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Determinant Factors Influencing the Adoption of Agroforestry Practices by Small-holder Farmers in Legambo District of Northeastern Ethiopia

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BAHIR DAR UNIVERSITY

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GRADUATE PROGRAM

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M.Sc. Thesis

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (M.Sc.) in "Agroforestry"

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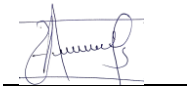
THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mrs. Zinet Alye Yimam** entitled "**Determinant factors influencing the adoption of agroforestry practices by small-holder farmers in Legambo District of Northeastern Ethiopia"**. We here by certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in "**Agroforestry**".

Board of Examiners

Haile Shiferaw (PhD)		**July 24, 2024**.
Name of External Examiner	Signature	Date
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Name of Internal Examiner	Signature	Date
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Name of Chairman	Signature	Date

DECLARATION

This is to certify that this thesis entitled "**Determinant factors influencing the adoption of agroforestry practices by small-holder farmers in Legambo District of Northeastern Ethiopia**" is submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "**Agroforestry**" to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mrs. **Zinet Alye Yimam** (ID. No. BDU 1301397) is an authentic work carried out by her under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

Zinet Alye Yimam		**July 10, 2024**
Name of the Student	Signature	Date
Belayneh Ayele (PhD)		**July 10, 2024**.
Name Supervisor	Signature	Date

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LIST OF ABBREVIATIONS/ACRONYMS

AEZs	Agro Ecological Zones
AFPs	Agroforestry Practices
ANRS	Amhara National Regional State's
CSA	Central Statistical Agency
FGDs	Focus Group Discussions
ha.	Hectare
HHs	Households
ICRAF	International Centre for Research in Agroforestry
KII	Key Informant Interview
KM	Killo Meter
LDANRDO	Legambo District Agricultural and Natural Resource Development Office
m.a.s.l	Meter above sea level
NGOs	Non-Governmental Organizations
NTFPs	Non-Timber Forest Products
SSA	Sub–Saharan Africa
SPSS	Statistical Package for Social Studies

ABSTRACT

Despite widespread reports concerning the role of agroforestry for economic advantage, soil protection, fuel wood, and environmental benefits, not much is known about rural households' determinant factors of agroforestry practices. This study was conducted to address determinant factors affecting adoption of agroforestry practice in the Legambo District. A cross-sectional research design was applied in four Kebeles of Legambo district involving 361 sample households. Multi-stage sampling techniques were employed to select the district, Kebeles, and sample households. Descriptive statistics and the binary logit model were used to analyze the data. The result from Likert scale on farmers' perceptions about the benefits of agroforestry practices indicated that the mean score of 3.85, 3.65 and 3.58 of the respondents perceived that agroforestry conserves soil and water, improves soil nutrients, and increases farm income, respectively. The result from descriptive statistics, 64.5% of the respondents had adopted different agroforestry practices. Of scattered tree on crop land (63.7%) was mostly adopted by household, while, 13.6% adopted alley cropping. The result indicated that the proportion of adopters of agroforestry practices was higher than non- adopters. Binary linear regression analysis showed adoption of AFPs in the study area was significantly ($p \leq 0.05$) influenced by age, gender, education level, land size and livestock ownership. However, the total land size of the HHs had negative and significant ($P \leq 0.02$) influence. Conflict with neighbor landowners ($P \leq 0.053$) and economic status ($P \leq 0.208$) were not significant in determining the adoption of agroforestry practices. Therefore, efforts are expected from the concerned bodies to enhance the adoption of agroforestry in the study area

Keywords/Phrases: *Agroforestry practices, perception, adoption, Logit model*

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CHAPTER 1: INTRODUCTION

1.1. Background and Justification

Land degradation is increasing globally in the form of soil erosion and nutrient depletion, which poses a particular threat to the livelihoods of those living in sub-Saharan Africa (SSA) (Tully *et al.*, 2015). Extreme weather events like heavy rainfall and drought jeopardize the subsistence agriculture that supports over half of the population in Sub-Saharan Africa (Cordingley *et al*., 2015; Mohammed *et al*., 2022; Wubaye *et al*., 2023). Furthermore, cultivated lands have expanded to vulnerable hillsides, shrunk, and become more fragmented due to rapid population growth (Teklewold *et al*., 2013). Another major problem in many developing nations is deforestation, which is mostly brought on by commercial and subsistence farming (Hosonuma et al., 2012). According to Pachauri *et al*. (2014), deforestation is estimated to account for 17% of the world's CO2 emissions. It also continues to deplete forest resources, which has led to increased land degradation, low productivity, and poverty (Kiyani *et al*., 2017).

Ethiopia is face these facts, as its agriculture sector has not succeeded in significantly reducing soil erosion (Teklewold *et al*., 2013; Teshome *et al*., 2016). Because of this, soil loss is still a serious problem in this nation, especially in the highlands, where it averages 20 t ha^{-1} $year^{-1}$ (Hurni et al., 2015). According to Yesuf *et al*. (2005), the annual cost of land degradation in Ethioipia ranges from 2.0 to 6.8% of the nation's agricultural GDP. This contributes to food insecurity and exacerbates the effects of the country's recurrent droughts (Adgo *et al*., 2013). This has led to the development of several policies throughout the nation to promote various measures to address these issues and improve agricultural productivity. Among measures, AFPs are the ones that imply a distinctive arrangement of elements in terms of both space and time to diversify the production of farms and forests while preserving natural resources (Amare *et al*., 2018).

There is evidence that using AFPs could help slow down or even stop the rate at which soil erosion and degradation are occurring (Meijer *et al*., 2015; Montagnini and Metzel, 2017; Sharma and Sharma, 2017; Waldron *et al*., 2017; Amare *et al*., 2018; Saqib *et al*., 2019). Practitioners and international organizations such as the World Bank, ICRAF, government agencies, and NGOs have also recognized the contribution of AFPs to livelihoods in rural areas

(Munsell *et al*., 2018). As a result, approximately 350 million AFPs adopters worldwide dedicated at least 5 to 10% of their farms to AFPs (Pattanayak *et al*., 2003). There has also been an increase in the adoption AFPs among smallholder farmers in developing countries, particularly in SSA (Valbuena *et al*., 2012; Owombo *et al*., 2018). In addition to stopping land degradation, AFPs offer ecosystem services and functions that encourage farmers in SSA to adopt them (Fagerholm *et al*., 2016; Kuyah *et al*., 2017).

Moreover, the practices fulfill multiple good and services. Thus, the use of AFPs enhances crop yield and soil fertility while acting as a buffer and stabilizing the environment. Additionally, trees from AFPs can provide a variety of wood and wood products that can be sold to generate income (Amadi, 2013). Additionally, farmland trees provide fuelwood and fodder; they also enhance household income (Amare *et al*., 2018); improve soil property (Bajigo and Tadesse, 2015); and support biodiversity conservation and the production of a variety of products (Negash *et al*., 2012). Therefore, Adoption of practice is a process with a sequence of stages through which farmers' gain knowledge , seek information about the likely consequences of adoption and form an attitude towards it; decide to adopt or reject the technologies, implement the technologies; and confirm their technologies decision by seeking reinforcement, and discontinue it if exposed to conflicting experiences and messages.

Agroforestry is as a solution for alleviating land degradation and related challenges needs to be well adopted by the community. Despite these potential benefits, adoption of agroforestry has not been widespread in many parts of Africa (Mbow et al., 2014). A clear understanding of the determinant factors in farmer decision-making regarding adoption of agroforestry is crucial in improving land management practices for sustainable livelihoods. This study was initiated with the aim of assessing farmers' perception and factors affecting the adoption of agroforestry practices in the study area.

1.2. Statement of the Problem

In Ethiopia, agroforestry practices are a major source of livelihood, particularly for the rural poor. It enhances farmers' living standards by providing food, and fuel and improving the fertility of agricultural land.

But they have faced ongoing deforestation and land degradation especially in the South Wollo Zone of Ethiopian highlands, where the study area district is situated (Tesfa & Mekuriaw, 2014). The main causes of soil erosion and severe degradation are improper land management in South Wollo's highlands (Tafere and Nigussie, 2018; Ibrahim *et al*., 2022). This has become one of the biggest threats to livelihoods and has further contributed to the decline in agricultural production. The problem has been made worse by recurrent drought and high rainfall variability, especially in the study area (Little, 2008; Agidew and Singh, 2018).

As a result, the farming systems in the Legambo district are becoming increasingly dependent on external factors and increasingly vulnerable to fluctuations in the climate. A significant portion of the district's farmers engage in subsistence farming in addition to routinely participating in safety-net programs and other humanitarian aid initiatives (Nigussie et al., 2017; Gebru *et al*., 2019; Gebre, 2022). Since 2004 (Tafere and Nigussie, 2018), the Amhara National Regional State's (ANRS) Bureau of Agriculture has initiated and reinforced various AFPs in recognition of the issues of land degradation and deforestation being faced.

Various researchers conducted studies on determinant factor influencing adoption of agroforestry practices in different parts of Ethiopia (Tafere and Nigussie, 2018; Beyene and Mekonnen, 2019; Gebru *et.al* 2019; Rojas *et.al,* 2020). However, the determinant factor of agroforestry practices vary from place to place and are not well documented. Some of the previous researchers conducted in the district on agroforestry practices. For instance, Habtemariam and Belay (2019) conducted a study on Home garden agroforestry practices in the Legambo district,northestern Ethiopia, and they were only focused on the species composition, the status of native species, and the utilization of species. However, the author did not consider determinant factors that influence the adoption of AFPs. Studies have not been much focus on understanding how different socio-economic factors influence farmers' perceptions of the practices and how they are adopted (Tafere and Nigussie, 2018). So, this study is aimed to fill the above information gap on determinant factors that influence the adoption of AFPs by smallholder farmers in the Legambo District of northeastern Ethiopia.

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1.3. Objectives of the Study

1.3.1. General objective

The overall objective of this study was to investigate and contribute knowledge and skill on determinant factors that influence the adoption of AFPs by smallholder farmers in the Legambo District of northeastern Ethiopia.

1.3.1. Specific objectives

The specific objectives of this study were to:

- To assess the perception of farmers toward agroforestry practice in the study area.
- To identify the adoption of agroforestry practices in the study area.
- To analyze the socio-economic factors influencing the adoption of AFPs by smallholder

1.4. Research Questions

This study answers the following research questions in order to meet the above objectives:

1. Which AFPs were used by smallholder farmers?
2. What factors affect smallholder farmers' adoption of AFPs?
3. What did smallholder farmers think about AFPs and their benefits?

1.5. Significance of the Study

The result of this study would be expected to be important in the following ways, firstly, It is expected that this study will add to the body of knowledge and information that will help develop a robust local capacity for AFP adoption. Such data is helpful in directing district-wide reforestation initiatives in agricultural areas. Secondly, the findings may be helpful for extension organizations that advise smallholder farmers on how to plan and implement developed AFPs. Thirdly, the study provides a picture of study area situations on choice of farmers' acceptance of agroforestry practices including, feelings of indigenous knowledge and experiences to other farmers. Finally, the results of this study may enhance the use of AFPs by farmers in the area, experts in the field, development experts, agricultural planners

1.6. Scope of the Study

Geographically, this study emphasizes only the selected four kebeles of Legambo district, Northeastern Ethiopia. Thematically, this study considered the perception, adoption of agroforestry practice and socioeconomic factors that affect agroforestry practices in rural households.. Methodologically, this study used both qualitative and quantitative approaches. Questionnaires and key informant interviews were used to collect information on determinant factor of adopting AFPs. Descriptive statistics and the binary logit model were used to analyze the data.

1.7. Limitations of the Study

The respondents were not easily accessible due to their social management and farming activities. The data collectors were going on when the respondents were found. In addition, there was a challenge to get experts for an in-depth interview from Kebeles and district administration. The respondent's unwillingness to give information to the questionnaires because of lack of understanding the usefulness of the study. The lack of good internet access, were the major problem.

CHAPTER 2: LITERATURE REVIEW

2.1. Concepts and Definitions of Agroforestry

The term "agroforestry" refers to a collection of land use techniques and agroforestry technologies, which include the incorporation of woody perennials into agricultural systems (Hall, 1989). Agroforestry systems are distinguished by specific practices that, when combined, constitute a dominant land-use system in a given locality. These systems are defined by the environment, the species and arrangement of plants, management, and the social and economic roles they serve. Although the system has been in use for a very long time, the integration of farming and trees became more common in recent centuries as food production increased and monocropping became the norm (Liu, 2019). Then, in the late 1970s, agroforestry gained popularity as an alternative and attracted a lot of attention from the international development community as the effects of intensifying food production systems on the environment and society became more apparent following the Green Revolution (Hall, 1989).

Thus, agroforestry is a modern term for a long-standing set of land-use techniques. Therefore, even the most basic agroforestry system is more complex than a monocropping system in ecology and economy because of the variety of mixtures (Liu, 2019). This integrated approach addresses land use issues by enabling farmers to concurrently produce fuel, fiber, food, and fodder from a single unit of land. The advantages of agroforestry are greater in terms of ecology, economy, and structural complexity and take longer to manifest (years) than those of intensified agricultural systems (Nair, 1985).

Worldwide, a wide range of agroforestry systems are in use, and based on the criteria used, they can be categorized in several ways. One way to classify them, for instance, is according to their main purpose. The components of agroforestry systems can also be categorized: silvopastoral systems, which produce livestock and woody plant species, agrosilvopastoral systems, which produce livestock, woody plant species, and seasonal plants (Nair, 1985). Agrosilvicultural systems, on the other hand, produce woody plant species and seasonal plants. In addition, a temporal component of classification takes into account the different species found in the agroforestry system and the extra advantages of trees, like their ability to conserve soil, cast shade, and ward off wind (Nair, 1985). Small landholders in the tropics, and especially in sub-

Saharan Africa, use this system to address environmental sustainability and food production at the same time (Valbuena *et al*., 2012; Owombo *et al*., 2018; Jiru, 2019).

2.2. Agroforestry Systems in Ethiopia

The foundation of the Ethiopian economy is agriculture, which generates 42–45% of the nation's GDP (Teklewold *et al*., 2013). Nevertheless, it suffers from the effects of climate change (Mohammed *et al*., 2022; Wubaye *et al*., 2023), soil erosion, and land degradation (Hurni *et al.*, 2015). Literatures indicates that agroforestry systems based on trees have a substantial positive impact on poverty reduction (Meijer *et al*., 2015; Montagnini and Metzel, 2017; Sharma and Sharma, 2017; Waldron *et al*., 2017; Amare *et al*., 2018; Saqib *et al*., 2019). Planting trees alongside annual crops is a way to increase land productivity and diversify production, which helps farmers combat crop failure brought on by climate change and land degradation (Agidie et al., 2013*;* Amare *et al*., 2018).

Owing to its remarkable advantages in terms of the economy, society, and environment, nearly all Ethiopian smallholder farmers are more knowledgeable about the agroforestry system and practices (Meijer et al., 2015). According to (Nair, 1993), an agroforestry practice is a particular land management operation on a farm or other management unit that involves the placement of agroforestry components in space and/or time. According to (Bajigo & Tadesse, 2015) and Abiyu *et al*. (2016), there are many different AFPs in Ethiopia; The most common traditional AFPs in Ethiopia were planting trees and shrubs in farmlands and homesteads. Nonetheless, the review's findings by Amare *et al.* (2018) showed that there are not many studies that particularly discuss farmland agroforestry. The major types of agroforestry practice are the following:

Home garden AFPs

According to Nair (1993), cited by Endale (2019), home garden agroforestry practice is a land-use system that involves the intentional management of multipurpose trees, annual and perennial crops, and livestock within the compounds of individual houses. The entire tree-crop-animal unit is then intensively managed by family labor. In home garden agroforestry, which is associated with the three scientific disciplines of forestry, animal husbandry, and agronomy, respectively, trees, cattle, and crops are most commonly recognized as the three stable ecosystems (Mehari and Abera, 2019). Home garden types of AFPs are practiced throughout the country of Ethiopia.

Nevertheless, the goal, species of trees, farmer's interest, and management style of home garden agroforestry land use practices have differed amongst locations. According to Mehari and Abera (2019) and Endale (2019), the practice has been widely accepted and adopted in the southern and southwestern region of the country. Common species found in home gardens' upper story include *Cordia africana, Milletia fruginea, Albezzia gummifera, Ficus species*, and Acacia species.

Farmland AFPs

This kind of AFP also known as a parkland AFP involves the continuous growth of a tree linked to a cereal crop, like sorghum, maize, or teff (Nair, 1985). To have the least possible effect on the companion crop, trees would be strewn throughout a crop field, typically ranging from one to twenty trees per hectare. These kinds of trees, which are scattered across agricultural land, can be supported by planting new trees or by protecting and carefully tending to naturally regenerated trees. In the central highlands of Ethiopia, about half of the farmers (42%) are interested in planting dispersible trees on their land (Duguma and Hager, 2009). *Cordia africana* intercropping with maize in Bako and western Ethiopia, as well as *Acacia albida*-based agroforestry in the Hararghe Highlands and Debrezeit area, are some excellent examples of this practice (Abera and Mehari, 2019; Endale, 2019).

Woodlot AFPs

It involves planting and managing multipurpose woody perennials over time to yield fuel wood, poles, and stakes for climbing crops; food and animal components can be incorporated into woodlots, particularly in the early stages of establishment (Nair, 1985). Additionally, it has been confirmed that a large number of farmers planted trees on their small woodlots as the best alternative to conventional land use practices. As a result, it helps smallholder farmers in Ethiopia's Eza district meet the needs of their families by providing income, building materials, and firewood (Zerga, 2015).

Smallholder farmers in Ethiopia, especially in rural areas, cultivate woodlot tree-based agroforestry land use (Duguma and Hager, 2009). The primary goals of introducing eucalyptus into Ethiopia were to decrease natural forest degradation and increase the availability of tree products. Currently, however, this view has gradually shifted to one that is more benefits-oriented and market-driven. The best way to help smallholder farmers in the Arsi Zone of

Oromia improve their living conditions is to plant eucalyptus woodlots, which provide both income and wood products for domestic use (Mekonnen, 2010). Moreover, an estimated 6% of the ANRS's total area is made up of forest resources, which include bamboo and plantation forests (1.23%), woodlands (4.2%), high forests (0.48%), and woodlands (4.2%). Over the past 15 years, the region's total forest resources have shown a slight increase in area coverage. The main benefit is that the area has the biggest woodlots in the nation thanks to eucalyptus plantations and rehabilitation initiatives in the eastern and, more recently, western highlands of Amhara (Wassie, 2017).

Hedgerow intercropping

Although hedgerow intercropping is used throughout the country, it is most commonly used in the Hararghe highlands of eastern Ethiopia for sorghum/maize and chat (*Catha edulis*). Vegetation found along rivers, water banks, streams, and similar areas is known as riparian zone vegetation. There are many intermittent and perennial rivers in Ethiopia, and some of these streams and rivers sustain a significant number of species with relatively dense vegetation. The vegetation along the Awash and Eliwoha waterways, which are home to *Acacia tortilis, Acacia nilotica, Balanites aegyptiaca, Tamarindus indica, Tamarix spp., and Ziziphus* spp., is one example of riparian zone vegetation in Ethiopia (Abera and Mehari, 2019).

Boundary planting

This involves planting multiple trees, fruit trees, shrubs, and grasses in single or multiple lines (Kinyili, 2020; Kassa and Nigussie, 2022).To create boundaries and buffer zones between farms to prevent conflicts with neighboring farmers, boundary planting is a common practice in the northern part of Ethiopia. The common tree species planted at the border of a farm and a road is Eucalyptus globules. In the past few years, field boards lined with single rows of Eucalyptus globules trees have taken center stage in the central highlands of the landscape (Kassa and Nigussie, 2022).

2.3. Roles and Benefit of AFPs

2.3.1. Socio-economic benefits

The majority of the population in the nation depends on rain-fed agriculture, which is impacted by climate variability. Among the numerous AFPs that are accessible, their multifaceted

influence on agricultural systems makes them especially valuable. Accordingly, AFPs are a potent instrument for tackling regional and worldwide development issues and offer a multitude of economic, social, and ecological advantages (Amare *et al*., 2018). It is successful in boosting agricultural yields, reducing land degradation, and enhancing the security of food and livelihood. According to Tafere and Nigussie (2018), Abera and Mehari (2019), Tega and Bojago (2023), and other sources, an increase in revenue from tree products is computed using both non-timber forest products (NTFPs) and timber forest products, which include fruit, firewood, honey, spices, timber, pole, and bark.

On-farm trees were planted or maintained primarily to guarantee food and income throughout the year, according to a survey on AFP's contribution to rural household farm income in Sodo Zuria District, Southern Ethiopia (Tega and Bojago, 2023). They discovered that the mean annual gross income from different AFPs was 32,471.24 ETB/ha^{-1}/yr^{-1} for adopters and 15,990.90 ETB/ha^{-1}/yr^{-1} for nonadopters. Additionally, Melaku *et al*. (2014) report that in the Kaffa Zone, farmers receive 47% of their income from non-timber forest products (NTFPs), while Kebebew and Urgessa (2011) report that in Jimma Zone, southwest Ethiopia, home gardens AFPs generate an average annual income of 1683 ETB. Many literary works demonstrate the advantages of trees and shrubs for traditional medicine in various regions of Ethiopia (Hunde, 2006; Abera, 2014).

Accordingly, about 52 species of medicinal plants were found in the Boosat district in central-eastern Ethiopia (Hunde, 2006), and 39 species of medicinal plants that are used to treat a variety of illnesses were distinguished in the Jimma zone in southwest Ethiopia (Abera, 2014). For instance, *Euphorbia candelabrum* for ringworm, *Millettia ferruginea* for fungal infection, *Vernonia amygdalina* for diarrhea and stomach ache, *Croton macrostachyus* for malaria, diarrhea, epilepsy, ringworm, and skin rash, and *Cordia africana* for evil eyes. Shade service is provided by tree-based agroforestry land use practices. In Southwestern Ethiopia, people congregate under a shade tree for religious purposes, such as playing, and social issues (Negash *et al*., 2012). However, the practice of agroforestry on farmlands is disappearing in many agricultural settings in Ethiopia as a result of the rise in demand for fuel wood and the degradation of the surrounding forests (Tega and Bojago, 2023).

2.3.2. Environmental/ecological benefits

In most African nations, land degradation and decreasing soil fertility pose a serious threat to agricultural productivity and have an impact on human welfare (Tully *et al*., 2015). Farmland trees have several important functions that benefit both human and environmental health (Meijer *et al*., 2015; Montagnini and Metzel, 2017; Amare *et al*., 2018; Saqib *et al*., 2019). Restoring soil organic matter and nutrient contents through litter addition and decomposition, trees in agroforestry systems use deep roots to absorb and pump back nutrients that have been leached (Kassa and Nigussie, 2022). Moreover, leguminous trees are frequently incorporated into agroforestry practices due to their capacity to fix atmospheric nitrogen and improve soil fertility (Munsell *et al*., 2018).

Additionally, the loss of organic matter, related nutrients, and soil fertility caused by erosion is the main factor reducing crop yield. Therefore, maintaining and restoring fertility is crucial. Woody perennials can adapt to steeply sloping sites that are inappropriate for traditional cropping or grazing because of their root systems. In agroforestry, nitrogen-fixing trees, or legumes, can thrive in challenging locations with low soil fertility and a history of erosion (Bajigo & Tadesse, 2015; Hombegowda *et al*., 2022). Similarly, trees on agricultural fields produce a calm atmosphere in which people can live, shade other living things, act as windbreaks, keep the soil fertile, and affect the climate of a specific region (Fagerholm *et al*., 2016; Kuyah *et al*., 2017).

Contribution of Agroforestry to the preservation of biodiversity is also expanding quickly (Bajigo and Tadesse, 2015). Due in large part to their high biodiversity and multiuse products with comparatively low labor, financial, or other inputs, the long-standing practices of tropical traditional agroforestry systems, primarily home gardens, are generally regarded as sustainable production systems (Abera and Mehari, 2019; Kassa and Nigussie, 2022). Additionally, agroforestry has a special responsibility to reduce the buildup of greenhouse gases in the atmosphere (Fagerholm *et al*., 2016; Kuyah *et al*., 2017). Because forests store a significant amount of carbon in the form of soil and vegetation biomass, they are vital to the global carbon cycle. CO2 from the atmosphere is also sunk by it. More trees in agricultural landscapes generally have a greater potential to sequester carbon (Owombo *et al*., 2018).

2.4. Adoption, Farmer's Perceptions and Influencing Factors of AFPs

2.4.1. Definition of adoption

Most commonly, adoption is defined as the adopter's choice to apply and use an innovation (agroforestry) as the most practical solution for a particular need (Jha *et al*., 2021). In our case, the adopters are smallholder farmers. An idea, method, or object that is widely embraced and utilized by a person, group, or community is referred to as innovative in this context. In this study, a farmer is deemed to have adopted agroforestry if they have incorporated the use of woody perennials into their farming system (Nair, 1985) and have persisted in doing so (Jha *et al*., 2021).

2.4.2. Definition of farmer perceptions

This paper defines farmer perceptions as the farmer's subjective preferences, which are inherent factors that may impact the decision-making processes within the context of adopting agricultural technologies. A variety of previous actions, experiences, observations, and future objectives all influence farmers' perceptions. Individual traits affect how people perceive things, leading them to adopt AFPs knowingly or unknowingly, satisfy the demand for forest products, and provide income for their households. These traits include attitudes, motives, interests, past experiences, and expectations (Jha *et al*., 2021). Farmers' perceptions are subject to change as new information becomes available and their initial impressions are modified (Meijer *et al*., 2015). The reality may or may not align with the perceptions of farmers. Therefore, regardless of how closely farmer perceptions match reality, they are all taken into account in the study to prevent biased results (Jha *et al*., 2021).

Previously conducted studies (Agidie *et al*., 2013; Kiyani *et al*., 2017; Jahan *et al*., 2022; Tega and Bojago, 2023) on farmers' knowledge and perceptions of AFPs have generally relied on qualitative methods. Ibrahim *et al*. (2022) have reported that a negative perception can hinder the adoption of any technology. These factors include awareness of the practices benefits and drawbacks. Innovation will probably be embraced, accelerated, and maintained in the future if it is thought to be advantageous. To sustainably increase agricultural productivity through the current agroforestry system, farmer perception is a critical factor (Tafere and Nigussie, 2018; Ibrahim *et al*., 2022).

2.4.3. Factors that affect adoption of AFPs

In Ethiopia, smallholder farmers have yet to widely adopt agroforestry, despite the practice's widespread promotion, positive examples, and documented advantages. Agroforestry projects in Ethiopia, like those in many other regions of the world, have had varying degrees of success, which frequently vary from place to place (Amare *et al*., 2018; Tafere and Nigussie, 2018). Failures and successes in agroforestry are highly localized, and there are obvious reasons for the low adoption rates and/or quick abandonment of the practice after adoption. There is some research on the variables influencing Ethiopian farmers' decisions to implement agroforestry on their farms and in their households. A review of this literature shows that smallholder farmers' adoption of AFPs is influenced by a variety of factors, the majority of which vary from study to study and from region to region. A table with all the variables in the adoption model for this study is given in Table 3.2. The socioeconomic and demographic aspects of agroforestry practices are among the many factors that influence farmers' adoption of AFPs (Tafere and Nigussie, 2018; Ibrahim *et al*., 2022).

Socio-economic factors

Adoption of agroforestry is positively correlated with farmer membership in various associations (Abiyu *et al*., 2016; Gebru *et al*., 2019; Ibrahim *et al*., 2022; Tega and Bojago, 2023). To supply inputs like premium seeds and fertilizers, the resources needed, and to have a positive impact on the adoption of agroforestry, one must have access to microcredits through membership in various social organizations (Abera and Mehari, 2019; Ibrahim *et al*., 2022; Tega and Bojago, 2023). Similar findings are found by Ibrahim *et al*. (2022) in the Jama district of Northeastern Ethiopia, where they discovered that a farmer's ability to access microcredits and public funds may enable them to hire labor during the early stages of AFP implementation (before the outputs being experienced or observed), which in turn have influenced the agroforestry practices overall adoption. Furthermore, Tega and Bojago (2023) found a positive correlation between engagement in off-farm activities and the adoption of agroforestry in Southern Ethiopia's Sodo Zuria District.

Land ownership has a positive impact on AFP adoption (Melaku and Asfaw; Amare *et al*., 2018). According to Sebukyu and Mosango (2012), Tafere and Nigussie (2018), and Ibrahim *et al.* (2022), the adoption of agricultural technology, such as agroforestry, is positively impacted by

prior knowledge gained through advancing age. Additionally, they discovered a positive correlation between the size of farms and plots and the adoption of agroforestry, possibly because larger farms have more space for agroforestry experiments and practices. Similarly, farm size was positively correlated with the adoption of farmland agroforestry, according to a study conducted by Amare et al. (2018) on the practices and advantages of agroforestry on smallholder farmers in Ethiopia.

Socio-economic factors like education level have also had an impact on the adoption of AFPs. According to Ibrahim *et al*. (2022), the adoption of AFPs is being positively and significantly impacted by the educational level of farmers. And so, compared to farmers with less education, farmers with greater education have embraced better AFPs. On the other hand, (Tafere and Nigussie (2018) found that education has a direct impact on how new technologies are adopted and how decisions are made at the farm level. While AFPs are not readily adopted by literate people, they are by illiterate people. It is also stated that AFP adoption is highly influenced by wealth status (Ibrahim *et al*., 2022). Adoption decisions are expected to be influenced by wealth for several reasons, including the fact that wealthier farmers may be better able to take on risks and have greater access to resources. This is because AFPs have a high upfront cost, which includes paying for the purchase of different supplies like seeds, fertilizer, pesticides, water pumps for irrigation, and other expenses.

Furthermore, the size of the livestock affected the adoption of AFPs; adoption was found to be positively correlated with livestock owned by a farmer (Nigussie *et al*., 2017; Solomon, 2019; Ibrahim *et al*., 2022). An additional factor influencing farmers' adoption of AFPs is their perception and interactions with extension agents. Agidie *et al*. (2013) studied farmers' perceptions of AFPs in the upper Blue Nile basin of Ethiopia's Koga watershed. The author concluded that there is a positive and statistically significant correlation between AFP adoption and perception. Furthermore, because agroforestry is a more knowledge-based practice, farmers who engage with extension agents may be more prepared to adopt AFPs and have favorable perceptions (Nkamleu and Manyong, 2005). In contrast, the other study conducted by Amare *et al*. (2018) claimed that extension agents have no appreciable impact on Ethiopia's adoption of farmland agroforestry. Agroforestry adoption is adversely impacted by land conflicts (Owombo *et al*., 2018). Adoption of agroforestry is positively impacted by secure land rights and tenure

(Owombo *et al*., 2018). Adoption of agroforestry is positively impacted by having access to seed-selling programs and a dependable seed supply (Tafere and Nigussie, 2018).

Demographic factors

The demographic factor is another significant factor influencing the adoption of agroforestry practices in the specified households. Age, sex, marital status, and family size are among the variables that make up the demographic factor. An Ethiopian study by Gebru *et al*. (2019) demonstrates a negative relationship between adopter age and AFPs adoption. Similarly, the age of the household head has a positive and significant impact on the adoption of agroforestry practices, according to the findings of a study by Tafere and Nigussie (2018). on household-level determinants of AFPs. Households may occasionally lose labor and time as a result of illness or poor health, which could hinder the adoption of agroforestry (Kassie, 2016). According to the authors' findings, the adoption of agroforestry practices is positively and significantly impacted by age, sex, marital status, and family size. Gender also plays a major role (Amare *et al*., 2018; Tafere and Nigussie, 2018). Adoption of agroforestry has also been found to be positively correlated with household size (Sanou *et al*., 2019; Ibrahim *et al*., 2022). One common indicator of labor availability for adoption is the size of the prospective adopter's household (Ibrahim *et al*., 2022).

2.5. Conceptual Framework

This section introduced the conceptual framework that directs the investigation by creating a model of interest. Various factors are included in the framework that are intended to influence farmers' adoption of agroforestry practices, specifically socio-economic and demographic factors were to be taken into account when evaluating AFPs. Farmland size, education level, livestock ownership, and other socioeconomic and demographic variables were all considered as study elements. The conceptual framework of this study is presented below (Figure).

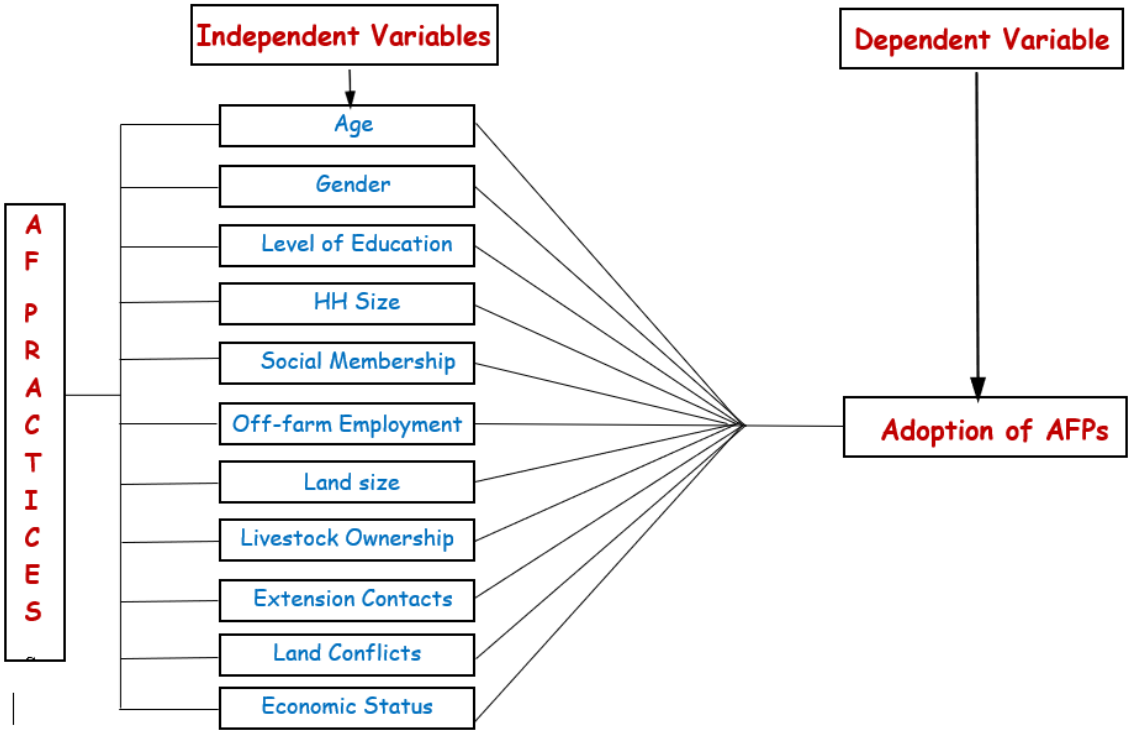

Figure 2.1: Schematic diagram of the conceptual framework.

CHAPTER 3: MATERIAL AND METHODS

3.1. Description of the Study Area

This study was carried out in the Legambo district of Northeastern Ethiopia. Geographically the district is located within the coordinates of 10°43'0' to 11°1'00" North and 38°54'0' to 39°26'0" East (Figure 3.1). Its entire area is 1,017.35 km^2. Legambo district has a mean annual temperature of 14°C and annual rainfall ranging from 768 mm in the midlands to 1393mm in the humid highlands, with an annual average rainfall of 1037 mm. The topography of the district is characterized by a complex topography made up of Plain (7.1%), gentle slopes (27.4%), mountain cliff (22.2%) and gorges (43.3%). An altitude of the district ranges from 1831 to 4111 m.a.s.l. 49.4% and 48.4% of Legambo distinct lays in Woyna dega (mid-land) and *Dega* (highland) agro ecologies, respectively. However, the remaining 2.2% of the distinct is Wurich or high frost-prone highlands (Belete, 2015).

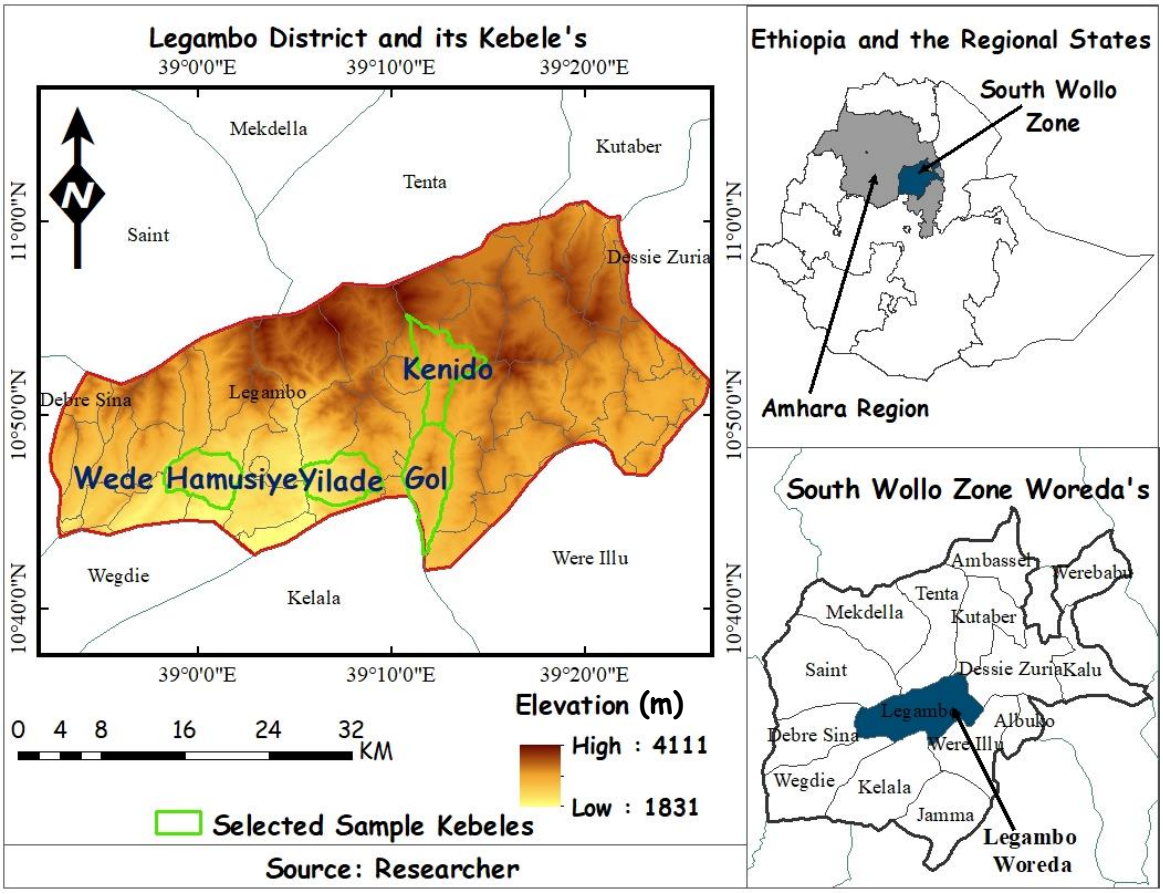

Figure 3.2: Location map of the Legambo district in Ethiopia

The major land-use types of the district are dominated by cultivated land (69%), grazing land (10%), forest land (2%), water bodies (1%), infrastructure and settlement (3%), and unproductive land (15%) (Belete, 2015). *Olea africana, Accacia abyssinia, Cordia africana, Eucalyptus globules, Sesbania sesban,* and other fodder tree and shrub species found in the district are typical tree species covering the forest land (LDANRDO, 2023 unpublished). According to Ethiopian Central Statistical Agency (CSA), the district has a total population of 165,026 of whom 81,268 were males and 83,758 were females (CSA, 2007). The district has a total HHs of 39,078 and a population density of 162.21 people km^2. The majority of farmers in the district rely on agriculture for their livelihoods. They are practicing ‘‘mixed’’ farming systems including crop production and sedentary livestock grazing. Crop production is mostly rain fed though in some area’s irrigation is practiced (LDANRDO, 2023 unpublished).

3.2. Research Design, Sampling techniques, and Sample Size

3.2.1. Research Design

This study employed a cross-sectional research design, that is, the data were gathered from households. The study mainly used a quantitative approach complemented by a qualitative approach. That is, adapted mixed method research design as a research approach. A quantitative research approach was applied for getting information about the adoption of agroforestry practices and its determinants using structured questionnaires whereas a qualitative research approach was employed using key informant interviews and focus group discussion data gathering instruments.

3.2.2. Sampling techniques

A multi-stage sampling procedure was followed in this study. As a first step, Legambo district was chosen purposefully from South Wollo Zone due to the existence of research gaps. As part of the second stage, the district kebeles were stratified according to agro-ecological zones (AEZs) characteristic: Dega (highland) and Woyina Dega (midland), and then two kebeles were randomly chosen from each AEZs (Table 3.1). In the third stage, the sample HHs from each Kebeles were selected by a simple random sampling technique. These techniques were created for all members to have an equal chance of selection, and random selection attempts ensured the sample was representative of the whole population.

3.2.3. Sample size determination

Scientific research requires the determination of a sample size. There are various approaches to determining the sample size of the population for a HHs survey. Consequently, sample size (n) for this study was determined using Yamane (1967). Thus, out of the total HHs in the sampling kebeles, 361 HHs were randomly selected from both mid and highland agro-ecologies. The number of sample HHs was determined using the following formula, which was developed by Yamane (1967).

$$\mathbf{n} = \frac{\mathbf{Z}}{\mathbf{1+Z(e)^2}} \text{,,,} \mathbf{(1)}$$

Where n is the sample size, Z is the population size (total HHs in sampled kebeles) and e is level of precision (5%). The respective numbers of HHs were also be allocated for each sampled kebele based (Table 3.1). The following proportional allocation formula from Kothari (2004) was applied to determine the sample size at the Kebele level.

$$\mathbf{n} = \frac{\mathbf{Zi*j}}{\mathbf{Z}} \text{,,} \mathbf{(2)}$$

Where: n is the Kebele level sample size, Zi represents the total number of HHs in each sampled kebele, j represents the overall sample size of the study based on the previously mentioned formula (Eq. 1), and Z represents the total population size of the selected kebele.

Table 3.1: Total HHs in each kebeles and respective numbers of sample HHs

№	Sample kebeles	AEZs	Number of HHs	Sample HHs	Proportion in percent
1	Yilada	Midland	1031	100	27.7
2	Wede Hamusye	Midland	919	89	24.6
3	Gole	Highland	676	66	18.3
4	Kindo	Highland	1098	106	29.4
	Total		3724	361	100

3.3. Data Types and Sources

To draw out the necessary information for the given research, it has been decided on the types of data that need to be collected and the source from which the data are to be gathered. The primary

data were collected from the sampled HHs on 12 important explanatory variables that were selected to influence the adoption of AFPs, farmers' perceptions of the benefits of adopting AFPs, and farmers' practices of AFPs. In accordance with earlier research, the following independent variables were employed in this analysis: age, gender, education, size of HH, participation in social networks, employment outside the farm, land size, economic status, livestock ownership, and contact with extension agents, and conflict over land with nearby landowners (Table 3.2).

3.4. Methods of Data Collection

The study mainly utilized primary data that were collected from scientifically selected sample households, FGD and KII in the study area. The study utilized a structured interview schedule method to collect a quantitative data. On the other hand, the qualitative data were collected from KII and FGD using a semi-structured interview (checklists). The five key informants in the study site were conducted with the assistance of developmental agents to gather general information about the criteria for assessing farmers' economic status. Someone who has lived there continuously for a long time and is knowledgeable about the village HHs and the study area was considered a KI for this particular study. Therefore, HHs economic status was determined by the amount of commercial crops produced and the size of the land following Ibrahim *et al*. (2022). In addition, other primary data was collected through focus group discussions. Four focus group discussions (FGD) were held (one FGD in each kebele) and the number of focus group participants in one group ranges from 8-12 members. The participants in FGD include men and women farmers of various age levels.It was organized to obtain detailed information on farmers' adoption of AFPs.

A five-point Likert scale was incorporated into the survey questionnaire in order to gather data on the perceptions of smallholder farmers regarding the benefits of the adoption of AFPs. According to Nemoto and Beglar (2014), the Likert scale allows responses to be graded on a range of 1–5, 1–7, or 1–10, which enables the creation of a set of prospective measures. Numerous studies (e.g., Kareem *et al*., 2017; Solomon, 2019; Dewi et al., 2021; Tega and Bojago, 2023) have demonstrated the validity and reliability of the five-point Likert scale. Therefore, using a Likert-type five-point continuum scale (1 = strongly disagree (SA), 2 =

disagree (DA), 3 = neutral (N), 4 = agree (AG), and 5 = strongly agree (SA), respondents were asked to indicate the degree to which they agreed with each indicator.

Furthermore, field observations through transect walk in each kebele were conducted to identify the AFPs in the study area. In order to guarantee the accuracy of the information gathered, field observations were conducted beginning with the problem identification phase and continued throughout the entire data collection process. The objective was to comprehend land uses, topography, forest resources, current AFPs, farming practices, and sources of livelihood.

3.4. Methods of Data Analysis

This study used a combination of data analysis methods for quantitative and qualitative data. The quantitative data was coded and entered into the SPSS tool version 26. Data collected from key informant and focus group discussions were narrated qualitatively. The values of the variables were calculated and displayed as tables using descriptive statistics (the standard deviation, mean, frequency, and percentage). Cross-tabulation was also computed independently for each independent variable and dependent (adopters and non-adopters) to compare the impact of the explanatory variables on adoption. A weighted mean was determined for each perception indicator as follows in order to analyze the data gathered using a Likert scale to evaluate smallholder farmers' perceptions of the advantages of adopting AFPs:

$$\mathrm{WM} = \frac{[(\mathbf{fSA}*\mathbf{5})+(\mathbf{fAG}*\mathbf{4})+(\mathbf{fN}*\mathbf{3})+(\mathbf{fDA}*\mathbf{2})+(\mathbf{fSD}*\mathbf{1})]}{\mathbf{n}} \quad \textbf{(3)}$$

Where: weights of 5, 4, 3, 2, and 1 are assigned to perceptions of SA, A, N, DA, and SD, respectively; WM stands for weighted mean; f for frequency; and n for total sample size. Following that, the means for each indicator were categorized as follows: 1-1.49 strongly disagree (SD), 1.50–2.49 = disagree (DA), 2.50–3.49 = neutral (N), 3.50–4.49 = agree (AG), and 4.50–5.00 = strongly agree (SA) following Begum *et al*. (2020) and Tega and Bojago (2023). In the results and discussion section, the responses from the development agents, key informants, and focus group participants were qualitatively described and briefly presented.

A binary logistic regression model (at $p < 0.05$) with categorical explanatory variables was used to analyze the determinant factors that affect the adoption of AFPs. Since the binary logistic regression model closely approximates the cumulative normal distribution, it was chosen for this

study. From a mathematical perspective, it is simply straightforward and lends itself to a meaningful interpretation. According to Hailemariam *et al*. (2012), many farmers may also adopt multiple technologies at the same time because they complement one another and share constraints. As such, it is critical to consider the adoption of land management practices as simultaneous multiple-choice decisions (Tafere and Nigussie, 2018). Thus, the general binary logistic regression model that was employed to determine AFP adoption is displayed in Eq. 4. Therefore, in order to address the study's identified problem, a number of explanatory variables related to individuals, HHs, and socio-economic status have been chosen from the literature (Table 1). An adopter or nonadopter is a categorical dichotomy, which is the dependent variable of this study. For nonadopters, the dependent variable was recorded as "0," and for adopters, it was recorded as "1.".

$$\ln\left(\frac{Z}{1-Z}\right) = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots + \beta nX \quad \textbf{(4)}$$

Where: P = the probability of adopting AFPs, β0 = intercept, which is the estimation of the probability of adopting AFPs when X = 0, β1 to βn = coefficients of the independent variables representing the impact of these variables on the likelihood of adoption of agroforestry, and X1-Xn are hypothesized explanatory variables.

Table 3.2: An overview of relevant literature, hypotheses, and expected relationships between the adoption of AFPs and independent variables.

Variables & Symbol	Hypothesis	Expected Outcome	References
Age (X1)	Adopters who are older have more rights and resources, making them more likely to adopt agroforestry technologies. A young farmer, however, may find agroforestry's benefits and market response too slow. Therefore, older farmers are more likely to adopt.	Positive	(Abiyu *et al*., 2016; Gebru *et al*., 2019; Ibrahim *et al*., 2022; Tega and Bojago, 2023)
Gender (X2)	There are more women than men in the district of Legambo, and most decisions are made by the head of the family, who is generally a woman. Female-led family units face labor and time restrictions. Subsequently, gender (female) is expected to be negatively associated with the adoption of agroforestry.	Negative	(Abiyu *et al*., 2016; Sanou *et al*., 2019; Melaku and Asfaw, 2020; Syano *et al*., 2022)
Level of education (X3)	By reading and writing, a farmer is able to obtain and use information, thus finding solutions. Thus, agroforestry adoption is expected to be positively affected.	Positive	(Kassie, 2016; Ibrahim *et al*., 2022; Tega and Bojago, 2023)
HH size (X4)	The adoption of agroforestry may be positively	Positive	(Syano *et al*., 2022;

	affected by a larger HHs size, with more members, and a better division of labor as well as better time management.		Ibrahim *et al*., 2022; Tega and Bojago, 2023)
Membership in social networks (X5)	Farmers in rural regions are supported by social networks and organizations, such as financial loans, training, information exchange, and sharing of resources. Therefore, being a member of a social network is expected to positively impact the adoption of agroforestry.	Positive	(Cadger *et al*., 2016; Abera and Mehari, 2019; Ibrahim *et al*., 2022; Tega and Bojago, 2023)
Off-farm Employment (X6)	In general, off-farm employment indicates a diversified income and a decrease in farm labour. Off-farm employment is expected to negatively affect agroforestry adoption due to its labor and resource intensive requirements.	Negative	(Ibrahim *et al*., 2022; Tega and Bojago, 2023)
Land size (X7)	In some cases, an agroforestry system may not be economically feasible or otherwise feasible if the farm size is below a certain threshold. Agroforestry and integrated farming may not be possible on very small plots, for instance. The adoption of agroforestry is therefore expected to be positively associated.	Positive	(Amare et al., 2018; Melaku and Asfaw, 2020; Ibrahim *et al*., 2022; Tega and Bojago, 2023)
Livestock (X8)	Ownership of livestock has a significant impact on the adoption of AFPs. Indicators of HHs wealth and resource availability include the number of cattle. AFPs are more likely to be adopted by wealthy farmers.	Positive	Nigussie *et al*., 2017; Solomon, 2019; Ibrahim *et al*., 2022)
Extension contacts (X9)	The contact between a farmer and extension workers is expected to have a positive relation on adoption of different AFPs.	Positive	(Kaua, 2020; Tega and Bojago, 2023)
Land conflict (X10)	When farmers experience conflicts related to boundaries, it discourages farmers from taking action like adopting agroforestry. Therefore, a negative association between land conflict and adoption of agroforestry is expected.	Negative	Abiyu *et al*., 2016; Owombo *et al*., 2018; Ibrahim *et al*., 2022)
Economic status (X11)	Agroforestry requires a lot of inputs and resources at first, and its benefits take some time to become apparent; therefore, farmers with relatively high incomes may be more likely to adopt agroforestry due to better access to money, time and labor.	Positive	(Kinyili, 2020; Melaku and Asfaw, 2020; Ibrahim *et al*., 2022)

CHAPTER 4: RESULTS AND DISCUSSION

This chapter presents and analyzes the data that was gathered in order to address the fundamental research questions and accomplish the objectives. As mentioned in Chapter 1, the main objective of this study is to assess the factors that influence the adoption of AFPs and the farmers' perceptions of the advantages and types of AFPs used by smallholder farmers in the Legambo district of the South Wollo Zone. In this chapter, the collected data from the selected kebeles is summarized and analyzed in order to realize the ultimate objective of the study. This chapter first presents an analysis of the respondent's demographic, social, and economic characteristics. To ascertain the relationship between the dependent and independent variables, a binary logistic regression analysis is then presented. Key findings from each objective were discussed in the context of the body of existing literature.

4.1. Socio-economic Characteristics and Influences on Adoption of AFPs

An overview of the general demographic and socio-economic characteristics of respondents and their influence on the adoption of AFPs is presented in Tables 4.3. The results show that the only socio-economic characteristics of the respondents that have an insignificant effect on the adoption of AFPs are conflict with neighbor landowners (P ≤0.053) and economic status (P≤0.208). The availability of local less expensive seeds or seedlings for planting on their land could be one reason why adopters' economic has not been found to have an insignificant impact on the adoption of AFPS. Four age groups were identified from the respondent farmers: under 30 years old (8.5%), 35–45 years old (49.5%), 46–64 years old (37%), and 65 years and above (5%). Table 4.3 shows that the farmers who adopted AFPs are mostly in the 35–45 and 46–64 age groups. The age of farmers appears to have a significant (P≤0.000) impact on the adoption of AFPs.

The young (below 30 years) farmers were less interested in adopting AFPs (1%) compared to the farmers under the age category of 30–45 (36.5%). The possible reason for this could be that since the adoption of AFPs takes a longer time, younger might have acquired a shorter and less experience of AFPs than elders. Young people's ease of migration to surrounding towns in searching for employment opportunities could be another factor. On the other hand, elderly individuals are more likely to live year-round in their rural residential areas. (Tafere and

Nigussie, 2018). Of the total HH respondents, approximately 35% are female, and of those, only 17.5% have adopted AFPs. Additionally, there is evidence that AFP adoption has been significantly ($P \leq 0.000$) impacted by gender. The percentage of male farmers adopting AFPs is 46.8%, higher than that of female farmers (17.7%). According to Table 4.3, there are five categories for farmer education levels: no education (54%), 1-4 school (17%), 5-8 school (21.26%), 9-12 school (7%), and certificate/diploma (1.5%). Compared to farmers who attended education under the category of 9-12, 16% and 19.6% of respondents who attended formal education under the categories of 1-4 and 5-8, respectively, have a high adoption rate of AFPs (Table 4.3). It seems that adopting AFPs has become less acceptable as a result of increasing education level. The reason for this could be that young adults with higher levels of education relocate more easily to adjacent urban areas in search of employment, primarily because they anticipate a better and more modern lifestyle in towns.

In terms of HHs size, the majority of the adopters of agroforestry had a HHs size ranging between 4-6 family members, which was higher than that of the non-adopters. The study area's rate of AFP adoption was found to be positively and significantly ($P \leq 0.000$) impacted by the size of the HH. This is a result of the need for more forest products as a result of growing families, who require more for construction, fencing, and wood/charcoal for both commercial and domestic use. The majority of respondents in the study area (64.5%) who adopted AFPs had farmland, and 38% received their land as a gift from family members. As a result of these two factors (ownership of farmland and the source of that land), AFPS adoption is significantly ($P \leq 0.000$) affected. The survey of this study classified the land holding size (Table 4.3) of the farmer into four categories: 0.125–0.5 ha, 0.51–0.75 ha, 0.76–1 ha, and over 1 ha. A majority of respondents (23.8%) who did not adopt AFPs have land sizes ranging from 0.125 to 0.5 ha, which has also significantly ($P \leq 0.000$) influenced the adoption of AFPs.

Additionally, the respondents' economic status was categorized and proportionately rich (6%), medium (59.5%), and poor (38%), with the majority of AFP adopters (36.5%) falling into the medium economic status category. Since most respondents (85.5%) engaged in only agricultural activities, 82.5 owned livestock which positively and significantly ($P \leq 0.000$) influenced the adoption of AFPs. Similarly, 63.5% and 60.5% of respondents adopted AFPs indicated they were

members of organizations or committees and had contacts with extension workers, respectively, showing that these two variables significantly (P ≤0.000) influenced adoption (Table 4.3).

Table 4.1: Demographic and socio-economic characteristics of respondents and their influence on adoption of AFPs

Variables	Categories	Adoption of farmers		Total (%)	Chi-square	DF	P-value
		Non-adopters	Adopters				
		Count (%)					
Age	Below 30	27 (7.5)	3 (0.8)	30 (8.31)	45.40	3	0.000
	30–45	47 (13)	131 (36.3)	178 (49.3)			
	46–64	47 (13)	87 (24.1)	134 (37.12)			
	65 and above	3 (0.9)	16 (4.36)	19 (5.26)			
Gender	Male	66 (18.3)	169 (46.8)	235 (65.1)	15.99	1	0.000
	Female	62 (17.2)	64 (17.7)	126 (34.9)			
Education level	No education	94 (26)	101 (27.97)	195 (54)	110.34	4	0.000
	1-4 school	1 (0.55)	58 (16)	59 (16.34)			
	5-8 school	6 (1.66)	71 (19.6)	77 (21.33)			
	9-12 school	24 (6.64)	1 (0.27)	25 (6.93)			
	Certificate/diploma	3 (0.83)	2 (0.55)	5 (1.39)			
HH size	1-3	10 (2.8)	13 (3.6)	23 (6.37)	33.08	3	0.000
	4-6	85 (23.5)	199 (55.1)	284 (78.67)			
	7–9	8 (2.2)	28 (7.8)	36 (9.97)			
	Above 9	5 (1.4)	13 (3.6)	18 (4.99)			
Farm land	Yes	104 (28.8)	232 (64.3)	336 (93.07)	43.02	1	0.000
	No	24 (6.6)	1 (0.3)	25 (7.55)			
Source of land	Lease	27 (7.96)	16 (4.72)	43 (12.68)	28.90	2	0.000
	Freehold	19 (5.60)	88 (25.96)	107 (31.56)			
	Given by family	61 (18)	128(37.76)	189 (55.75)			
Land size	0.125–0.5 ha.	78 (23.21)	102(30.36)	180 (53.57)	30.4	3	0.000
	0. 51–0.75 ha.	24 (7.14)	102(30.36)	126 (37.50)			
	0.76–1 ha.	1 (0.3)	21 (6.25)	22 (6.55)			
	Over 1 ha.	1 (0.3)	7 (2.08)	8 (2.38)			
Economic status	Poor	77 (21.33)	128(35.46)	205 (56.8)	3.14	2	0.208
	Medium	39 (10.8)	87 (24.1)	126 (34.9)			
	Rich	13 (3.6)	17 (4.7)	30 (8.3)			
Off-farm employment	Yes	33 (9.1)	20 (5.5)	53 (14.68)	19.51	1	0.000
	No	95 (26.3)	213 (59)	308 (85.32)			
Livestock ownership	Yes	92 (25.5)	205 (56.8)	297 (82.27)	14.70	1	0.000
	No	44 (12.2)	20 (5.54)	64 (17.73)			
Extension contacts	Yes	94 (26)	219 (60.7)	313 (86.7)	30.27	1	0.000
	No	34 (9.4)	14 (3.9)	48 (13.30)			
Members to organizations	Yes	108 (29.9)	229 (63.4)	337 (93.35)	25.75	1	0.000
	No	20 (5.5)	4 (1.1)	24 (6.65)			
Conflict with neighbor land holder	Yes	3 (0.9)	23 (6.85)	26 (7.74)	3.732	1	0.053
	No	101 (30)	209 (62.2)	310 (92.26)			

4.2. Farmer's Perception on the Benefits of Adopting AFPs

A number of statements about the advantages of adopting AFPs were given to the respondent farmers, who were asked to rank them from strongly disagreeing to strongly agreeing. Table 4.6 presents the findings from the analysis of this objective. As can be seen from the table, most respondents agreed with the set of adopting AFPs benefit statements, with a small minority strongly agreeing and disagreeing. For example, the statement "Adoption of AFPs conserves soil and water" received a total mean score of 3.85, indicating strong agreement (5.3%), agreement (83.9%), and disagreement (9.1%) among the sample of respondents. Additionally, AFPs enhance soil nutrients and boost farm income; 79.2 and 76.7% of respondents agreed with these statements, respectively, and the total mean fell between 3.50 and 4.49, suggesting that a significant portion of respondents agreed with the statement (Tega and Bojago, 2023). Perceptions from farmers who are FGD members and KI corroborate this result. They claim that planting a variety of leguminous trees in the farm field improves yields by decreasing soil erosion and increasing soil fertility, which is also consistent with Kassie's (2016) findings. These results are also in line with those of (Kiyani et al., 2017; Jahan et al., 2022; Tega and Bojago, 2023), who found that, in comparison to no AFPs, AFPs help conserve soil and water, improve soil nutrients, and increase the income of agroforestry adopters.

Conversely, some farmer respondents indicated that they were unsure or did not believe that implementing AFPs was necessary to achieve the set of AFP benefit statements, thus they answered in the neutral category of the statements that were provided. The respondents' perceived percentage of disagrees with each of the benefits of AFPs ranged from 9 to 27%. Only 9% of sample respondents disagreed with the benefit statement, which stated that using AFPs would conserve soil and water. These findings indicated how crucial it was for farmers to contact extension workers, as this contact significantly ($p \leq 0.018$) influenced how farmers perceived the contribution of AFPs to soil and water conservation (Table 4.6). On the other hand, the largest percentage of farmers' perceptions that fell under the disagree category (27%) supported the idea that adopting AFPs would not benefit them by reducing the risk of complete crop failure. According to key informants, there are plausible reasons for these conclusions: farmers believed that since the canopy of trees covered a large portion of the farm field, crop yields were lower because light could not enter; this caused crop failure rather than reducing it. This suggested that

the respondents did not know enough about the different agroforestry management practices. The rationale for this result was consistent with that of Tega and Bojago (2023), who discovered that farmers in their study area were less aware of the advantages of AFPs in terms of lowering the risk of total crop failure due to the shade effect of AFPs that was already existed.

The respondents' mean perceptions were likewise generally positive and above average for each statement of benefits of adopting AFPs, as indicated by the mean (3.43–3.85) and overall average scores (3.65) (Table 4.6). This suggests that farmers had a positive perception of the advantages of adopting AFPs. In spite of this, some farmers who were aware of the benefits of AFPs did not adopt them. It was socio-economic factors, rather than awareness, that influenced adoption of AFPs, as indicated in section 4.2. Similar to this result, Agidie et al. (2013) showed that bio-physical and socio-economic factors affect adoption of AFPs, rather than awareness and perception. On the other hand, farmers' perceptions of the statements regarding the benefits of adopting agroforestry, namely that AFPs can lower the risk of total crop failure, were on average 3.43. The implication here is that the farmers were not entirely convinced of AFPs' ability to lower the likelihood of total agricultural failure.

Table 4.2: Perception of the respondent on the benefits of adopting AFPs.

Statements	Respondents' response						
	SA (5)	AG (4)	N (3)	DA (2)	SDA (1)	Mean	SDE
	Count (%)						
Adoption of AFPs conserves soil and water	19 (5.3)	303 (83.9)	6 (1.7)	33 (9.1)	0 (0)	3.85	0.644
Adoption of AFPs improves soil nutrients	0 (0)	286 (79.2)	22 (6.1)	53 (14.7)	0 (0)	3.65	0.724
Adoption of AFPs increases farm income	0 (0)	277 (76.7)	17 (4.7)	67 (18.6)	0 (0)	3.58	0.785
AFPs can improves soil cover	0 (0)	276 (76.5)	26 (7.2)	59 (16.3)	0 (0)	3.60	0.754
Adoption of AFPs improves micro-climate	0 (0)	275 (76.2)	6 (1.7)	80 (22.2)	0 (0)	3.54	0.833
Adoption of AFPs improves crop production	17 (4.7)	280 (77.5)	21 (5.8)	45 (12.5)	0 (0)	3.75	0.747
AFP reduces fuel wood gathering time	11 (3)	271 (75.1)	24 (6.6)	55 (15.2)	0 (0)	3.66	0.769
AFPs practices have an economic advantage	15 (4.1)	261 (72.2)	40 (11)	45 (12.5)	0 (0)	3.81	0.718
AFPs reduced risk of complete crop failure	10 (2.8)	234 (64.8)	20 (5.5)	97 (26.9)	0 (0)	3.43	0.917
Average						3.65	

The advantages of AFPs as perceived by HH respondents were also examined using cross-tabulation and percentage analysis concerning various explanatory variables (Table 4.7). The findings showed that age, education level, land ownership, and extension contacts were

independent variables that had a significant impact on HHs' perceptions of the advantages of adopting AFPs. The age of respondents had a significant (p≤ 0.000) impact on the respondents' perceptions of the benefits of adopting AFPs, with increasing age being associated with increased perceptions. The outcome could be explained by the fact that elderly people may have a more positive perception of the practices' because they have had longer experiences with adopting AFPs (Tafere and Nigussie, 2018). Furthermore, in comparison to those who did not attend formal education, the respondents perceived the adoption of AFPs positively in light of their education, which had a significant influence (p ≤ 0.000). While the respondent's perception was positively impacted by education, the adoption of AFPs appears to have been negatively impacted by education level for the reasons covered in section 4.2. Ownership of farmland has also had a significant (p ≤0.018) impact on respondents' perceptions. With only 10% of HH respondents disagreeing, the majority of respondents (70.4) acknowledged and agreed with the benefits of adopting AFPs.

Furthermore, the contacts HH respondents had with extension workers had a significant (p ≤ 0.018) impact on farmers' perceptions (71.5%) regarding the benefits of adopting AFPs. This might be because farmers have better access to information and technologies when they interact with extension agents. Farmers who interact with extension agents may be better equipped to adopt AFPs and have positive perceptions because agroforestry is a more knowledge-based practice (Nkamleu and Manyong, 2005). Several factors, including gender, land size, off-farm employment, ownership of livestock, and organization membership, were found to have, although not significant, impact on respondents' perceptions in the study area. Interestingly, being an adopter or non-adopter of AFPs did not seem to have any significant impact on the respondent's perception. On the other hand, farmers who had a positive attitude towards the roles of AFPs were more likely to adopt them. This finding is consistent with other studies that have shown a positive association between HH perceptions of the value of adopting AFPs and their adoption, such as those by Irshad et al. (2011) and Ibrahim et al. (2022). The cross-tabulation result (Table 4.7) generally showed that the selected socio-economic factors had both significant and non-significant influences on the dependent variable, which were farmers’ perceptions of the benefits of adopting AFPs.

Table 4.3: Influences of selected variables on respondents' perceptions of adopting AFPs

Variables	Categories	Perception of farmers					Chi-square	P-value
		SA	AG	N	DA	SDA		
		Count (%)						
Age	Below 30	1 (0.3)	20 (5.5)	0 (0)	9 (2.5)	0 (0)	30.75	0.000a
	30–45	0 (0)	143 (39.6)	27 (7.5)	8 (2.2)	0 (0)		
	46–64	0 (0)	109 (30.2)	20 (5.5)	5 (1.4)	0 (0)		
	65 and above	0 (0)	15 (4.2)	1 (0.3)	3 (0.83)	0 (0)		
Gender	Male	1 (0.3)	175 (48.5)	33 (9.1)	26 (7.20)	0 (0)	2.798	0.424
	Female	0 (0)	103 (28.5)	13 (3.6)	10 (2.77)	0 (0)		
Education level	No education	0 (0)	134 (37.1)	28 (7.8)	33 (9.14)	0 (0)	55.104	0.000a
	1-4 school	0 (0)	56 (15.5)	1 (0.3)	2 (0.55)	0 (0)		
	5-8 school	0 (0)	59 (13.3)	17 (4.7)	1 (0.3)	0 (0)		
	9-12 school	1 (0.3)	24 (6.6)	0 (0)	0 (0)	0 (0)		
	Certificate/diploma	0 (0)	5 (1.4)	0 (0)	0 (0)	0 (0)		
Farm land	Yes	0 (0)	254 (70.4)	46 (12.7)	36 (9.97)	0 (0)	20.8	0.000a
	No	1 (0.3)	24 (6.6)	0 (0)	0 (0)	0 (0)		
Land size	0.125–0.5 ha.	0 (0)	137 (38)	29 (8)	14 (3.88)	0 (0)	6.327	0.388
	0. 51–0.75 ha.	0 (0)	98 (27.1)	13 (3.6)	15 (4.16)	0 (0)		
	0.76–1 ha.	1 (0.3)	16 (4.4)	3 (0.8)	2 (0.55)	0 (0)		
	Over 1 ha.	1 (0.3)	4 (1.1)	1 (0.3)	2 (0.55)	0 (0)		
Off-farm employment	Yes	1 (0.3)	42 (11.6)	4 (1.1)	6 (1.66)	0 (0)	7.281	0.063
	No	0 (0)	236 (65.4)	42 (11.6)	30 (8.31)	0 (0)		
Livestock ownership	Yes	0 (0)	226 (62.6)	41 (11.4)	30 (8.31)	0 (0)	6.334	0.096
	No	1 (0.3)	52 (14.4)	5 (1.4)	6 (1.66)	0 (0)		
Extension contacts	Yes	0 (0)	258 (71.5)	44 (12.2)	11 (3)	0 (0)	10.01	0.018a
	No	1 (0.3)	30 (8.3)	2 (0.6)	15 (4.15)	0 (0)		
Members to organization	Yes	1 (0.3)	256 (70.9)	46 (12.7)	34 (9.42)	0 (0)	4.134	0.064
	No	0 (0)	22 (6.1)	0 (0)	2 (0.6)	0 (0)		
Adoption	Adopter	1 (0.3)	182 (50.4)	17 (4.7)	14 (3.88)	0 (0)	2.155	0.541
	Non-adopter	0 (0.3)	96 (26.6)	29 (8)	22 (6.09)	0 (0)		

Statistically significant (P = ≤0.05) influence on the adoption of AFPs is indicated by letter a.

4.3. Determinant Factors for the Adoption of AFPs

Binary linear regression analysis showed that small-holder farmers' adoption of AFPs in Legambo district was significantly ($p \leq 0.05$) influenced by age, gender, education level, land size and livestock ownership (Table 4.4). Adoption of AFPs, however, was positively correlated with gender ($P \leq 0.000$) and livestock ownership ($P \leq 0.000$). The odds ratio showed that the rate at which male HHs who adopted AFPs was four times higher than that of females. This suggested that male respondents were more likely to adopt AFPs. A similar finding has been reported by Tafere and Nigussie (2018) in south Wollo Zone, Desse Zuria and Kallu districts, who found that HHs with male heads are more likely to adopt AFPs. Ibrahim et al. (2022) also found that male HHs which adopted AFPs were one times more likely to adopt AFPs compared to female-headed HHs in Jama district, Northeastern Ethiopia, but the positive influence of

gender was insignificant. Additionally, the findings align with research from sources other than Ethiopia and those reported by Syano et al. (2022) in their investigation of the variables influencing the adoption of AFPs in Kenya. This suggested that male respondents were more likely to adopt AFPs. The reason for this could be that men have traditionally held positions of power and control over resources that are useful for the HH, such as land. In addition, women in Sub-Saharan Africa face more obstacles than men in securing the labor required for land preparation and other agricultural tasks (Moraine et al., 2014). Therefore, even if female farmers were willing to adopt AFPs, the increased labor requirements would likely discourage them because AFPs are complex and labor-intensive compared to other agricultural technologies.

The adoption of AFPs by farmers was also found to be positively and significantly (P ≤ 0.000) correlated with livestock ownership. The odds ratio showed that respondents who owned livestock adopted AFPs at a rate that was more than 1.58 times higher than that of respondents who did not. Likewise, adopting AFPs was more prevalent among farmers with larger livestock's, supporting the findings of Ibrahim et al. (2022). This may be because the farmer owes livestock, which forces them to look for additional sources of feed for their animals and encourages them to adopt AFPs. Furthermore, although the relationship was not statistically significant, the adoption of AFPs is positively correlated with farmers' farmland ownership (ß ≤ 3.98), economic status (ß ≤0.684), contact with extension agents (ß ≤ 0.12), and membership in organizations (ß ≤ 1.11). The findings of this study are similar to those of Tafere and Nigussie (2018) as well as Ibrahim et al. (2022). It was found that farmland ownership, economic status, contact with extension agents, and organizational membership were positively correlated with adoption of AFPs.

Table 4.4: Binary logistic regression showing the influence of demographic and socio- economic factors on adoption of AFPs.

Variable	Categories	B	S.E.	Wald	df	Sig.	Exp (B)
Age	Below 30	-5.88	2.861	4.225	1	0.04a	0.003
	30–45	-0.446	1.863	0.057	1	0.811	0.640
	46–64	-0.312	2.034	0.024	1	0.878	0.732
	65 and above (Ref.)						
Gender	Male	1.41	0.314	20.295	1	0.000a	4.110
	Female (Ref.)						
Education level	No education	0.477	0.924	0.267	1	0.605	1.612
	1-4 school	4.466	1.360	10.777	1	0.001a	87.000

	5-8 school	2.876	1.007	8.159	1	0.004a	17.750
	9-12 school	-2.77	1.369	4.100	1	0.043a	0.062
	Certificate/diploma (Ref.)						
HH size	1-3	-1.399	1.043	1.800	1	0.180	0.247
	4-6	-1.139	0.882	1.670	1	0.196	0.320
	7–9	-0.580	1.197	0.234	1	0.628	0.560
	Above 9 (Ref.)						
Farm land	Yes	3.980	1.027	15.009	1	0.002	53.538
	No (Ref.)						
Source of land	Lease	-1.967	0.591	11.070	1	0.001	0.140
	Freehold	0.743	0.428	3.011	1	0.083	2.102
	Given by family (Ref.)						
Total land size	0.125–0.5 ha.	-3.19	1.371	5.419	1	0.020a	0.041
	0. 51–0.75 ha.	0.112	1.354	0.007	1	0.934	1.118
	0.76–1 ha.	1.166	1.967	0.351	1	0.553	3.208
	Over 1 ha. (Ref.)						
Economic status	Poor	0.684	1.118	0.374	1	0.541	1.982
	Medium	0.084	1.112	0.006	1	0.939	1.088
	Rich (Ref.)						
Off-farm employment	Yes	-0.445	2.076	0.046	1	0.830	0.641
	No (Ref.)						
Livestock ownership	Yes	1.58	1.867	0.098	1	0.000a	4.558
	No (Ref.)						
Contact with extensions	Yes	0.120	0.798	0.022	1	0.881	1.127
	No (Ref.)						
Membership to organizations	Yes	1.110	1.153	0.927	1	0.336	3.036
	No (Ref.)						
Conflict with neighbor land holder	Yes	-0.72	1.056	22.545	1	0.754	5.55
	No (Ref.)						
Constant		-.831	2.057	0.163	1	0.686	0.436

Statistically significant (P = ≤0.05) influence on the adoption of AFPs is indicated by letter a.

Conversely, the results of the binary logistic regression model indicated that the independent variables of age, education level, and land size had a statistically significant negative impact on the dependent variable, which is the adoption or non-adoption of AFPs (Table 4.4). Reducing the age of the HH head resulted in a significant (P ≤0.04) decrease in AFP adoption. When the age of the head of the HH was compared between under and over 30, the adoption rate of AFPs was approximately six times lower in the former group. Therefore, AFPs are more likely to be implemented on farms by older HHs than by younger ones. This result is consistent with those by Gebreegziabher et al. (2010), Abiyu et al., (2016), Hagos (2016), Syano et al. (2022), and Ibrahim et al. (2022) who found that the adoption of agricultural technology is negatively impacted by lower age of farmers. A plausible explanation for this outcome could be that older people have a longer and more thorough experience with AFPs than younger people, as certain AFPs require a longer time to be adopted. Research conducted in the Gobu Seyo District of East

Wollega by Waktola and Fekadu (2021) has also demonstrated a positive correlation between the adoption of coffee shade agroforestry technologies and the number of years of agricultural experience.

The adoption of AFPs by HHs was found to be negatively and significantly ($P \leq 0.043$) influenced by the farmers' educational level. It is generally accepted that farmers will be better able to understand and implement AFPs if they have more educational attainment. This research, however, showed that the adoption of AFPs contradicted this general assertion. The findings showed that HH heads who are more educated adopt AFPs at a rate that is around three times lower than that of those who are less educated or uneducated. Similar results show that education has no effect on the adoption of AFPs, as reported by Jara-Rojas et al. (2020). However, our result is in contrast to the findings of a study conducted by Syano et al. (2022), which evaluated the factors influencing the adoption of AFPs in the drylands of Eastern Kenya and discovered a positive correlation between education level and adoption AFPs. Additionally, the results contradict other research reports (eg., Gebreegziabher et al., 2010; Abiyu et al., 2016; Hagos, 2016; Kassie, 2016; Tafere and Nigussie, 2018; Ibrahim et al., 2022;), which examined the positive effect of the HH head's education level on the adoption of AFPs. The low adoption of AFPs among the educated might be due to informal and formal employment and businesses that provide quick money (Gbetibouo, 2009). Moreover, livestock and AFPs are not always the focus of the knowledge acquired in formal education (Jera and Ajayi, 2008).

Adoption of AFPs in the study area was also found to be negatively and significantly ($P \leq 0.02$) influenced by the total land size of the HH (Table 3.4). The adoption rate of the practice is approximately three times lower among landholders with comparatively smaller land areas (0.125–0.5 ha) compared to those with larger land areas. This is because, aside from home gardens, AFPs need a lot of land, so farmers with smaller holdings are less likely to adopt the other practices (Tafere and Nigussie, 2018). A small-scale landholder's agricultural land is vital to their survival and provides essential sustenance to their HHs. The farmers are fearful that they will lose a lot of land if AFPs are adopted on their farmland. Comparatively, larger-scale landowners are more likely to plant trees on their land. There was a higher adoption rate of AFPs among farmers with larger landholdings in this study. This is in line with the results of Syano et al. (2022), who found that landowners with larger holdings have higher planting motivation than

those with smaller holdings. The findings also align with those of Ibrahim Ibrahim et al. (2022), who demonstrated that small-scale farmers in northeastern Ethiopia were negatively impacted by land size when adopting AFPs. Therefore, it is imperative to assist farmers in planning how to incorporate AFPs on land that they believe to be small in comparison to their other uses. The land holdings of the farmers must also be taken into account by stakeholders when designing AFPs.

This study also showed that the adoption of AFPs was negatively impacted, although not significantly, by HHs size, source land, off-farm activities, and conflicts with neighbor landholders. Consistent with previous studies (e.g., Tafere and Nigussie, 2018), farmers with small HH sizes, and off-farm activities are less likely to adopt AFPs than farmers with large large HH sizes, and no off-farm activities. It was also noted that during the experts and FGDs, five obstacles to adopting AFP were identified. These obstacles include land size and scarcity, laziness, a shortage of tree seeds or seedlings, the issue of the survival rate of tree seedlings, and overgrazing/deforestation. The participants highlighted that in highland sampled kebeles, seedling survival problems were the most common barrier to adopting AFP. In addition, Ashraf et al. (2015) and Ibrahim et al. (2022) reported that the adoption of AFPs was negatively impacted by land size, scarcity, and low seedling survival rates. These findings are consistent with the findings of the current study. In addition, the findings corroborated Mahmood and Zubair's (2020) result that the two primary obstacles to AFP adoption in Pakistan's Indus River Basin are farmer laziness and deforestation. These obstacles emphasize the necessity for agriculture extension workers to raise awareness of management techniques that increase the survival rate of planted seedlings and to introduce and plant environmentally friendly trees.

4.4. Description of AFPs in the Study Area

In addition to improving agricultural productivity and resilience to climate variability, AFPs can address problems with soil fertility, soil erosion, and produce diversification (Ashango and Mesene, 2019). Nonetheless, the degree to which farmers adopt agroforestry determines the success of AFPs. The most popular AFPs (Figure 4.2) were scattered trees in croplands and woodlots, which were planted by 63.7% and 58.2% of smallholder farmers, respectively (Table 4.5). The benefits of these practices contributed to their adoption. The widespread use of scattered trees in croplands may have resulted from farmers realizing the effects of current soil

erosion and the beneficial role that scattered trees play in reducing erosion and enhancing soil fertility. Additionally, woodlots were utilized as a source of fuel, to generate income from the sale of timber, and as a building material for homes. The low cost of establishment and handling related to coppicing after harvesting is another factor influencing the widespread adoption of woodlots (Iiyama et al., 2017).

Figure 4.3: Different AFPs adopted in the study area.

The third most adopted AFP was scattered trees grown in rangelands (56.8%) established for different purposes, including fuelwood and forage. The fourth most adopted AFP was home garden, which was adopted by 55.7% of respondents (Figure 4.2). The nature of home garden agroforestry, which can be practiced in any homestead, does not require a large amount of land, involves all family members in its management, and is protected from free-grazing may be the reason why 55.7% of respondents adopted the practice. Alley-cropping (13.6%) was less adopted due to the fact that certain plant species, seeds, or plant materials are required for the establishment. They require additional management, especially to prevent cattle from ingesting or trampled plants until they reach their ideal size. This aligns with other studies, like the one carried out by Tafere and Nigussie (2018), who discovered that the lack of robust local legislation to address the problem of free grazing and camel damage to planted seedlings intended for alley cropping.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Even if Legambo district is among the deforested parts of the south wollo zone, adoption of Agroforestry practices still exists under a serious challenge. The study identified why some farmers adopted agroforestry practices and others not. Accordingly, being male headed household, household with large family size and non-educated household, households that had farmland and livestock, household who did not have off farm employment, households who had frequent contact with extension services and membership to organization were providers adopted agroforestry practice in the study area.

The results indicated that the majority of the respondent had perceived the economic advantage, soil protection, fuel wood, and environmental benefits of adopting AFPs. Consequently, over half of the respondents had adopted different agroforestry practices. But not all farmers who had a positive attitude were adopters of agroforestry practice may be due to various socio-economic factors. Farmers perceived that agroforestry conserves soil and water", improves soil nutrients and increases farm income. It was also found in the study that were planted scattered trees in cropland (63.7%), home gardens (58.2%), range lands (56.8%), wood lots (55.7%), and Alley-cropping *(*13.6%) in the study area.

The study concluded that the independent variables of gender(being male) and livestock ownership at ($P \leq 0.000$) were positively correlated with adoption of practices. Conversly, adoption of practices had a statistically significant negative impact with age, education level, and land size. HH size, extension contact, membership to organization were Positive and insignificant correlation with adoption. Economic status, off-farm employment, conflict with neighbor land holder had Negative and insignificant impact.It was observed that five barriers were identified by the experts, KII, and FGDs to hinder the adoption of AFP including land scarcity and size, laziness, insufficient tree seeds or seedlings, the problem of tree seedling survival rate, and overgrazing/deforestation.

5.2. Recommendations

Based on the findings of this study, the following recommendations are given:

- Farmers' perceptions on agroforestry practice had positive contribution on its adoption. So, awareness needs to be created by extension workers for large farmers to bring the positive attitude of farmers towards agroforestry practice. However, there are still farmers who have a positive perception on agroforestry but did not adopt it. Therefore, special attention needs to give to such kind of farmers and detail investigation should be undertaken in order to know their cases of not adopting the agroforestry practice.
- Extension services positively contributing for adoption of agroforestry practice in the study area. Therefore, the quality and extent of the extension service should be more strengthened in order to foster the expansion and adoption of agroforestry practice.
- Female headed households in the study area are not adopting the agroforestry practice. Therefore, the concerned both including the extension agents should give due attention to female headed farmers and work closely to enhance their adoption of agroforestry practice thereby improving their livelihood.
- Further research is needed on establishment and tree management practices of AFPs; identification of AFPs trees compatible with the agroecology of the area and assessment of the types of tree species used in each AFPs and its richness

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APPENDIX

Appendix 1: Research Questionnaires

Self-introduction

Good morning or afternoon. Let me introduce myself to you. I'm Zinet Alye. This research questionnaire is to assist in studying ‘‘**Determinant Factors Influencing the Adoption of Agroforestry Practices by Small-holder Farmers in Legambo District of Northeastern Ethiopia’’**. This research forms part of the requirement for the award of an M.Sc. degree in **Agroforestry**, a program the researcher is currently pursuing at the University of Bahir Dar, Ethiopia. The research findings are solely for academic purposes; respondents are therefore assured of confidentiality regarding any information given in this questionnaire. Your opinion is therefore only required for educational purposes and will be treated confidentially.

Questionnaires prepared for face-to-face interview with sample HHs

Serial number of questionnaires ……..

Part 1: Demographic and socio-economic factors influencing adoption of AFPs

1.1 Gender of HH head/respondent.
(1) Male [ ] (2) Female [ ]

1.2 Age of HH head/respondent.
(1) Below 30 [ ] (3) 46–64 [ ]
(2) 30–45 [ ] (4) 65 and above [ ]

1.3 Education level of the HHs
(1) No education [ ] (4) 9-12 school [ ]
(2) 5-8 school [ ] (5) Certificate/diploma [ ]
(3) 1-4 school [ ]

1.4 HH size.
(1) 1–3 [ ] (3) 7–9 [ ]
(2) 4–6 [ ] (4) Above 9 [ ]

1.5 Do you have a farm land?
(1) Yes [ ] (2) No [ ]

1.6 How did you obtain your farm land?
(1) Lease [ ] (3) Given by family [ ]
(2) Freehold [ ] (4) Others (Specify) [ ]…….

1.7 Total land size available for farming including grazing land (ha)?
(1) 0.125–0.5 ha. [ ] (3) 0.76–1 ha. [ ]
(2) 0. 51–0.75 ha. [ ] (4) Over 1 ha. [ ]

1.8 Did you have contact with any extension agent during the 2015 production year?
(1) Yes [ ] (2) No [ ]
If yes, specify how many times?.....

(1) 1 – 4 times [ ] (3) 9 – 12 times [ ]
(2) 5 – 8 times [ ] (4) >12 times [ ]

1.9 Are you a member of an organizations/committees/and political parties?
(1) Yes [ ] (2) No [ ]
If yes, specify the organizations/committees/and political parties?
[……..……
……
……..……..……]

1.10 Do you engage in other activities apart from farming?
(1) Yes [ ] (2) No [ ]

1.11 Did you face any land conflicts in the last 12 months with your neighbor land holder?
(1) Yes [ ] (2) No [ ]

1.12 Do you own livestock?
(1) Yes [ ] (2) No [ ]

1.13 State your economic status.
(1) Poor [ ] (3) Rich [ ]
(2) Medium [ ]

Part 2: Information on the different types of AFPs

2.1 Do you practice home garden AFPs (trees/shrubs with annual crop and livestock's)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……..……
……
……..……..……]

2.2 Do you have wood lots (plot of trees with no further intercropping conserved for benefits like fuel, fodder, timber etc.)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……..……
……
……..……..……]

2.3 Do you have fodder banks (establishment of forage legumes)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……..……
……
……..……..……]

2.4 Do you have boundary plantation (trees planted in single or multiple lines for boundary?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice
[……..……
……
……..……..……]

2.5 Do you have trees on rangelands (scattered trees grown in range lands)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……...……
……
……..……..……]

2.6 Do you practice alley-cropping AFPs (cultivated crops between row of trees)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……...……
……
……..……..……]

2.7 Do you have scattered trees on cropland (scattered trees grown in crop lands)?
(1) Yes [ ] (2) No [ ]
If yes, please mention your reasons for adopting the practice.
[……...……
……
……..……..……]

Part 3: Perceptions of farmers regarding the adoption of AFPs (please rate 1-5)

№.	Statement	Response				
		Str. agree	Agree	Neutral	Disagree	Str. disagree
3.1	Adoption of AFPs conserves soil and water					
3.2	Adoption of AFPs improves soil nutrients					
3.3	Adoption of AFPs increases farm income					
3.4	AFPs can improves soil cover					
3.5	Adoption of AFPs improves micro-climate					
3.6	Adoption of AFPs improves crop production					
3.7	AFP reduces fuel wood gathering time					
3.8	AFPs practices have an economic advantage					
3.9	AFPs reduced risk of complete crop failure					
3.10	Adoption of AFPs conserves soil and water					

Questionnaires prepared for interview with forest experts and KII

Expert name……Signature……..……Date……
…….. Kebele……..Village…….

1. How do you describe agroecology of your working district?
[……
……...……
……..……
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……]

2. How do you describe AFPs in your working district?

[……
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3. Is there any AFPs practiced in your area?

(1) Yes [ ] (2) No [ ]

If your answer is yes, what are the most AFPs?

[……
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4. If your answer is no, what are the reasons?

[……
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……]

5. How do you describe the motivation and contact of farmers with agricultural and NRM experts for advice?

[……
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6. What is the perception of farmers towards the benefits of AFPs?

[……
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……]

7. What are the local environmental challenges related with adopting AFPs?

[……
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……..]

Questionnaires prepared for FGDs with sample respondents

1. What are the local environmental challenges related with adopting AFPs?
[……
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……]

2. What factors affect smallholder farmers' adoption of AFPs?
[……
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3. What do farmers in your local area think about AFPs and their benefits?
[……
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……]

4. What types of AFPs are used by farmers in your local area?

[……
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……..……
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……]

5. Do you think adoption of AFPs improved your crop production? If the answer is yes how?

[……
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……..……
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……]

6. What are the barriers that hinders the perceptions of farmers towards AFPs?

[……..……
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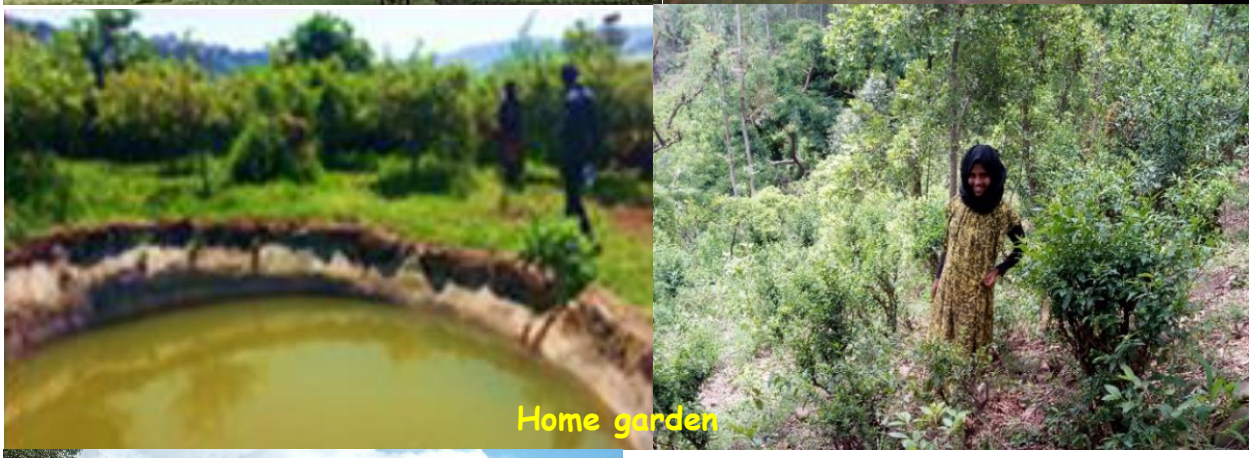
……]

Appendix 2: Lists of stratified kebeles by AEZs in Legambo district

№.	Highland AEZs	Midland AEZs
1	Werento	Gerezewiya
2	Key mebrat	Genetie
3	Feta	Selamber
4	Fesho	Wede-hamusye
5	Buso	Hetetera
6	Yetinora	Yilada
7	Gurach	Kore
8	Dereba	Arigiti
9	Tincha	Sada Korkora
10	Chuluke	
11	Bwabwato	
12	Kindo	
13	Tach Akasta	
14	Tikile	
15	Gol	
16	Mesobit	

Appendix 3: Sample photos taken with respondents during face-to-face interviews and FGDs (source: authors, 2023).


Scattered trees on range land


Home garden


Multi-purpose woodlots

Appendix 4: Typical AFPs observed during field observation in Legambo district. (Source: authors, 2023).

AUTHOR'S BIOGRAPHY

The author was born in 1995 to her father Alyu Hayder and her mother Fatuma Ahmed in a small rural village called Debat (around the town of Mekane Selam), Borena District, South Wollo Zone, Ethiopia. When she reached school age, her father took her to primary school (1-8) at the Soye primary school in the administrative town of Mekane Selam from 2001 to 2009. After completing primary school, she continued her education at the higher secondary school called Walelgn Mekonin secondary and preparatory school (9-12) from 2010 to 2014. Zinet Alye developed a great passion for science when she was in high school. She received her B.Sc. degree in Forestry from Wollo University, College of Agriculture in 2017. After her Bachelor of Science in Forestry, the Ethiopian Ministry of Science and Higher Education (MoSHE) hired her as a Graduate Assistant for the newly opened Department of Forestry at Mekdela Amba University. She worked as a Graduate Assistant for over a year, teaching courses and engaging in scientific issues such as research and community service. She is currently an M.Sc. candidate in Agroforestry in the Graduate Program of the College of Agriculture and Environmental Sciences at Bahir Dar University. Her research interests lie in the areas of mountain forestry, agroforestry, and biodiversity.