree species was done for diversity assessment in 50 farmlands from five kebeles in the Gambela district. Statistical tools such as descriptive statistics, frequency and correlation were used to analyze the data. The results showed that the study area has a high level of tree diversity (H'=3.31), with 39 tree species belonging to 21 families. The most frequent family found in the study was *Fabaceae* (7 species). The most frequent species found in the study farmlands were *Mangifera indica*, *Azadirachta indica*, and *Diospyros mespiliformis.* The survey results suggest that there are several factors that influence tree species diversity on farmland, including motivations for planting trees, tree management practices, grazing on farmland, Promoting multiple benefits of tree planting, promoting best tree management practices, and promoting alternative livestock management practices that do not involve grazing on farmland could help increase tree species diversity on farmland.

Keywords: Tree diversity, farmland, Evenness, Shannon index, Gambella, Ethiopia

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1. INTRODUCTION

1.1 Background

Ecological scientists are now placing greater emphasis on biodiversity conservation due to the high levels of biodiversity loss. The continued deterioration of the natural resource base poses a serious threat to both ecological systems and agricultural production, as highlighted by Balana et al, (2010). The negative impacts of biodiversity loss on local populations are also numerous. Biodiversity plays a crucial role in enabling ecosystems to recover from environmental shocks (Sunderland , 2011), regenerating and maintaining forest ecosystems (Khasa and Dancik, 1997), and enhancing agricultural productivity (Christopher et al,. 1995). Biodiversity loss, therefore, weakens the potential role of biodiversity in the ecosystem.

While there are many causes of biodiversity loss, high population density (Aswani et al, 2008) and unsustainable agriculture (FAO, 2016) are major contributors. One way to ensure biodiversity conservation is by adopting sustainable agriculture strategies that balance agricultural production and biodiversity conservation, as suggested by Mohan et al, (2007). Agroforestry is an example of such a prudently managed agriculture. It can play a significant role in conserving and enhancing biodiversity from farms to the landscape level in both tropical and temperate regions of the world, as highlighted by Coomes et al. (2004) and Jose (2012). Agroforestry is part of a multifunctional working landscape that promotes biodiversity conservation.

Ethiopian's biodiversity has been under tremendous pressure due to the increasing need for timber, forest products, and agricultural land (Yitebitu et al, 2010). Sustainable agricultural management strategies should prioritize minimizing these pressures. Industrial agriculture relies on expensive inputs from off-farm, such as pesticides and fertilizers, many of which generate by-products that harm the environment (Horrigan et al, 2002) and are often unaffordable for poor farmers (Shiva 1993). Therefore, economically productive and environmentally sustainable approaches to agricultural production are considered promising strategies to provide the local population with sufficient agricultural returns while maintaining a high level of biodiversity at the local farms.

McNeely and Scherr, (2012) have emphasized the importance of considering both biodiversity conservation and sustainable local livelihoods when planning and managing conservation landscapes. These two objectives are often viewed as conflicting, leading to conflicts between conservation agencies and local communities. However, one potential solution to this conflict is agroforestry. According to a study by G. Schroth et al., (2013) intentional tree planting and management by rural communities through agroforestry can help conserve biodiversity by reducing pressure on forests and forest conversion, enhancing habitat for wild biodiversity, and improving landscape connectivity.

Intensive agricultural investments are currently expanding in Gambella, a region in Ethiopia. These investments involve converting virgin lands into cultivation fields. Unfortunately, the recent observations indicate that this has led to human and livestock population pressure, and inappropriate land use. For sustainable land management, biodiversity conservation, and the development of food security solutions, knowledge of the tree species that are present in agricultural systems is essential (Endale et al., 2017). Consequently, conservation measures that basis on the accurate information is top urgent need in the study area.

1.2 Statement of the Problem

Tree species diversity is important for the provision of ecosystem services in agricultural landscapes. Trees provide a variety of benefits to farmers, including shade, windbreaks, fodder, and timber. They also help to improve soil quality, water retention, and biodiversity. However, tree species diversity is declining in many agricultural landscapes due to deforestation, land-use change, and climate change. However, little is known about the tree diversity in agricultural landscape and the factors that influence tree species diversity on farmland in Gambella. Previous researches have focused on the forest areas to assess the tree species diversity and distribution (Kassie et al., 2020, Aman 2021, Edae, 2015). Due to the presence of high population growth rates, widespread poverty, and intensive agricultural land use in areas where many protected forest ecosystems of global value are located, the possibility of expanding the number or surface area of these ecosystems is limited. Consequently, conservation approaches are increasingly focused on creating broader "conservation landscapes" that encompass diverse land uses within a mosaic pattern (Boffa et al., 2005). This study aimed to fill this gap through assessing tree species diversity, abundance and distribution, and investigating the relationship between tree species diversity and socioeconomic factors affecting the diversity in the Gambella Woreda of Ethiopia.

1.3 Objectives of the Study

1.3.1 Main Objective

To investigate the diversity of trees found in the agricultural landscape of Gambella Woreda in Gambella Region.

1.3.2 Specific Objectives

1. To identify the different tree species, present in the agricultural landscape of Gambella Woreda.
2. To determine the abundance and distribution of tree species in the study area.
3. To assess the socioeconomic factors that influence the diversity of trees in the agricultural landscape in the area.

1.4 Significance of the Study

Sustainable biodiversity conservation requires information on the biodiversity of the ecosystem and its associated threats (Ren et al., 2006). This information will be an important input for biodiversity managers and planners to formulate sustainable management options. The present study will provide baseline information on the tree species diversity in the study area and its associated factors. The knowledge on tree species composition, relative abundance and distribution and the associated socioeconomic factors is valuable for natural resources managers and to suggest alternative management strategies so as to adverse the impacts of the already existing threats. The study will also pave the way for other researches to carry further detail study on the ecological, economic and cultural use of the tree species in the study area.

2. REVIEW OF LITERATURE

2.1 Biodiversity and Its Loss in Agricultural Landscapes

Biodiversity has been defined as “diversity at genetic, species and ecosystem level” (Gaston, 2010). However, in practice the term ‘biodiversity’ is still mainly associated with individual species in natural or semi-natural habitats (areas not managed with a production goal). Such kind of understanding fails to consider the impacts of human sub-systems on biodiversity of surrounding natural areas (Negash et al, 2012; Moonen and Bàrberi, 2008).

Biodiversity is ecologically important for the regeneration and maintenance of forest ecosystems (Khasa and Dancik, 1997). There is a direct relationship between biodiversity and human well-being (Jose, 2012).A strategy that is designed to conserve biodiversity also benefits the target people. Biodiversity conservation priority areas have been benefiting world’s poorest people (Turner et al,. 2012).Diversity ranging from genetic diversity to the diversity of ecosystems contributes to agricultural productivity and the healthy functioning of the ecosystem.

Biodiversity plays a crucial role in maintaining the resilience of ecosystems to environmental shocks (Sunderland, 2011). However, a natural system is not in a state of equilibrium, but is constantly changing. Socioeconomic sustainability in terms of adjusting to socioeconomic change implies dynamics in species diversity (Abebe et al, 2010; Gowdy 1997; Sunderland, 2011). Studies have shown biodiversity in agroecosystems have been declining at the genetic, species, and ecosystem level (Gaston, 2010; Jackson et al, 2007). This decline of agricultural biodiversity has caused agricultural and economic losses, jeopardizing productivity and food security, and leading to broader social costs (Thrupp, 2004).

The loss of biodiversity is lowering the strength and capacity of the ecosystems to provide essential goods and services (Bodede, et al. 2011). The loss of biodiversity even at the genetic level holds the bulk of negative consequences. As genetic diversity supports food security and can provide resilience against pests, diseases and changing environmental conditions, its loss inevitably brings on the susceptibility of the ecosystem (Ineke, et al. 2007).

The trend of agricultural biodiversity erosion is continuing at a rapid pace in many places as monoculture systems and uniform technology models tend to predominate in industrial agricultural production (Thrupp, 2004).Technological development in agriculture has led to a diminished use of biodiversity in food production and the provisioning of other ecosystem services (Giampietro, 1997).

Consequently, food production with off-farm sources of inputs (Jackson et al, 2007) results in diet simplification (large but poor-quality food), which in turn causes food insecurity; food intake that is continuously insufficient to meet dietary energy and nutrient requirements (Sunderland, 2011). Thus, eliminating, minimizing or avoiding impacts harmful to biodiversity is consistent with the UN Convention on Biological Diversity and other relevant international obligations, taking into account national socioeconomic conditions (Jose, 2012).

A biodiversity-based paradigm for sustainable agriculture is a potential solution for many of the problems associated with intensive, high input agriculture, and for greater resilience to the environmental and socioeconomic risks that may occur under uncertain future conditions (Jackson et al, 2007).That said, it is reasonable to rely on a mixed portfolio of species to ensure the availability of food, raw materials and ecosystem services under uncertain future circumstances (Weikard, 2002).

2.2 Biodiversity and Ecosystem Services with Agro ecological Approach

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Kremen and Ostfeld, 2005: cited by Scherr and Mcneely, 2008). However, the term ecosystem function itself is a problematic concept to understand. For example, according to

(Srivastava and Vellend, 2005), High productivity is often not desired in lake management, but would be when managing a forest for carbon credits. This makes the term ecosystem function, subjective to value judgement.

Certain ecosystem services provided by biodiversity in natural habitat can also be provided by native and non-native species in human managed settings, e.g. food production. Other ecosystem services, especially regulating services are decreasing in agriculturally managed surroundings. However, certain management strategies such as Agroforestry try to combine the productivity of agriculturally managed systems with the provisioning of ecosystem services that are better provided by natural ecosystems, especially regulating ecosystem services.

The implication is that even where biodiversity in native habitat has been significantly reduced to make way for e.g. sufficient food provisioning, high level of these services can be provided through carefully applied land management approaches such as Agroforestry. Thus, Sustainable production and biodiversity conservation can be mutually supportive in providing multiple ecosystem services to farmers and society (Scherr and Mcneely, 2008; Souza et al,. 2012; Thrupp, 2004).

The challenge of biodiversity conservation, however is intensified by population growth and accompanied demand for food and other services. In this regard, that more land will is likely to be required to grow crops, especially to meet the needs and wants of an increasing population (Scherr and Mcneely, 2008). However, increases in food production should have not been at the expenses of biodiversity and associated ecosystem service provisioning (Sunderland, 2011). By the way, there is considerable evidence that concludes increase in food production have come largely from increases in productivity rather than increases in cultivated area (Steppler and Nair, 1987). Smith, (2013) has called this ‘’sustainable intensification’’. So, sustainable intensification must deliver more products per unit of input resource, whilst preventing damage to the ecosystem services that underpin human health and wellbeing.

2.3 Measuring Plant Biodiversity in Farmlands

Measures and monitoring are a prerequisite for management for biodiversity (Khasa and Dancik, 1997). Farmlands are important in situ conservation sites and in accordance with the Convention of Biological Diversity Article 7, 8 and 10(c), inventories in such areas can help in the identification and conservation of biodiversity while assessing the sustainability of the system (Das and Das ,2005).

Biodiversity can be evaluated in terms of the number of different types of biological structures present (Huston and Marland, 2003). The most common measure of biodiversity is the number of species in an area, and the primary concern about human effects on biodiversity is expressed at the loss of species (Huston and Marland, 2003).Species diversity can be a useful tool for the ecologist, but one must be clear as to the particular definition and measure being used (Hamilton, 2005). Indeed, species composition, structure and function of farmlands may be influenced by ecological, socioeconomic and cultural factors (Kumar and Nair, 2006; Lamont et al, 1999).

Biological diversity can be quantified in different ways. A diversity index is a mathematical measure of species diversity in a community. The two main factors taken into account when measuring diversity are richness and evenness. So that, diversity index must be sensitive to both factors, thus must also be sensitive to the different number of species in two or more communities (Mueller, D. and Ellenberg, H. 1974). The components of species diversity that are used to express the biodiversity condition of the given area include the number of species present (species richness), their relative abundances (species evenness), and the particular species present (species composition) (Stuart et al, 2000).

Diversity is thus measured by recording the number of species and their relative abundances. The two components may be examined separately or combined in some form of index like the Shannon Diversity Index. Simpson’s index is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species. Like Simpson index, Shannon's index accounts for both the abundance and evenness of the species present (Magurran, A.E. 2004).

Species richness refers to the total number of species in a community while evenness is the relative abundance of species within the sample or community. The two components can be examined independently or combined in some form of index. Richness can be expressed in a mathematical index to compare diversity between sites. Species richness index is of great importance in assessing taxonomic and ecological values of habitats (Zerihun Woldu, 1985). A number of diversity indices have been devised each of which seeks to express the diversity of a sample by a single number. Of the various indices, the most frequently used is the simple totality of species numbers to give species richness (Magurran, A.E. 1988). Among many of the species diversity indices, diversity and evenness are often calculated by using Shannon diversity index. It is the most widely used index because of its power to combine species richness with evenness better than other indices (Kent, M. and Coker, P. 1992).

Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Feyera Senbeta, 2006). Moreover, these diversity indices provide information about community composition. Well-being of ecological systems can be measured by community diversity indices (Fikadu Erenso et al, 2014).

The meaning attributed to richness measures is 'the more, the better' for semi-natural ecosystems and 'the more, the more sustainable' for agroecosystems (Moonen and Bàrberi, 2008).

Species density is also used to measure the presence or absence of the species. For example, the density of trees refers to the number of individual trees and shrubs per hectare and per farm (Abebe et al, 2013). In this regard, the size of the farmland mostly determines the density of species. For instance, the study case (Mohan et al, 2007) has reported that farmers who own and manage small farm intensify their planting patterns to adapt to their land constraints while in the larger gardens, the planting is less dense but production might be similar (kadu Erenso et al., 2014).

2.4 Measurement of similarity and dissimilarity

Similarity indices measure the degree to which the species composition among two or more plant community (habitat types) is alike; whereas dissimilarity coefficient assesses which of the whether or not two or more plant community (habitat types) differ in composition. Sorenson's coefficient of similarity is the most common binary similarity coefficient, because it relies on presence or absence data and also gives more weight to species that are present in community types and less weight to species that are present in only in one community type (Kent, M. and Coker, P. 1992).

In addition, Sorenson's coefficient of similarity used to calculate the degree of similarity among more than two plant community types to observe the highest and lowest similarity between each community groups (Zerihun Tadesse et al., 2017).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in Gambella Woreda, which is located in the Anuak zone of Western Ethiopia. The district is part of the Gambella National Regional state and is bordered by Abobo to the south, Itang special woreda to the west, and the Oromia region to the north and east. The gambella woreda grid reference is between 7^0 N to 8^0 N latitude and 33^0 E to 35^0 E longitude. The administrative center of the district is Abol, and the total surface area coverage of the district is 2,586 km^2. Despite being the most economically developed woreda in the region, its economy is mainly based on agriculture, with no agricultural cooperation in place. The district has a forest cover of around 20%, according to the Central Statistical Agency (CSA) report of 1995.

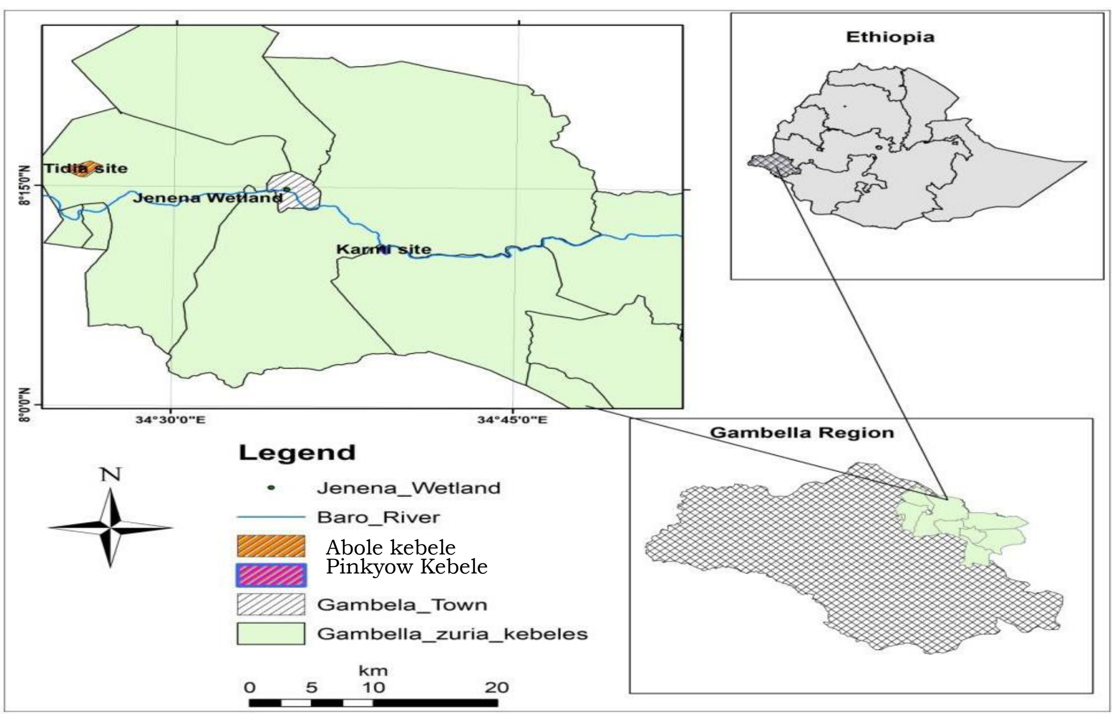

Fig. Map of the Study Area

Gambella Woreda is composed of 13 kebeles, according to its administrative structure. The largest ethnic groups in the area are Anywa, Majang, and Komo, which make up more than 90% of the population. The remaining population is made up of highlanders from Amhara, Kaffa, Gurage, Kambata, Tigrai, and Oromo ethnic groups, which cover less than 10% of the population.

According to the gambella Woreda Health Office's 2018 report, the total population of Gambella Woreda is 15,615, with 8,099 males and 7,516 females.

The mean annual temperature in Gambella Woreda ranges from 17.3℃ to 28.3℃, with the absolute maximum temperature occurring in mid-March at around 45℃, and the absolute minimum temperature occurring in December at 10.3℃. The annual rainfall in the lower altitudes of the woreda varies from 900-1,500 ml, while at higher altitudes, it ranges from 1000-1,700 ml. The annual evapotranspiration in the area reaches about 1,612 ml, with the maximum value occurring in March at around 212 ml, according to Jember, Ketema, and Prem. The rainy season starts at the end of April and lasts until October, with the maximum rainfall occurring in July. The woreda has two main harvesting times, Meher and Belg, with crops being harvested from September to February and from March to August, respectively. The Baro River crosses almost 90% of the kebeles in the woreda. Due to favorable soil, topography, and climate conditions, Gambella Woreda is known to be one of the most fertile areas in Gambella Region and is suitable for growing various types of tree species.

3.2 Types and Methods of Data Collection

3.2.1 Types and Sources of Data

For this study, both primary and secondary data were collected. Secondary data sources included various published documents, seminar papers, project reports, and legal documents from relevant offices. On the other hand, primary data were collected through questionnaires, interviews with individuals and key informants, focus group discussions (FGDs), field observations, These methods were used to gather information directly from the study area and its inhabitants, providing first-hand insights into the tree diversity and agricultural practices of smallholder farmers in Gambella Woreda.

3.2.2 Household Selection

To conduct this study, five kebeles were selected purposively, namely Abol kebele, Abol ker kebele, Opagna kebele, Pinkiu kebele, and Siri kebele. These kebeles were chosen due to the widespread practice of tree planting in farmlands and their accessibility for conducting the study. A total of 50 households were randomly selected for interviews and tree diversity assessments. This sample size was deemed sufficient to gather representative data on the tree diversity and agricultural practices of smallholder farmers in Gambella Woreda. As the sample Kebeles have no equal number of total households (HHs), unequal number of samples was assigned to them for the sake of sample proportionality as shown below.

Table 1: Sample Determination from Each Kebele

Kebele	**Total HHs**	**Percentage**	**Sample drawn**
Abol twon	326	18.294	9
Abol ker	203	11.391	6
Opagna	274	15.375	8
Pinkew	545	30.583	15
Siri Mejang	434	24.354	12
Total	**1782**		**50**

Random sampling method was used in this study to ensure that all potential participants had an equal chance of being selected. This technique was used to avoid any potential biases that could arise from non-random selection methods. By selecting participants randomly, the sample was more likely to be representative of the larger population, which increased the generalizability of the findings. Therefore, random sampling was deemed an appropriate method for selecting participants in this study.

3.2.3 Household Survey Methods

To achieve the specific objective of investigating the socioeconomic factors that influence tree diversity in the agricultural landscape of Gambella Woreda, semi-structured questionnaires, focus group discussions (FGDs), and personal observations were employed. Appendix A provides more information on the questionnaires used.

A face-to-face, semi-structured interview was conducted with sampled individuals to collect primary data.

The questionnaire was tested with 15 randomly selected households, and based on the results of the pre-test, necessary modifications were made, such as avoiding repitition, they have told me that, the questionnaires was prepared brefilly and accurately Enumerators who were knowledgeable about the area were recruited from the study areas and were informed about the objectives, methods of data collection, and interviewing techniques.

The interviews were conducted with smallholder agricultural landowners to collect necessary information, including the size of their agricultural land per hectare owned. Therefore, the surveys were translated from English to Amharic and/or to dha-agnwa language orally by the help of translator. The translator was used in all cases to conduct the surveys and ensure that the meaning of the questionnaires was accurately conveyed.

Two FGDs, each containing 6-10 people, were conducted in each kebele to support and cross-check the information provided by individual respondents. FGDs also helped to obtain important information that was not covered by the individual questionnaires. These methods were used to gather comprehensive data on the socioeconomic factors affecting tree diversity in the study area.

3.2.4 Biodiversity Inventory Methods

To obtain species inventory data, a complete enumeration was conducted in sample farmlands to assess plant diversity, frequency, and density. A total of 50 farmlands were sampled in five kebeles, and in each farmlands, all tree species were identified and counted in the field. The identification and nomenclature of the species followed the Flora of Ethiopia and Eritrea, as well as other related literature sources such as Berhan et al,. (1989), Edwards et al. (1995), Edwards et al. (1997), Edwards et al. (2000), Hedberg et al. (2003), Tadesse (2004), and Tesemma, (2007). These sources were used to ensure accurate and consistent identification of the tree species in the study area.

3.3 Data Analysis

For this study, all data collected were coded, entered, summarized, and analyzed using Microsoft Excel 2016 and Statistical Package for Social Science (SPSS), Version 26. Descriptive statistics were used to analyse household demographic variables and socioeconomic characteristics. These statistical tools provided detailed summaries of the data, including measures of central tendency, variability, and frequency distributions. Correlation analysis was conducted to test the strength and direction of the relationship between independent variables and the dependent variable (species richness). The results of the correlation analysis were used to gain insights into the socioeconomic factors that affect tree diversity in the study area.

3.3.1 Method of Analysis of Tree Inventory Data

To evaluate plant diversity in the study area, the Shannon-Wiener diversity index, Sorenson similarity, and dissimilarity indices were calculated. The Shannon index (H') was used to measure the relative abundance of different species. This index is highly sensitive to sample size and gives more weight to rare species (Wiener, 1948, cited by Negash et al, 2012). The Shannon index was calculated using the following formula:

$$Shannon\ Index\ (H') = -\sum_{n=1}^{\infty} pi\left(lnpi\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where P is the proportion (n/N) of individuals of particular species (**n**) divided by the total number of individuals (**N**), **ln** is the natural log, **Σ** is the sum of the calculations.

Species evenness expresses how evenly the individual species of the community are distributed. It was calculated as:

$$E = {}^{H'}/_{Hmax} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

H'= Shannon diversity index

$$Hmax = lnS \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

lnS is the natural logarithm of species richness

Species evenness ranges from zero to one, with zero indicating no evenness and one indicating complete evenness. To measure the similarity or dissimilarity of the different sampled communities, Sorenson indices were used.

$$\text{Sorenson's Coefficient (CC)} = \frac{2C}{2C+S1+S2} \ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where C is the number of species the two communities have in common

S1 is the total number of species found only in community 1, and

S2 is the total number of species found only in community 2.

This index can also be modified to a coefficient of dissimilarity by taking its inverse:

$$Sorensen's\ dissimilarity = 1 - CC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Relative frequency can be calculated as:

$$Relative\ frequency = \frac{frequency\ of\ one\ species}{total\ frequency} X100 \text{………..…...} (6)$$

The relative density, in a similar way, was also computed by the formula;

$$Relative\ density = \frac{density\ of\ one\ species}{total\ density} X100 \text{…………..………} (7)$$

4 RESULTS AND DISCUSSIONS

4.1 General Study Population Characteristics

A total of **39** male headed households (78%) and **11** females headed households (22%) were included in this research. The study included a total of 50 respondents, whose ages were distributed across five categories: 15-24 (6 respondents, 12%), 25-34 (10 respondents, 20%), 35-44 (6 respondents, 12%), 45-54 (13 respondents, 26%), and 55 and above (15 respondents, 30%) (Table 2). The median land size for all households was **1.26he**, where the minimum land size being **0.125he** and the maximum land size **10he**.

Table 2: Age Groups of the Respondents

	Frequency	**Percent**
15-24	6	12.0
25-34	10	20.0
35-44	6	12.0
45-54	13	26.0
55 and above	15	30.0
Total	50	100.0

The respondents' education levels were categorized into five groups: those who can't read and write (24%), those who can read and write (22%), those who completed 1-4 grades (28%), those who completed 5-8 grades (22%), and those who completed high school (4%) (Table 3).

Table 3: Education level of household head

	Frequency	Percent
Can't read and write	12	24.0
Can read and write	11	22.0
1-4 grade	14	28.0
5-8	11	22.0
High school	2	4.0
Total	50	100.0

4.2 Tree Species Diversity, Abundance and Distribution

The study found a total of 39 tree species belonging to 21 families in the small holder's agricultural landscape of the study area. The most frequent family found in the study was *Fabaceae* (7 species). *Ebenaceae* and *Moraceae* were tied for the second most frequent family, with each having 3 species present in the farmlands. Other families with two species each were *Meliaceae, Rubiaceae, Rutaceae, Ulmaceae, Balanitaceae, Anacardiaceae, Combretaceae,and Boraginaceae.* The remaining families - *Flacourtiaceae, Loganiaceae, Sterculiaceae, Apocynaceae, Asteraceae, Moringaceae, Myrtaceae, Euphorbiaceae, Proteaceae, and Bignoniaceae* - were represented by only 1 species each (fig. 1).

This finding of *Fabacea* as a dominant species family is in line with the report of Endale et al. (2017) who assessed tree species in the farmlands of semi-arid East Shewa Zone. However, the number of tree species and the families were lesser than the report of Munish et al., (2008), who conducted an assessment in in 90 randomly selected individual farmlands and identified 47 tree species belonging to 23 families in Usambaras Tanzania.

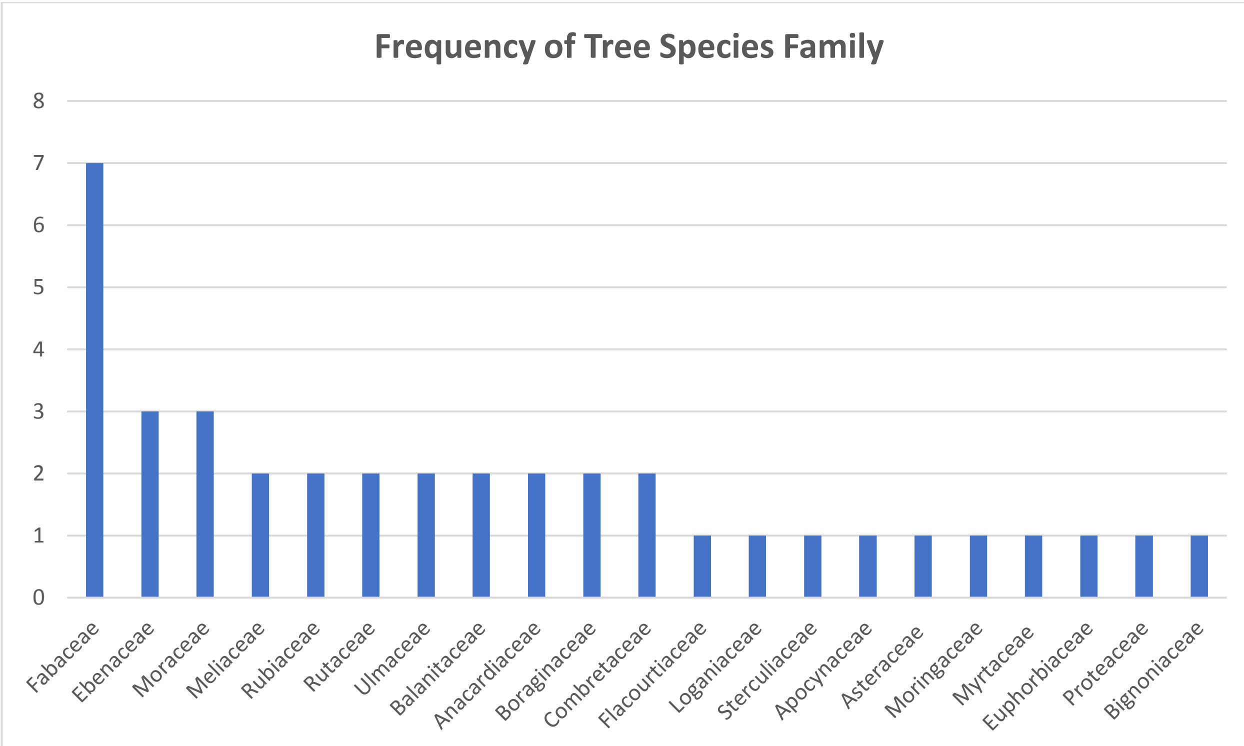

Figure 1: Tree Species Family Frequency in the Study Area

Table 4: Descriptive Statistics of Species Richness

	N	Minimum	Maximum	Mean	Std. Deviation
Number of Species	50	11.00	24.00	16.1200	3.47375

The descriptive statistics presented above provides a summary of the distribution of species richness across the study farmlands. The mean number of species present was 16.12, with a range from 11 to 24 species. The standard deviation of 3.47 indicates that there was some variation in species richness across the farmlands, with some having more or less than the average number of species present. The number of species found in this study is higher than previous report from Nepal farmlands (30) (Kharal and Oli, 2008).

4.3 Frequency and Density of the Species

The most frequent species found in the study farmlands were *Mangifera indica, Azadirachta indica, and Diospyros mespiliformis,* with 38, 33, and 30 occurrences respectively (table 5).

Mangifera indica, also locally known as manga, is a widely cultivated fruit tree and is highly valued for its fruit, according to the respondents. *Azadirachta indica,* also locally known as Biy Biy (neem), is an important plant with a wide range of uses,such as shade,firewood for recreation and so on *Diospyros mespiliformis,* locally known as Orowyyee (Agn), is a slow-growing tree that produces edible fruit and is reported to be used for shade and traditional medicine.

Other tree species such as Oncoba spinosa, Balanites aegyptiaca, Entada abyssinica, Moringa stenopetala and Terminalia laxiflora. These species are also valued for their various uses, including as sources of food, medicine, timber, and firewood.

Table 5: Most Frequent Species in the Study Area

S.no	**Local Name**	**Species Name**	**Frequency**	**Relative frequency**
1.	Manga (mjg)	*Mangifera indica*	**38**	4.589372
2.	Biy biy (Agn)	*Azadirachta indica*	**33**	3.985507
3.	Orowyyee (Agn)	*Diospyros mespiliformis*	**30**	3.623188
4.	Adiquala (Agn)	*Oncoba spinosa*	**27**	3.26087
5.	Toyun (mjg)	*Balanites aegyptiaca*	**27**	3.26087
6.	Pok (Agn)	*Entada abyssinica*	**26**	3.140097
7.	Shiferaw (A)	*Moringa stenopetala*	**25**	3.019324
8.	Jukul (mjg)	*Terminalia laxiflora*	**24**	2.898551
9.	Toow (Agn)	*Balanites aegyptiaca*	**24**	2.898551
10.	Downg (Agn)	*Gardenia ternifolia*	**23**	2.777778

Key: Agn = Agnuak, Mjg = Mejang, Am = Amharic

The top dense species found in the study farmlands were *Mangifera indica, Grevillea robusta, Acacia abyssinica, Azadirachta indica, Ficus sur, Cordia africana, Croton macrostachyus, Moringa stenopetala, Lepidotrichilia volkensii, Diospyros mespiliformis,* and *Acacia nilotica* (table 6).

Mangifera indica had the highest density, with 225 individuals found in the study area. *Grevillea robusta,* and *Acacia abyssinica,* were the second and third most dense species, with 72 and 65 individuals respectively. *Grevillea robusta,* is a fast-growing tree that is often planted for timber and fuel-wood. Other dense species included *Azadirachta indica, Ficus sur Cordia africana, Croton macrostachyus, Moringa stenopetala Lepidotrichilia volkensii, Diospyros mespiliformis,* and *Acacia nilotica.* These species are also valued for their various uses, including as sources of food, medicine, and timber.

Table 6: The densest Tree Species in the Study Area

S.no	**Local Name**	**Species Name**	**Density**	**Relative density**
1.	Manga (mjg)	*Mangifera indica*	**225**	12.90138
2.	Gravila	*Grevillea robusta .*	**72**	4.12844
3.	Grar (A)	*Acacia abyssinica.*	**65**	3.727064
4.	Biy biy (Agn)	*Azadirachta indica*	**64**	3.669725
5.	Shola	*Ficus sur*	**60**	3.440367
6.	Dampaeu (mjg)	*Cordia africana*	**56**	3.211009
7.	Bisana	*Croton macrostachyus*	**51**	2.924312
8.	Shiferaw (A)	*Moringa stenopetala*	**48**	2.752294
9.	Kijang (Agn)	*Lepidotrichilia volkensii*	**48**	2.752294
10.	Orowyyee (Agn)	*Diospyros mespiliformis*	**46**	2.637615
11.	Alaro (Agn)	*Acacia nilotica*	**46**	2.637615

The Shannon Diversity index (H') of 3.31 suggests that there is a high level of diversity among the tree species present in the study farmlands. This index takes into account both the number of species present and their relative abundance, with higher values indicating greater diversity (table 7).

The evenness (E) value of 0.91 indicates that the species present are relatively evenly distributed in terms of their abundance. This means that there is not a large dominance of any one species in the study area, which further supports the high level of diversity suggested by the Shannon Diversity index.

The Sorenson Similarity index of 0.24 indicates that there is a relatively low degree of similarity between the tree species present in different farmlands of the five sample Kebeles. This suggests that there is a high degree of variation in the tree species composition across the Kebeles in the study area, which may be influenced by factors such as soil type, topography, and land use history.

Table 7: Tree diversity, Distribution and Similarity

Shannon Diversity (H')	**Evenness (E)**	**Sorenson Similarity**
3.31	0.91	0.243

4.3 Socioeconomic Factors Affecting Tree Diversity in the Study Area

4.3.1 Descriptive Analysis of Socioeconomic Variables

The results of the survey conducted on 50 respondents show that 20% of them planted trees for soil health improvement, 6% for biodiversity conservation, 30% for climate change mitigation, 32% for economic benefit, and 12% for other reasons. In terms of managing their trees, 32% prune their trees, 6% manage pests and diseases, 20% fertilize their trees, and 42% do nothing to manage their trees. Moreover, 54% of the respondents do not allow grazing on their farmland, while 46% do. As for irrigation, 74% of the respondents do not irrigate their farmland, while 26% do. In addition, 60% of the respondents do not use pesticides, while 40% do. (table 8).

Table 8: Descriptive Statistics on Socioeconomic Variables

Question	**Response**
Have you ever participated in any trainings related to sustainable farmland management?	No (50%), Yes (50%)
If you have planted trees, what was your primary motivation for doing so?	Sol health improvement (20%), Biodiversity Conservation (6%), Climate change mitigation (30%), Economic benefit (32%), Other (12%)
How do you manage your trees?	Pruning (32%), Pest and disease mngt (6%), Fertilization (20%), I do nothing (42%)
Do you allow grazing on your farmland?	No (54%), Yes (46%)
Do you irrigate your farmland?	No (74%), Yes (26%)
Do you use pesticides?	No (60%), Yes (40%)
Do you have access to market for your farm products?	No (46%), Yes (54%)
Access to Credit	No (56%), Yes (44%)

The survey results suggest that there are several factors that influence tree species diversity on farmland. Planting trees for climate change mitigation and economic benefit were the primary motivations for a significant proportion of respondents, while soil health improvement and biodiversity conservation were fewer common motivations. This implies that encouraging farmers to plant trees for multiple benefits, including soil health, biodiversity conservation, and climate change mitigation, could help increase tree species diversity on farmland. Moreover, the survey results indicate that managing trees through pruning, fertilization, and pest and disease management is not a common practice among the respondents. This suggests that promoting best practices for managing trees could help increase tree species diversity on farmland.

Additionally, the survey results reveal that allowing grazing on farmland leads to lower tree species richness. Therefore, promoting alternative livestock management practices that do not involve grazing on farmland could help increase tree species diversity. It was also found that access to markets and credit is limited for some respondents. Improving access to markets and credit could provide incentives for farmers to invest in planting and managing trees, which could ultimately increase tree species diversity on farmland.

4.3.2 Correlation Analysis

The table below presents the Pearson correlation coefficients between the number of species and various variables. The correlation coefficients indicate the strength and direction of the relationship between the variables. The correlation between the number of species and sex of respondents is very weak and insignificant with a value of 0.053 and a p-value of 0.712. The correlation between the number of species and age of respondents is strong and significant with a value of 0.624 and a p-value of less than 0.01, indicating that as age of household head increases, the capacity of tree planting practice also increases (table 9).

The correlation between the number of species and education level of household head is strong and significant with a value of -0.604 and a p-value of less than 0.01, indicating that as education level increases, the number of species decreases. The correlation between the number of species and land size of the sample household is strong and significant with a value of 0.762 and a p-value of less than 0.01, indicating that as land size increases, the number of species increases.

The correlation between the number of species and years of farming is strong and significant with a value of 0.606 and a p-value of less than 0.01, indicating that as years of farming increase, the number of species increases. This result agrees with the previous report by Kharal and Oli (2008) who found that the species diversity and species richness increase as the years of settlement of households increase. These authors also have reported a positive correlation between species richness and farmland size.

The correlation between the number of species and participation in sustainable farmland management training is strong and significant with a value of 0.728 and a p-value of less than 0.01, indicating that participation in such training leads to higher species richness.

The correlation between the number of species and allowing grazing on farmland is weak and significant with a value of -0.159 and a p-value of less than 0.05, indicating that allowing grazing leads to lower species richness. The correlation between the number of species and irrigating farmland is moderate and significant with a value of 0.528 and a p-value of less than 0.01, indicating that irrigating leads to higher species richness. The correlation between the number of species and using pesticides is moderate and significant with a value of -0.415 and a p-value of less than 0.01, indicating that using pesticides leads to lower species richness.

The correlation between the number of species and receiving financial or technical support for tree planting on farmland is strong and significant with a value of 0.697 and a p-value of less than 0.01, indicating that receiving such support leads to higher species richness.

Table 9: Correlation Analysis between Species Richness and Socioeconomic Variables

		Number of Species
Number of Species	Pearson Correlation	1
	Sig. (2-tailed)	
	N	50
Sex of respondents	Pearson Correlation	.053
	Sig. (2-tailed)	.712
	N	50
Age of respondents	Pearson Correlation	.624**
	Sig. (2-tailed)	.000
	N	50
Education level of household head	Pearson Correlation	-.604**
	Sig. (2-tailed)	.000
	N	50
Number of household members	Pearson Correlation	.124
	Sig. (2-tailed)	.391
	N	50
Land size of the sample household	Pearson Correlation	.762**
	Sig. (2-tailed)	.000
	N	50
How many years have you been farming?	Pearson Correlation	.606**
	Sig. (2-tailed)	.000
	N	50
Have you ever participated in any trainings related to sustainable farmland management?	Pearson Correlation	.728**
	Sig. (2-tailed)	.000
	N	50
Do you allow grazing on your farmland?	Pearson Correlation	-.159
	Sig. (2-tailed)	.271
	N	50

Do you irrigate your farmland?	Pearson Correlation	.528**
	Sig. (2-tailed)	.000
	N	50
Do you use pesticides?	Pearson Correlation	-.415**
	Sig. (2-tailed)	.003
	N	50
Have you ever received any financial or technical support for tree planting on your farmland?	Pearson Correlation	.697**
	Sig. (2-tailed)	.000
	N	50

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study found that the study area had a high level of tree diversity, with a total of 39 tree species belonging to 21 families. The most frequent family found in the study was *Fabaceae* (7 species). The most frequent species found in the study farmlands were *Mangifera indica, Azadirachta indica,* and *Diospyros mespiliformis*. The Shannon Diversity index (H') of 3.31 suggests that there is a high level of diversity among the tree species present in the study farmlands. This index takes into account both the number of species present and their relative abundance, with higher values indicating greater diversity.

The evenness (E) value of 0.91 indicates that the species present are relatively evenly distributed in terms of their abundance. This means that there is not a large dominance of any one species in the study area, which further supports the high level of diversity suggested by the Shannon Diversity index.

The Sorenson Similarity index of 0.24 indicates that there is a relatively low degree of similarity between the tree species present in different farmlands of the five sample Kebeles. This suggests that there is a high degree of variation in the tree species composition across the Kebeles in the study area, which may be influenced by factors such as soil type, topography, and land use history.

The survey results suggest that there are several factors that influence tree species diversity on farmland. Planting trees for climate change mitigation and economic benefit were the primary motivations for a significant proportion of respondents, while soil health improvement and biodiversity conservation were fewer common motivations. This implies that encouraging farmers to plant trees for multiple benefits, including soil health, biodiversity conservation, and climate change mitigation, could help increase tree species diversity on farmland.

Moreover, the survey results indicate that managing trees through pruning, fertilization, and pest and disease management is not a common practice among the respondents. This suggests that promoting best practices for managing trees could help increase tree species diversity on farmland.

Additionally, the survey results reveal that allowing grazing on farmland leads to lower tree species richness. Therefore, promoting alternative livestock management practices that do not involve grazing on farmland could help increase tree species diversity

5.2 Recommendations

Based on the findings of this study, the following recommendations are made to increase tree species diversity on farmland in Gambella Woreda:

Encourage farmers to plant trees for multiple benefits, including soil health, biodiversity conservation, and climate change mitigation. This could be done through awareness-raising campaigns, training programs, and financial incentives.

- Promote best practices for managing trees, such as pruning, fertilization, and pest and disease management. This could be done through training programs and extension services.

- Promote alternative livestock management practices that do not involve grazing on farmland. This could be done through training programs, extension services, and policy changes.

- Improve awareness for farmers. About tree species diversity

6 REFERENCES

Abebe Tesfaye, K. F. Wiersum, and F. Bongers. 2010. "Spatial and Temporal Variation in Crop Diversity in Agroforestry Homegardens of Southern Ethiopia." Agroforestry Systems 78: 309–322.

Aman, K., 2021. The Potential Role of Agroforestry In Community-Based Protected Area Management (CBPAM). The Case of Gambella National Park (Doctoral Dissertation).

Aswani Musotsi, Aj Sigot, Moa Onyango, and Anne Aswani Musotsi. 2008. "The Role of Home Gardening in Household Food Security in Butere Division of Western Kenya." African Journal of Food Agriculture Nutrition and Deveelopment 8: 378–88.

Balana Bedru, Babulo M, Erik Mathijs, and Bart Muys. 2010. "Assessing the Sustainability of Forest Management: An Application of Multi-Criteria Decision Analysis to Community Forests in Northern Ethiopia." Journal of Environmental Management 91: 1294–1304.

Berhan Tewolde Egziabher, Gebre, Hedberg Olov, Tadesse Mestin, Frils Ib, Hedberg Inga.1989. "Flora of Ethiopia and Eritrea." 3: 1–659.

Bilew, A., Kitessa, H. and Balcha, A., 2015. Floristic composition and structural analysis of Gelesha forest, Gambella regional State, Southwest Ethiopia. Journal of Ecology and the Natural Environment, 7 (7), pp.218-227.

Bodede AI, Temowo OO, and Bodede OJ. 2011. "1-5." Continental J. Agricultural Science 5(3): 1–5. http://www.wiloludjournal.co.

Boffa, J.M., Turyomurugyendo, L., Barnekow-Lillesø, J.P. and Kindt, R., 2005. Enhancing farm tree diversity as a means of conserving landscape-based biodiversity. Mountain Research and Development, 25(3), pp.212-217.

Christopher J. Humphries, Paul H.Williams, Richard I. Vane-Wright. 1995. “Measuring Biodiversity Value for Conservation.” Annual Reviews of Ecological System 26: 93–111.

Coomes Oliver T, Natalie BAN Coomes, and Natalie Ban. 2004. “Cultivated Plant Species Diversity in Home Gardens of an Amazonian Peasant Village in Northeastern Peru.” Economic Botany 58(3): 420–34.

Das Tapasi, and Ashesh Kumar Das. 2005. “Inventorying Plant Biodiversity in Homegardens: A Case Study in Barak Valley, Assam, North East India.” Current Science 89: 155–61.

Edae, D., Soromessa, T. and Senbeta, F., 2015, Woody Species Composition and Community

Analysis in Managed and Community Used Forest Sites in Gelesha Kebele, Mejengir Forest, Gambella National Regional State. Journal of Natural Sciences Research www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.5, No.17

Endale, Y., Derero, A., Argaw, M. and Muthuri, C., 2017. Farmland tree species diversity and spatial distribution pattern in semi-arid East Shewa, Ethiopia. Forests, trees and LiveLihoods, 26(3), pp.199-214.

Edwards Sue, Mesfin Tadesse, and Sebsibe Demissew. 2000. “Flora of Ethiopia and Eritrea.” 2(1): 1–532.

Edwards Sue, Mesjin Tadesse, and Inga Hedberg. 1995. “Flora of Ethiopia and Eritrea.” 2(2): 1–456.

Edwards Sue, Sebsebe Demissew, and Inga Hedberg. 1997. Flora of Ethiopia and Eritrea. Addis Ababa, Ethiopia.
Endale, Y., Derero, A., Argaw, M. and Muthuri, C., 2017. Farmland tree species diversity

and spatial distribution pattern in semi-arid East Shewa, Ethiopia. Forests, trees and LiveLihoods, 26(3), pp.199-214.

FAO (Food Agricultural Organization). 2016. Ethiopia's Forest Resource Level Submission to the UNFFCC Ethiopia. Addis Ababa, Ethiopia.

Gaston Kevin J. 2010. "Biodiversity." In Conservation Biology for All, New York: Oxford University Press, 27–44.

Giampietro Mario. 1997. "Socioeconomic Constraints to Farming with Biodiversity." Agriculture, Ecosystems and Environment 62: 145–67.

Gowdy John M. 1997. "The Value of Biodiversity: Markets, Society, and Ecosystems." Land Economics 73(1): 25–41.

Hamilton Andrew J. 2005. "Species Diversity or Biodiversity?" Journal of Environmental Management 75: 89–92.

Horrigan Leo, Robert S Lawrence, and Polly Walker. 2002. "Review How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture." 110(5): 445–56.

Ineke Voster, and Venter Sonja .L. H.J., Jansen van Rensburg Willem, Van Zijl J.J.B. 2007. "The Importance of Traditional Leafy Vegetables in South Africa By." African Journal of Food Agriculture Nutrition and Deveelopment 7(4): 2–11.

Jackson L., U. Pascual, and T. Hodgkin. 2007. "Utilizing and Conserving Agrobiodiversity in Agricultural Landscapes." Agriculture, Ecosystems and Environment 121: 196–210.

Jose Shibu. 2012. "Agroforestry for Conserving and Enhancing Biodiversity." Agroforestry Systems 85: 1–8.

Kharal, D.K. and Oli, B.N., 2008. An estimation of tree species diversity in rural farmland of Nepal. Banko Janakari, 18(1), pp.3-10.

Khasa P D, and B P Dancik. 1997. “Sustaining Tropical Forest Biodiversity.” 4(1/2): 1–31.

Kumar B.M., Nair, P.K.R. 2006. 3 Advanced Agroforestry Tropical Homegardens; A Time-Tested Example of Sustainable Agroforestry. 3rd ed. AA Dordrecht, The Netherlands: Springer. www.springer.com.

Lamont Susan R, W Hardy Eshbaugh, Adolph M, Greenberg Lamont, and Adolph M Greenberg. 1999. “Species Composition Diversity and Use of Homegardens among Three Amazonian Villages.” Economic Botany 53(3): 312–26.

Legas, M.S. and Taye, B., 2019. Impacts of human activities on wildlife: the case of nile lechwe (Kobus megaceros) gambella national park, southwest Ethiopia. International Journal of Biodiversity and Conservation, 11(1), pp.48-57.

McNeely, J.A. and Scherr, S.J., 2012. Ecoagriculture: strategies to feed the world and save wild biodiversity. Island press.

Mohan Soumya, P K Ramachandran Nair, and Alan J Long. 2007. “An Assessment of Ecological Diversity in Homegardens: A Case Study from Kerala State, India.” Journal of Sustainable Agriculture 29(4): 135–51.

Moonen Anna Camilla, and Paolo Bàrberi. 2008. “Functional Biodiversity: An Agroecosystem Approach.” Agriculture, Ecosystems and Environment 127: 7–21.

Munishi, P.K.T., Philipina, F., Temu, R.P.C. and Pima, N.E., 2008. Tree species composition and local use in agricultural landscapes of west Usambaras Tanzania. African Journal of Ecology, 46, pp.66-73.

Negash Mesele, Eshetu Yirdaw, and Olavi Luukkanen. 2012. “Potential of Indigenous Multistrata Agroforests for Maintaining Native Floristic Diversity in the South-Eastern Rift Valley Escarpment, Ethiopia.” Agroforestry Systems 85(9–28).

Scherr Sara J, and Jeffrey A Mcneely. 2008. “Biodiversity Conservation and Agricultural

Sustainability: Towards a New Paradigm of 'Ecoagriculture' Landscapes." The Royal Society 363: 477–94.

Schroth, G., da Fonseca, G.A., Harvey, C.A., Gascon, C., Vasconcelos, H.L. and Izac, A.M.N. eds., 2013. Agroforestry and biodiversity conservation in tropical landscapes. Island press.

Shiva Vandana. 1993. The Violence of Green Revolution: Third World Agriculture, Ecology and Politics. Penang, Malaysia: Zed Books.

Souza Helton Nonato de, Irene M. Cardoso Ron G.M. de Goede, Lijbert Brussaard, and Mirjam M. Pulleman Edivania M.G. Duarte, Raphael B.A. Fernandes, Lucas C. Gomes. 2012. "Protective Shade, Tree Diversity and Soil Properties in Coffee Agroforestry Systems in the Atlantic Rainforest Biome." Agriculture, Ecosystems and Environment 146: 179–96.

Steppler Howard A, and P K R Nair. 1987. Agroforestry a Decade of Development International Council for Research in Agroforestry Nairobi. Nairobi, Kenya: International Council for Research in Agroforestry.

Stuart Chapin, and Sandra Díaz Erika S. Zavaleta, Valerie T. Eviner, Rosamond L. Naylor, Peter M. Vitousek, Heather L. Reynolds, David U. Hooper, Sandra Lavorel, Osvaldo E. Sala, Sarah E. Hobbie, Michelle C. Mack. 2000. "Consequences of Changing Biodiversity." insight review articles Consequences 405: 234–41.

Sunderland T. 2011. "Food Security: Why Is Biodiversity Important? Sécurité Des Aliments: Pourquoi La Biodiverstiré Est-Elle Importante? Seguridad Alimentaria: ¿por Qué Es Importante La Biodiversidad?" International Forestry Review 13(3): 266–74.

Tadesse Mesfin. 2004. "Flora of Ethiopia and Eritrea." 4(2): 1–408.

Tesemma Azene Beiele. 2007. Useful Trees and Shrubs of Ethiopia: Identification, Propagation and Management for 17 Agroclimatic Zones. Nairobi, Kenya: RELMA in

ICRAF Project.

Thrupp Lori Ann. 2004. “The Importance of Biodiversity in Agroecosystems.” Journal of Crop Improvement 12(1/2): 315–37. http://www.haworthpress.com/web/JCRIP.

Turner Will R., and Elizabeth R. Selig Katrina Brandon, Thomas M. Brooks, Claude Gascon, Holly K. Gibbs, Keith S. Lawrence, Russell A. Mittermeier. 2012. “Global Biodiversity Conservation and the Alleviation of Poverty.” BioScience 62(1): 85–92. http://www.bioone.org/doi/full/10.1525/bio.2012.62.1.13.

Weikard Hans-Peter. 2002. “Diversity Function and the Value of Biodiversity.” Land Economics 78(1): 21–27.

Yitebitu Moges, Zewdu Eshetu, Sisay Nune. 2010. Ethiopian Forest Resources : Addis Ababa, Ethiopia.

BIOGRAPHICAL SKETCH OF THE AUTHOR

Kokebnesh Korma was born on May 7,1990 in dida kebele Gurage Zone Ethiopia. She is daughter of Korma Elala and Adanech Sime. Kokebnesh began her education at the Self-Help School in Dida Kebele completing her first cycle of primary education level (grade 1-4) she then attendee Butajira Mekicho School for her second cycle (grade 5-8) and went on to Butajira High School for her secondary education level. In 2011 She enrolled at Haramaya University where she studied Biology and graduated in 2013 following her graduation Kokebnesh began her teaching career in 2014 in Gambella Woreda located in the Gambella Region of Ethiopia. She has 11 years of experience as a teacher contributing to the education of her students and the community

Appendices

Appendix A

Questionnaire

Introduction

Dear respondent, my name is Kokebnesh Korma Elala and I am a masters student of Addis Ababa University in the field of Plant Biology and Biodiversity Management & Environmental Science. In my master thesis, I want to assess Tree Diversity on Small Holder's Agricultural Landscape in Gambella Woreda of Gambella Region, Ethiopia. This questionnaire is to be answered by household head. Thank you for agreeing to take part in this important survey. I highly appreciate if you could spend a few minutes providing information about your household livelihoods and home garden. Your name and the information provided by you will be kept strictly confidential and only be used for scientific purposes. Feel free to leave the fields blank if you are not comfortable providing the requested information.

Date of Interview________________

1.1 Personal Information Kebele________________

Age: 18-24 ❑ 25-34 ❑ 35-44 ❑ 45-54 ❑ 55 and above ❑

Level of education:

I can read and write ❑ I can't read and write ❑ 1-4 grade ❑

1-8 grade High school ❑ Bachelor's degree and above ❑

Marital Status: Married ❑ Single ❑ Divorced ❑ Widowed ❑

Employment status: Employee for wages ❑ Farmer❑ Self-employed ❑ Student ❑ Retired ❑

Number household members_______ Males ____ Females ______

I. Farm land Management and Tree diversity

1 What is the size of your farmland?

Local units .... he ....

2 What do you cultivate on this land? (Please encircle number/s of your choice)

1 Vegetable   2 fruit trees

3 Both vegetables and fruit trees   4 other (Please specify) ______

1. Do you currently have trees on your farmland?   1. No   2. Yes
2. How do you manage your trees?
   1. Pruning   3 Fertilization
   2. Pest and disease management 4 other   5. I do nothing
3. Do you allow grazing on your farmland?
   1. No   2. Yes
4. Do you irrigate your farmland?
   1. No   2. Yes
5. Do you use pesticides?
   1. No   2. Yes
6. Have you ever participated in any trainings related to sustainable farmland management?
   1. No   2. Yes

II. Socio-Economic Factors

1. How many years have you been farming?
   a. Less than 5 years
   b. 6-10 years
   c. 11-20 years
   d. More than 20 years
2. What is your primary source of income?

a. Farming
b. Employment
c. Off-farm income
d. Other (please specify) _____

3. Do you have secure tenure over your land?
   a. No   b. Yes
4. Do you have access to market for your farm products?
   a. No   b. Yes
5. If you have planted trees, what was your primary motivation for doing so?
   a. Soil health improvement
   b. Biodiversity conservation
   c. Climate change mitigation
   d. Economic benefit
   e. Other (please specify) ____
6. If you have not planted trees, what is primary reason for not doing so?
   a. Don’t believe in tree benefits
   b. Lack of access to seedlings or planting materials
   c. Lack of financial resources
   d. Other (please specify)
7. Have you ever received any financial or technical support for tree planting on your farmland?
   a. No   b. Yes
8. If you have received support, what kind was it?
   a. Financial
   b. Technical
   c. Both financial and technical
   d. Other (Please specify)
9. Do you have access to Credit?
   a. No   b. Yes

FGD Interview Guide

1. What types of agricultural practices do you engage in?
2. How do these practices affect the presence and diversity of trees in your area?
3. What role do trees play in your farming practices and overall livelihood? How do you perceive their importance?
4. In what ways do your agricultural practices affect the diversity of trees on your land? Can you share any specific experiences?
5. How does access to markets for your farm products impact your decisions about tree diversity? Can you discuss any related challenges?
6. What motivates you to plant or not plant trees on your farmland?
7. What types of support or resources would help you enhance tree diversity on your farmland? Can you share your experiences with any support you have received?
8. What resources (e.g., financial, technical) are available to you for managing tree diversity?
9. Have you received any training or support related to tree management? If so, from whom?
10. How does your community view tree diversity in relation to agriculture? Are there any communal practices or beliefs that influence tree management?
11. Are there any local traditions or practices regarding tree planting and conservation?
12. What challenges do you face in maintaining or increasing tree diversity in your agricultural landscape?

Appendix B

Information on Tree Species

S.no	**Local Name**	**Scientific name**	**Family name**	**Uses**
1.	Adewu (Agn)	Diospyros mespiliformis	Ebenaceae	Medicine, timber, firewood
2.	Adiquala (Agn)	Oncoba spinosa	Flacourtiaceae	Timber, medicine
3.	Alaro (Agn)	Acacia nilotica	Fabaceae	Firewood, Medicine, charcoal
4.	Downg (Agn)	Gardenia ternifolia	Rubiaceae	Edible (fruit), bee forage
5.	Kijang (Agn)	Lepidotrichilia volkensii	Meliaceae	Firewood, timber
6.	Lemunat (Agn)	Citrus sinensis	Rutaceae	Edible (fruit)
7.	Lero (Agn)	Celtis toka	Ulmaceae	Timber, fodder
8.	Liu (Agn)	Strychnos spinosa	Loganiaceae	Timber, Medicine, charcoal
9.	Orowyyee (Agn)	Diospyros mespiliformis	Ebenaceae	Shade, Medicine
10.	Pok (Agn)	Entada abyssinica	Fabaceae	Living fence, Medicine
11.	Tenga (Agn)	Antiaris toxicaria	Moraceae	Timber, Fiber(bark), medicine (leaves)
12.	Toow (Agn)	Balanites aegyptiaca	Balanitaceae	Shade, Fodder, Firewood
13.	Cholmi (mjg)	Lannea welwitschii	Anacardiaceae	Edible fruit, timber
14.	Dampaeu (mjg)	Cordia africana	Boraginaceae	Timber, shade
15.	Dimmin (mjg)	Diospyros mespiliformis	Ebenaceae	Firewood, timber, Medicine
16.	Duwe (mjg)	Baphia abyssinica	Fabaceae	Firewood, bee

				forage
17.	Gedem (mjg)	Sterculia africana	Sterculiaceae	Firewood, Fencing
18.	Jukul (mjg)	Terminalia laxiflora	Combretaceae	Timber, medicine (bark)
19.	Kogoden (mjg)	Anogeissus leiocarpus	Combretaceae	Bee forage, Medicine, Firewood
20.	Oleme (mjg)	Celtis toka	Ulmaceae	Timber, Fodder
21.	Tangnang (mjg)	Gardenia ternifolia	Rubiaceae	Edible (fruit), Bee forage
22.	Tengi (mjg)	Antiaris toxicaria	Moraceae	Timber, medicine
23.	Toyun (mjg)	Balanites aegyptiaca	Balanitaceae	Timber, firewood, charcoal
24.	Manga (mjg)	Mangifera indica	Anacardiaceae	Edible fruit
25.	Biy biy (Agn)	Azadirachta indica	Apocynaceae	Live fence, timber
26.	Grawa (A)	Vernonia amygdalina Del.	Asteraceae	Forage, timber
27.	Grar (A)	Acacia abyssinicaHochst.	Fabaceae	Timber, medicinal
28.	Shiferaw (A)	Moringa stenopetala(Bak. f.) Cuf.	Moringaceae	Medicinal
29.	Tringo (A)	Citrus medica L.	Rutaceae	Edible fruit
30.	Wanza (A)	Cordia africana Lam.	Boraginaceae	Timber
31.	Zeytuna (A)	Psidium guajava L.	Myrtaceae	Edible fruit
32.	Roka	Tamaridus indica	Fabaceae	Fodder, firewood, medicine
33.	Wacho	Acacia Seyal, Del	Fabaceae	Firewood, shade, timber
34.	Shola	Fidcus sur Forssk	Moraceae	Timber, Shade

35.	Bisana	Croton macrostachyus	Euphorbiaceae	Timber, Charcoal, bee forage
36.	Gravila	Grevillea robusta R.	Proteaceae	Timber, firewood
37.	Tila Zaf	Senna siamea	Fabaceae	Shade, Furniture, timber, firewood
38.	Chipolo	Kennedia robikanda	Bignoniaceae	Firewood, medicine

Key: Agn = Agnuak, Mjg = Mejang, Am = Amharic

Appendix C

Species Frequency and Density

S.no	**Local Name**	**Species Name**	frequency	**Relative frequency**	Density	**Relative density**
1.	Manga (mjg)	Mangifera indica	38	4.589372	225	12.90138
2.	Biy biy (Agn)	Azadirachta indica	33	3.985507	64	3.669725
3.	Orowyyee (Agn)	Diospyros mespiliformis	30	3.623188	46	2.637615
4.	Adiquala (Agn)	Oncoba spinosa	27	3.26087	42	2.408257
5.	Toyun (mjg)	Balanites aegyptiaca	27	3.26087	43	2.465596
6.	Pok (Agn)	Entada abyssinica	26	3.140097	39	2.236239
7.	Shiferaw (A)	Moringa stenopetala(Bak. f.) Cuf.	25	3.019324	48	2.752294
8.	Jukul (mjg)	Terminalia laxiflora	24	2.898551	41	2.350917
9.	Toow (Agn)	Balanites aegyptiaca	24	2.898551	43	2.465596
10.	Downg (Agn)	Gardenia ternifolia	23	2.777778	31	1.777523
11.	Grar (A)	Acacia abyssinicaHochst.	23	2.777778	65	3.727064
12.	Kijang (Agn)	Lepidotrichilia volkensii	23	2.777778	48	2.752294
13.	Shola	Fidcus sur Forssk	23	2.777778	60	3.440367
14.	Cholmi (mjg)	Lannea welwitschii	22	2.657005	31	1.777523

15.	Dampaeu (mjg)	Cordia africana	22	2.657005	56	3.211009
16.	Oleme (mjg)	Celtis toka	22	2.657005	39	2.236239
17.	Tenga (Agn)	Antiaris toxicaria	22	2.657005	38	2.178899
18.	Wacho	Acacia Seyal, Del	22	2.657005	37	2.12156
19.	Chipolo	Kennedia robikanda	21	2.536232	31	1.777523
20.	Dimmin (mjg)	Diospyros mespiliformis	21	2.536232	34	1.949541
21.	Gedem (mjg)	Sterculia africana	21	2.536232	35	2.006881
22.	Tangnang (mjg)	Gardenia ternifolia	21	2.536232	45	2.580275
23.	Roka	Tamaridus indica	20	2.415459	44	2.522936
24.	Tengi (mjg)	Antiaris toxicaria	20	2.415459	33	1.892202
25.	Adew (Agn)	Diospyros mespiliformis	19	2.294686	35	2.006881
26.	Gravila	Grevillea robusta R.	19	2.294686	72	4.12844
27.	Grawa (A)	Vernonia amygdalina Del.	19	2.294686	43	2.465596
28.	Kogoden (mjg)	Anogeissus leiocarpus	19	2.294686	44	2.522936
29.	Tila Zaf	Senna siamea	19	2.294686	39	2.236239
30.	Bisana	Croton macrostachyus	18	2.173913	51	2.924312
31.	Duwe (mjg)	Baphia abyssinica	18	2.173913	38	2.178899
32.	Lero (Agn)	Celtis toka	18	2.173913	24	1.376147
33.	Liu (Agn)	Strychnos spinosa	17	2.05314	22	1.261468
34.	Alaro (Agn)	Acacia nilotica	15	1.811594	46	2.637615
35.	Lemunat	Citrus sinensis	14	1.690821	18	1.03211

	(Agn)					
36.	Zeytuna (A)	Psidium guajava L.	12	1.449275	17	0.974771
37.	Wanza (A)	Cordia africana Lam.	10	1.207729	30	1.720183
38.	Tringo (A)	Citrus medica L.	9	1.086957	16	0.917431

Correlations

		Number of Species	Sex of respondents	Age of respondents	Education level of household head	Number of household members	Land size of the sample household	How many years have you been farming?	Have you ever participated in any trainings related to sustainable farmland management?	Do you allow grazing on your farmland?	Do you irrigate your farmland?	Do you use pesticides?	Have you ever received any financial or technical support for tree planting on your farmland?	Do you have access to market for your farm products?	Access to Credit
Number of Species	Pearson Correlation	1	.053	.624**	-.604**	.124	.762**	.606**	.728**	-.159	.528**	-.415**	.697**	.747**	.724**
	Sig. (2-tailed)		.712	.000	.000	.391	.000	.000	.000	.271	.000	.003	.000	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Sex of respondents	Pearson Correlation	.053	1	-.090	.139	.069	-.018	.124	.145	-.006	.125	-.138	.128	.006	.210
	Sig. (2-tailed)	.712		.533	.337	.634	.904	.392	.316	.968	.385	.339	.374	.968	.143

	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Age of respondents	Pearson Correlation	.624**	-.090	1	-.586**	-.029	.472**	.459**	.557**	-.076	.473**	-.245	.538**	.563**	.539**
	Sig. (2-tailed)	.000	.533		.000	.843	.001	.001	.000	.599	.001	.087	.000	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Education level of household head	Pearson Correlation	-.604**	.139	-.586**	1	.183	-.454**	-.426**	-.609**	.007	-.532**	.207	-.435**	-.719**	-.552**
	Sig. (2-tailed)	.000	.337	.000		.203	.001	.002	.000	.963	.000	.149	.002	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Number of household members	Pearson Correlation	.124	.069	-.029	.183	1	.041	-.120	.030	-.105	-.164	-.080	.069	-.113	-.024
	Sig. (2-tailed)	.391	.634	.843	.203		.775	.406	.839	.470	.256	.579	.636	.436	.870
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Land size of the sample household	Pearson Correlation	.762**	-.018	.472**	-.454**	.041	1	.394**	.613**	.046	.534**	-.323*	.576**	.653**	.507**
	Sig. (2-tailed)	.000	.904	.001	.001	.775		.005	.000	.750	.000	.022	.000	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50

How many years have you been farming?	Pearson Correlation	.606**	.124	.459**	-.426**	-.120	.394**	1	.641**	.124	.433**	-.237	.478**	.559**	.529**
	Sig. (2-tailed)	.000	.392	.001	.002	.406	.005		.000	.392	.002	.098	.000	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Have you ever participated in any trainings related to sustainable farmland management?	Pearson Correlation	.728**	.145	.557**	-.609**	.030	.613**	.641**	1	.040	.593**	-.327*	.718**	.843**	.725**
	Sig. (2-tailed)	.000	.316	.000	.000	.839	.000	.000		.782	.000	.021	.000	.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Do you allow grazing on your farmland?	Pearson Correlation	-.159	-.006	-.076	.007	-.105	.046	.124	.040	1	.093	.229	.015	-.034	-.171
	Sig. (2-tailed)	.271	.968	.599	.963	.470	.750	.392	.782		.519	.109	.916	.816	.234
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Do you irrigate your farmland?	Pearson Correlation	.528**	.125	.473**	-.532**	-.164	.534**	.433**	.593**	.093	1	-.391**	.730**	.547**	.577**
	Sig. (2-tailed)	.000	.385	.001	.000	.256	.000	.002	.000	.519		.005	.000	.000	.000

	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Do you use pesticides?	Pearson Correlation	-.415**	-.138	-.245	.207	-.080	-.323*	-.237	-.327*	.229	-.391**	1	-.241	-.393**	-.313*
	Sig. (2-tailed)	.003	.339	.087	.149	.579	.022	.098	.021	.109	.005		.091	.005	.027
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Have you ever received any financial or technical support for tree planting on your farmland?	Pearson Correlation	.697**	.128	.538**	-.435**	.069	.576**	.478**	.718**	.015	.730**	-.241	1	.578**	.640**
	Sig. (2-tailed)	.000	.374	.000	.002	.636	.000	.000	.000	.916	.000	.091		.000	.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Do you have;access to market for your farm products?	Pearson Correlation	.747**	.006	.563**	-.719**	-.113	.653**	.559**	.843**	-.034	.547**	-.393**	.578**	1	.656**
	Sig. (2-tailed)	.000	.968	.000	.000	.436	.000	.000	.000	.816	.000	.005	.000		.000
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Access to Credit	Pearson Correlation	.724**	.210	.539**	-.552**	-.024	.507**	.529**	.725**	-.171	.577**	-.313*	.640**	.656**	1

	Sig. (2-tailed)	.000	.143	.000	.000	.870	.000	.000	.000	.234	.000	.027	.000	.000	
	N	50	50	50	50	50	50	50	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).