Addis Ababa University

School of Graduate Studies

College of Development Studies

The Gum Tree (Eucalyptus) Farming in Ethiopia: Expansion and Implications on Land Use and Livelihoods of Rural Households, Evidence from Gurage Zone.

PhD Dissertation

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Addis Ababa, Ethiopia

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The Gum Tree (Eucalyptus) Farming in Ethiopia: Expansion and Implications on Land Use and Livelihoods of Rural Households, Evidence from Gurage Zone.

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A dissertation submitted to Center for Rural Development, College of Development Studies

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Dissertation Approval
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This is to certify that a thesis prepared by Aklilu Amiga entitled 'The Gum Tree (Eucalyptus) Farming in Ethiopia: Expansion and Implications on Land Use and Livelihoods of Rural Households, Evidence from Gurage Zone', submitted in fulfillments for the requirements for the Degree of Doctor of Philosophy (Rural Development) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

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This dissertation has been submitted for examination with my approval as university supervisor.

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Acronyms and Abbreviations

AASTU	Addis Ababa Science and Technology University
Asl	above sea level
CP	Changed Pixels
CSA	Central Statistics Agency
DAs	Development Agents
ERDAS	Earth Resources Data Analysis System
ETB	Ethiopian Birr
ESSGSI	Ethiopian Space Science & Geospatial Institute
FANTA	Food and Nutrition Technical Assistance Project Academy for Educational Development
FAO	Food and Agricultural Organization of the United Nations
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FGDs	Focus Group Discussions
GCP	Ground Control Point
GIS	Geographic Information System
Ha.	Hectare
HFIAS	Households Food Insecurity Access Scale
KC	Kappa Coefficient
KIIs	Key Informant Interviews
KP	Kappa Coefficient
LULC	Land Use Land Cover
MLM	Multinomial Logit Model
OA	Overall Accuracy
PA	Producer's Accuracy
RMSE	Root Mean Square Error
RS	Remote Sensing
SNNPRs	Southern Nations Nationalities and Peoples Regional State
TLU	Tropical Livestock Unit
UA	User's Accuracy
UP	Unchanged pixels
UTM	Universal Transfer Mercator
WB	World Bank
WFP	World Food Program
WGS	World Geodetic System

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Abstract

Due to its perceived superior economic benefits over conventional agriculture, eucalyptus tree farming is becoming more and more popular among smallholder farmers in the highlands of Ethiopia, including Gurage Zone. However, this practice has caused controversies from both a theoretical and practical standpoints. Despite the fact that smallholder farmers have embraced it quickly, there are inadequate studies on its environmental and livelihood effects to generate reliable insights so as to inform policy makers regarding its planting and use. This study seeks to fill some of the gaps by using a mixed research method. For this purpose a total of 480 sample households from six purposefully selected kebeles were identified using systematic random sampling procedures. In addition, Key Informant Interviews (KIIs), Focus Group Discussions (FGDs) as well as field observations and satellite images of the study area were used as data collection tools to generate the required data to address the research questions. The quantitative data were analyzed using appropriate econometric and descriptive data analysis methods, while the qualitative data were analyzed using the content analysis approach. The data analysis revealed that the majority of households believed eucalyptus trees to have a negative impact on the environment, while they perceived it as having a positive impact on their livelihoods. The ordered logit estimation indicated factors like total land holding, school year of household head and participation in non/off-farm activities to be significant factors in influencing the perceptions of households. The study further indicated eucalyptus tree to have a remarkable economic and social contribution to smallholder households' livelihoods. Among other advantages, its contribution as energy source for cooking was found to be almost 98%. While 92% of surveyed households reported using their own plantation to meet own demands for wood products. Moreover, eucalyptus tree benefits households to meet their emergency cash needs and contributes almost 31% to their total household cash income. The fractional logit model showed factors such as total household income, age of household head, livestock resource as well as distance from the main roads to be some of the important factors influencing the share of land households allocate to eucalyptus trees. For the year 2000, 2010, and 2021, the LULC maps' mean classification accuracy and overall Kappa values were found to be 89.17 and 0.83, respectively. The LULC assessment of the study area indicated eucalyptus trees to have expanded over the past two decades on average at a rate of 42 Ha. per annum, suggesting eucalyptus trees to be the major contributor to the LULC change of the study area. The LULC analysis further indicated that eucalyptus trees to have expanded at the expense of crop lands which were found to be on a declining trend over the past decade. The econometric estimation indicated that land size and proximity to main roads to be important factors influencing the plantation of eucalyptus trees by sample households. The study used HFIAS, FCS, and a composite indicator created from the aforementioned indicators to assess the food security situation of the study area. The result revealed various food security issues in the study area due to both food quantity and quality challenges. The composite food security indicator showed almost 44% and 31.2% of the sample households as food insecure and food secure, respectively. While the balance (24.8%) to be in the intermediate category. The multinomial logit model also revealed that a household's total land holdings and its livestock resources as some of the factors that positively influence the likelihood of being in the food secure category. The marginal effect suggests that a one-unit increase in income from eucalyptus trees will increase the likelihood of being in the intermediate group by 8.5% while decreasing the probability of being in the food secure and food insecure categories by 8.1% and 0.4%, respectively. This study suggests the need to address the issues surrounding eucalyptus trees. The first and most important step should be reaching a common understanding among the various stakeholders in recognizing eucalyptus as an important integral part of the smallholders farming system. This will require

continuous discussions and providing timely information on the need to integrate tree planting with crop production using various communication channels so that eucalyptus trees will be used properly to improve the socioeconomic conditions of the smallholder farmers without compromising the food production potential and the environmental qualities of the study area. In order to achieve this, the nation should formulate and implement a land use policy that give sufficient right to land owners to engaged in land development activities legally and confidently with the full support and recognition of experts and government authorities. In addition, this policy should give authorities sufficient legal right to monitor and regulate rural land use to ensure its sustainable utilization in such a way that it fosters the overall development of rural areas.

***Keywords**: Gum tree; Perception; Environmental effects; Eucalyptus expansion; Land use; Food insecurity; Land allocation; Livelihoods, Eucalyptus farming*

List of Papers that made the Dissertation

Paper I: Aklilu Amiga, Degefa Tolossa, and Abebe Damte (2022). Smallholder Farmers' Perception on Livelihood and Environmental Effects of Eucalypsuts Tree- An Empirecal Study in Gurage Zone, Ethiopia.

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Chapter 1: Introduction

1.1 Background of the Study

Driven by the ever increasing population especially in the developing world which leads to high demand for tree products, the global plantation of the gum tree (eucalyptus) has increased significantly (Bayle, 2019; McMahon and Jackson, 2019). Due to its adaptability to various climatic and poor soil conditions as well as its fast biomass production in relatively shorter period of time, eucalyptus tree was planted in 95 countries in 2015 making it the most widely planted tree species in the world (Zhang and Wang, 2021). Despite its wide ranging benefits, however, eucalyptus tree is also criticized by both practitioners and researches for its alleged ecological impact as some are concerned about its long-term impact on ground and surface water as well as on soil nutrient compared to other agricultural produces (McMahon and Jackson, 2019). Consequently, eucalyptus tree is one of the most contentious issues in many countries of the world including Ethiopia which introduced the tree almost a century ago.

Eucalyptus tree is a controversial issue not only to the public but also to practitioners and scholars in the area. According to Alemayehu and Melka (2022), the proliferation of eucalyptus trees in the highlands of Ethiopia is one of the most disputed issues in the country. These disputes are mainly due to genuine concerns of some development stakeholders about its potential impact on smallholders' livelihood and the environment (Jaleta et al., 2017; Bazzan et al., 2021). Over the past few decades, however, as the debate on the livelihood and environmental effects of eucalyptus tree were heating up, eucalyptus tree transformed itself from being just a homestead trees to an important integral part of smallholders' farming system in many part of the country (Gil et al., 2010) due to its wide range of economic advantages such as being less costly in terms of input requirement as well as the associated lower risks in production and marketing compared to crop enterprises (Tefera and Kassa, 2017; Alemayehu et al., 2018; Madalcho, 2019). Consequently, these trees currently dominate Ethiopian landscapes with coverage amounting to as much as 58% of total plantations according to Gil et al. (2010), making it one of the most important tree species in the country.

The rapid expansion of eucalyptus trees has raised concerns among stakeholders regarding its effects on land use and land cover (LULC) patterns in rural areas of Ethiopia. Eucalyptus plantation by smallholder farmers often requires diverting cultivated agricultural land away from food crop production (Getachew, 2016 ; Molla et al., 2023), which counters the mainstream argument that forests are cleared for the purpose of crop production (Berihun et al., 2019: Alemayehu and Melka, 2022). Consequently, eucalyptus plantation is becoming one of the major drivers of LULC changes in many rural areas of Ethiopia (Molla et al., 2023).

The principal agents in expanding eucalyptus trees in Ethiopia in general and the study area in particular are the smallholder farmers (Getachew, 2016; Zerga and Berta, 2016; Gizachew, 2017) who despite the perceived negative environmental effects and opposition of the local authorities, continue to plant it for its fast biomass production in a relatively short period of time (Alemie, 2009; Belay and Muluneh, 2016). This expansion is widely believed to be a natural response to population pressure (Zerga and Berta, 2016) in the face of degraded and limited access to natural forests (Dessie et al., 2019) and declining agricultural productivity (Waldron, et al., 2017; Duffy et al., 2021) as well as rising market demand for tree products (Dessie et al., 2019 ; Alemayehu and Yoseph, 2022) and the absence of effective land use policy and planning in the country (Gebeyehu et al., 2017). As a result, smallholder farmers continue to plant it on their cultivated farm lands leading to rapid changes in land use patterns with its far reaching and long lasting implications on rural livelihoods as well as the ecosystem in many central highlands of Ethiopia (Desalegn et al., 2014; Liang et al., 2016; Bazzan et al., 2021).

Given the recent change in land use patterns among smallholder farmers favoring tree planting over food crop production, food insecurity is probably the most pressing issue that has to be properly addressed (Chane et al., 2013; Getachew, 2016). This is to a large extent due to the fact that the Ethiopian agricultural system can hardly compensate for the consequent loss of crop land since it is characterized by inadequate technological developments, low modern input usages as well as poor institutional support (Gemechu, 2014; Getu and Almas, 2022; Tigre and Heshmati, 2022).

Given the extent of the problem, there are inadequate studies on the issues of eucalyptus trees in the study area. There are some studies done on these issues in Gurage Zone include Zerga

and Berta (2016), Gizachew (2017) and Kebede (2017). They did not, however, take into account the micro-level socioeconomic variables that affect eucalyptus tree expansion. In addition, to the best of my knowledge there are no studies on the issue of perceptions towards eucalyptus trees in Gurage Zone. This study, therefore, will provide research based information that can help policy makers and practitioners to achieve a more rational use of rural land that can maintain a balance between the demand for trees of smallholder farmers and their food production. Furthermore, this study is likely to contribute its share in narrowing the gap in stakeholders' perspectives regarding eucalyptus trees.

The overall goal of this research is to investigate whether eucalyptus trees can be recognized and properly utilized as an important component of smallholders' farming system to improve the socioeconomic conditions of the rural community in a sustainable manner. In other words, the study aims to carefully assess the potential effects of eucalyptus expansion and provide policymakers with useful scientific information to help them development binding regulations that can strike a balance between economic rewards and environmental sustainability.

1.2 Statement of the Problem

The very idea of doing a research on eucalyptus tree crossed my mind a few years prior to enrolling in the PHD program when I met people who had diverging perspectives about eucalyptus tree. On that day, I had the opportunity to meet a highly respected person from Gurage Zone who was a retired teacher and entrepreneur in a social gathering. During our discussion, he expressed his concern about the rampant expansion of eucalyptus trees in his village located in Ezha *wereda*- Gurage Zone. According to him, farmers were even removing their *enset* plantations to make way for eucalyptus trees as they believed it would generate more income. He also blamed eucalyptus expansion for changing the climate of the area which according to him is becoming increasingly hotter. He appeared genuinely worried and even asked me directly "What are you educated people going to do about this problem?" As we went deeper into the topic, I noticed that some participants had different views on the matter and even some started to justify the actions of the farmers. One participant went as far as saying "nowadays only a naive person would prefer cultivating *enset* and other crops over eucalyptus tree in our area."

Since that conversation, I had been diligently collecting information from various individuals who knew the area very well and by reading different materials surrounding the topic as well. Luckily, a few months after our discussion, I had the chance to visit the area myself to witness firsthand what impact eucalyptus tree expansion had on farmers and their opinions towards it. The extent of adoption and farmers' opinion towards the tree left me surprised as most farmers I encountered held positive views about it, although some expressed concerns that if planted in close proximity to *enset* plantations that might dry them out. Moreover, authorities do not approve and even largely oppose eucalyptus plantation in the area and hence farmers are uncertain about potential actions authorities might take. Henceforth, when presented with an opportunity to join this program, I decided to contribute my part in addressing some of the issues associated with eucalyptus trees.

Even though there are empirical evidences that showed trees to improve smallholder farmers' livelihoods by generating income and providing other benefits such as serving as source of energy and construction material, the rapid expansion of planted trees is a concerning issue because it is replacing farmland in many nations (Rasmussen, 2017; Yan et al., 2020). As a result of this unprecedented expansion of planted forest which is mainly demand driven (Tefera and Kassa, 2017; Molla, 2023) , more and more researchers and policy makers are becoming increasingly concerned about their interaction with rural livelihood (Payn et al., 2015; Van Der Meer Simo, 2020; Coleman et al., 2021). Ethiopia is not an exception to this global trend where planted forests are increasing dramatically mainly as a result of the plantation of eucalyptus trees by smallholder farmers on fertile cultivated lands (Dessie and Abtew et al., 2019; Molla, 2023).

In the past few decades, the expansion of Eucalyptus trees has accelerated in the Southern, Central and Northern highlands of Ethiopia (Molla et al., 2023). This tree species has become increasingly popular among smallholder farmers due to its economic benefits and high market demand for tree products-fuel wood, charcoal and timber (Gil et al., 2010), resulting in a rapid shift in LULC patterns across many rural areas of the country. The consequences are long-lasting both on production systems of smallholder farmers and ecological outcomes such as water resources, soil erosion and biodiversity (Molla et al., 2023). This suggests the need to investigate the potential impact of eucalyptus trees on rural households' livelihoods-food security and poverty alleviation (Payn et al., 2015).

Since 2000, the extent of planted forest has grown at an estimated annual rate of over five million hectares (Keenan et al., 2015), mostly as a result of a widespread practice of turning once fertile arable land into eucalyptus plantations. As there are genuine reasons to take this as an achievement, there is also growing concern about food crop production losses especially in those regions of developing countries where food related problems are rampant (Getachew, 2016; Bazzan et al., 2021) and the agricultural sector struggles with a variety of production (Gemechu, 2014; Getu and Almas, 2022) and marketing (Peralta and Swinton, 2009; Jagger and Pender, 2003) related challenges. Given the rapid expansion of eucalyptus on crop lands, its long-term effects on the food system of the community and the environment is becoming an increasingly concerning issue in many rural parts of Ethiopia, such as Gurage Zone (Bazzan et al., 2021).

To mention a few empirical evidences on eucalyptus expansion in Ethiopia, we can see the situation in Arsi Negelle where according to Jenbere et al. (2012), 11% of the cropland was already converted in to eucalyptus plantation. A study by Tola (2010) may give us a good picture of how scary the expansion and dynamics of eucalyptus tree looks like and how it is rapidly changing the LULC of many rural areas of Ethiopia. From his study in Central Oromia he stated that:

''Most farmers began planting eucalyptus around homesteads, mostly in backyards, and gradually expanding to agricultural land close to homesteads. At the same time, some farmers converted croplands that have lost crop production potential due to fertility exhaustions to eucalyptus plantation location even furthest away from homes. Currently in some parts of the district (Mulo)*, eucalyptus wood lots of neighboring households are closing together to create a large continuous plantations pattern.''*

Moreover, a study conducted in Gurage Zone by Zerga and Berta (2016) has shown that nearly all sample households had eucalyptus trees planted on their piece of land. In addition, they stated the number of poles sold in Ezha *wereda* increased from 175,188 in 2005 to 296,472 in 2007, which is a staggering 69.2% increase in just two years, according to the Ezha *wereda* Agriculture and Resource Development Office, as cited by Zerga and Berta (2016).

The eucalyptus conundrum in the study area has created frictions among smallholder farmers who want to plant eucalyptus trees on their land and government authorities who try to control these plantations in the absence of binding land use policy regulations. Conflicts and

widely shared complaints among smallholder farmers and government authorities are occasionally caused by miscommunication and mistrust (Feyisa et al., 2018). Thus, the opinions of smallholder farmers who are the main agents for eucalyptus expansion must be understood in order to manage eucalyptus trees effectively while taking smallholders' livelihood and the environment into account.

Though some researches claim that planted trees have positive impact on rural livelihoods (Rasmussen 2017; Dessie, Abate, et al. 2019; Yan et al., 2020; Alemayehu and Melka, 2022), there are also studies indicating trees not to be that effective in improving the livelihood of rural communities on a sustainable bases particularly due to their long-term ecological consequences (Coleman et al., 2021; Desta et al., 2023). For this reasons, the issue of planted forests in rural development is still highly debated (Van Der Meer Simo, 2020). The resulting policy recommendations, as a result of these conflicting views ranges from the one which promotes a 'complete banning' of eucalyptus trees from farm lands to a kind of laissez-faire approach (leaving the decision to the farmers' discretion). Therefore, this study provides empirical information which can help to reach a consensus about eucalyptus on both theoretical and practical stand points.

This study will be unique even though there have been other studies on the subject because, in addition to the inconsistent findings of earlier research, each rural area has its own unique characteristics with regard to the endowments of agricultural resources, agro-ecological conditions, and access to various institutions. Consequently, examining the impact of eucalyptus trees on rural food security, income generation and diversification, and household energy can provide empirical evidence of the ways in which eucalyptus trees are integrated with rural livelihoods. This information can then be used by policy makers and practitioners to make well-informed decisions regarding the use of eucalyptus trees and rural land.

Since eucalyptus farming is a common livelihood strategy practiced by smallholder farmers in Gurage Zone (Zerga and Berta, 2016; Gizachew, 2017), one essential question that needs to be empirically investigated is how it affects households' food security. Despite the fact that food security is a multi-dimensional issue, studies have indicated that livelihood strategies highly influence rural food security through their impact on households' access to multiple food entitlement (Ganiyo and Omotayo, 2016; Mutea et al., 2019; Tesema and Berhanu,

2019). Therefore, it is very essential to analyze smallholder farmers' food security status in Gurage Zone as one of the most important livelihood outcomes of eucalyptus expansion.

The effect of eucalyptus tree on food security of smallholder farmers is under studied in Ethiopia. In particular, in Gurage Zone, we were unable to find even a single study on this issue. Even the researches that are available such as Getachew (2016) on the impacts of eucalyptus cultivation on food security did not employ standard food security measures for assessing food security and did not take into account food security at household level. Moreover, the majority of food security studies in Ethiopia employed either a single indicator such as Alemseged (2016) and Garedew (2017), or two indicators such as Getachew (2018) and Dereje (2021). This study, however, used a different approach by employing a composite food security indicator which is derived by combining (integrating) two different food security indicators, which is quite uncommon in the Ethiopian context.

Previous studies on the effect of eucalyptus trees on food security did not indicate similar results. According to some researchers such as Getachew (2016) and Bazzana et al. (2021), eucalyptus tree damages the food security of smallholder farmers. Others, however, contend that eucalyptus trees can improve rural communities' food security by providing them with economic and ecological benefits (Feyisa et al., 2018; Bayle, 2019; Gebreegziabher et al., 2020). Studies have also found food insecurity problem in regions that are typically thought of as surplus producers. For instance, a study conducted by Furgasa and Degefa (2016) in Becho *wereda*, Central Oromia, found that 38% of the sampled households did not consume enough calories to lead an active and healthy life. This suggests the need to examine the actual food security situation of the so-called "food sufficient areas." In addition, communities that cultivate *enset* are generally perceived to be food secured, which is why food security studies are rare, if not completely nonexistent, in areas such as Gurage Zone. This reinforces the necessity to evaluate how eucalyptus tree affects food security in Gurage Zone.

Studies on food security show the importance of rural food production capacities in determining rural householders' status of food security. According to Birara et al. (2015), a number of factors contribute to Ethiopia's deteriorating food security status, but they identified lack of farmland and decline in food production capacity as the two most important factors. Though, eucalyptus trees are predicted to reduce farm households' ability to produce

their own food, at the same time they are likely to increase smallholders' income which can increase access to food by means of either enabling them to purchase food directly from market or increasing their food production capacity by increasing their ability to pay for essential farm inputs. This further substantiates the need for a rigorous investigation of the effect of eucalyptus trees on rural households' food security status.

Own food production is one of the most important determinants of the food security of the rural community (Degefa, 2005). Given the rapid expansion of eucalyptus plantation in the study area and the conversation of farm lands into eucalyptus plantations, competition between food crop and eucalyptus tree is a common phenomenal in Gurage Zone (Gizachew, 2017; Kebede, 2017). Thus, the analysis of the effect of eucalyptus tree on rural households' food security is very essential for the purpose of formulating effective land use policy that can serve to improve and maintain the food security of the rural communities in Ethiopia.
Various measures have been taken by government authorities to limit the expansion of eucalyptus trees, ranging from raising awareness to forcibly uprooting seedlings in the Gurage Zone (Zerga and Berta, 2016), which typically causes considerable resentment among smallholder farmers. Some scholars, like Getachew (2016), have openly advocated for outlawing the planting of eucalyptus trees on agricultural land, while others such as Feyisa et al. (2018) have openly opposed such actions since they could endanger the livelihoods and food security of millions of Ethiopian smallholder farmers. This implies that even scholars disagree on the subject of eucalyptus trees, and as a result, it is expected that this study will provide additional empirical information on these issues.

The reviewed literatures indicate that there is no clear conclusion as to how eucalyptus affects food security especially in Ethiopia. Some of the studies done concentrated on the effect of eucalyptus on household income and did not show how this impacts food security at household level using standard food security measurement tools. Generally speaking, they appear to expect that a gain in household income from eucalyptus will raise their purchasing power, which will ultimately improve food security. Others see the conversion of crop land into eucalyptus land as a threat to the food security of rural populations and advocated for a moratorium on tree planting to slow down the eucalyptus' rapid spread on lands used for producing food.

There is a clear knowledge gap linking the availability and the access component of food security at household level, as the expansion of eucalyptus in rural setting is believed to have a negative impact on own food production (food availability) but it is also likely to have a positive impact on households' purchasing power through increased money income from the sale of eucalyptus products (food accessibility). Moreover, since eucalyptus remains the main source of energy for cooking in the study area, it also contributes for food utilization component of food security.

Despite the existence of long-standing and widely held arguments for and against eucalyptus, a thorough investigation of eucalyptus expansion and its influence on food security and land use using conventional methodologies has not been done in satisfactory level to inform policy decisions in the study area. The question on whether and how to encourage the planting of eucalyptus trees still remains contentious in Ethiopia. Therefore, using standard tools and rigorous analysis, this study will be the first of its kind to establish a link between eucalyptus tree and food security. It will also provide recommendations that contribute to achieving a sustainable land use in rural Ethiopia.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this study is to assess the extent of eucalyptus tree expansion and its implications on land use and livelihoods of smallholder farmers in Gurage Zone, Central Ethiopia.

1.3.2 Specific Objectives

The following are the specific objectives of the study:

i) To assess the perceived effects of eucalyptus tree on smallholder farmers' livelihood and the environment (Paper I);
ii) To evaluate the contribution of eucalyptus tree to smallholder farmers' livelihoods and identify factors that influence the proportion of land allocated to eucalyptus trees (Paper II);
iii) To assess the expansion of eucalyptus trees and its contribution to the LULC dynamics of the study area (Paper III); and,

iv) To examine households' food security status and its determinants among eucalyptus farming households in the study area (Paper IV).

1.4 Research Questions

This study was undertaken to contribute to the settlement of controversies surrounding eucalyptus tree both from theoretical and practical standpoints by analyzing its expansion and its drivers as well as its consequences on land use and livelihoods of smallholder farmers in Gurage Zone. For this purpose, this study was under taken based on the following key research questions:

i) What does smallholder households' perception towards the livelihood and environment effects of eucalyptus tree look like? (Paper I).
ii) How does the contribution of eucalyptus tree to smallholder farmers' livelihoods look like? And what factors influence the share of land households allocate to eucalyptus trees? (Paper II).
iii) How does the expansion of eucalyptus tree in the study area look like? To what extent does eucalyptus tree plantation by smallholder farmers contribute to the LULC dynamics of the study area? (Paper III).
iv) How does the food security status of household in the study area look like? And how do eucalyptus trees and other socioeconomic factors affect smallholder farmers' food security in the study area? (Paper IV).

1.5 Significance of the Study

This study is relevant from both theoretical and practical perspectives, as evidenced by the fact that eucalyptus tree is one of the most contentious issues in Ethiopian agriculture. These controversies are mainly due to lack of consensus and mutual understanding of experts and government officials who usually are on the same side of the argument and the smallholder farmers on its short and long-term consequence on the food system and the environment. This controversy usually leads to the misallocation of scarce rural land resources and disappointment and even in some cases unnecessary confrontations between agricultural experts and smallholder farmers in many part of the country including Gurage Zone. Therefore, the significance of this study can be seen from two angles one is on adding on the existing and highly needed scientific information and knowledge to the dialogue on

eucalyptus tree among scholars and secondly to help development stakeholders come up to some sort of mutual understanding and trust with regard to planting eucalyptus tree as the existing confrontation and mistrust has to come to an end at some point in time.

Taking both the practical and theoretical gaps in mind, this study analyzed the perception and opinion of farm households towards eucalyptus tree, how the expansion of eucalyptus tree look like as well as to what extent eucalyptus expansion influenced the LULC changes observed in the study area. In addition, using standard food security indicators, the study investigated how eucalyptus tree affects the food security of smallholder households in Gurage Zone in such a way that the findings will be relevant to other parts of the country with similar development issues.

This study is unique in analyzing smallholder farmers' perception by using multiple indicators to examine the livelihood and environmental effects of eucalyptus tree as this will be relevant to understand farmers' views and their intention in planting eucalyptus trees. In addition, using satellite images and field observation to examine the extent of LULC changes, and micro level factors into account, the study calculated the rate of eucalyptus expansion in the study area. This can be used to predict the future LULC of the study area based on which policy maker can take preemptive measures.

Food security is the result of interrelated socio-economic and institutional factors among these a declining food production capacity which is likely to be the case in the face of rapid eucalyptus expansion, had not be considered properly. Therefore, this study examined how the expansion of eucalyptus tree affects food security at household level which can provide a very useful insight for both practical decisions making purpose and also enriching scientific knowledge in the area. This is because the available few studies did not have a clear cut conclusion as to how eucalyptus affects food security while the rest did not use universally accepted food security measurement tools.

Studies which concluded eucalyptus expansion has a negative impact on food security mention only about the conversion of crop land into eucalyptus planting land without taking into account the impact of cash income and other benefits obtained from eucalyptus on food security. This study, however, used a multiple standard food security indicators to analyze the effects of eucalyptus tree on food security. In addition and most importantly, this study used a composite food security indicator which is derived by integrating Households Food

Insecurity Access Scale (HFIAS) and Food Consumption Score (FCS) indicators to analyze in more detail the food security situation of households in the study area. Applying a composite food security indicator in the study area is one of the unique methodological contributions of this study.

In general, the study will contribute its share to the eucalyptus discourse to clarify the dilemma whether eucalyptus is a curse or a blessing or whether and how to encourage it. By doing so, it will give a clear guide to policy makers and experts as to how to control or support eucalyptus plantation in the different part of the country especially in the study area.

1.6 Scope and Limitation of the Study

Like any study, this study has its own limitation due to time and resource constraints. Consequently, the study had to be done in a limited geographical boundary and time frame. Therefore, the study was conducted in two *weredas*- Ezha and Cheha, found in Gurage Zone. It uses mainly a cross-sectional survey data obtained from questionnaires, FGDs, KIIs as well as field observations. In addition, satellite images of the study area were used to analyze LULC changes of the study area over time.

Given these constraints, efforts were exerted to select samples which are as representative as possible. Since we have used cross-sectional data we could not see the changes over time. Especially, issues of food security and eucalyptus expansion and its economic and social impacts could have been more effectively investigated had the study used time-serious data in addition to the cross-sectional data generated by the survey and the field observations. In addition, getting qualitative data for food security and perception issues was challenging due to inadequate time in the field work mainly due to financial constraints. However, the study used different techniques to get as accurate information as possible.

1.7 Methodological Approach

1.7.1 Philosophical Orientation of the Study

The researcher's beliefs regarding the proper methods for gathering and analyzing data related to a study subject can be characterized as their research philosophy. There are various theoretical viewpoints in research philosophy, including positivist, post positivism, interpretivism, idealism, and others. This helps the researcher to choose the ontology,

epistemology and methodologies (research philosophy) that emerge from them (Crotty, 1998; Holden and Lynch, 2004). Based on research questions, the nature of what we desire (ontology) and our beliefs about how to get it (epistemology) greatly influence how we choose to go about obtaining it (methodology) and which data to collect (sources) (Guba and Lincoln, 1994).

The research questions should determine the paradigm and the specific research method that should be employed (Teddlie and Tashakkori, 2009). The mixed research method can help us to integrate the quantitative and qualitative data collection tools as well as data analysis techniques (Johnson et al., 2007) in such a way that if applied properly, together can give a result which is better than either of the two used separately (Woolley, 2009). This means, this method allows using the combined strength of both methods to answer research questions effectively.

Given that the research questions of this study call for both qualitative and quantitative data collection and analysis techniques, we chose a mixed research methodology and a mixed philosophical approach (pragmatic approach). According to Creswell and Clark (2011), this strategy enables the use of several data collection techniques that allows triangulation, improving the reliability of research findings.

1.7.2 Research Methods

1.7.2.1 Sample Size and Methods of Data Collection

The study was undertaken in selected rural *kebeles* found in Cheha and Ezha *weredas* of Gurage Zone, Ethiopia. Due to resource limitations, we had to choose only two from the existing sixteen *weredas* based on the extent of eucalyptus farming practices and agro-climatic conditions. As a result, Ezha and Cheha *weredas* were purposefully selected not only because they are among the *weredas* where eucalyptus farming is wide spread (Zerga and Berta, 2016) but also due to the existence of all the three major agro-ecological conditions- *Dega*, *Weyinadega* and *Kolla.* The classification of agro ecological zones in Ethiopia are mainly based on altitude and according to Hurni (1998) Dega agro ecological zone includes those areas with altitude ranging from 2300 to 3200 meters above sea level (asl) while Weyinadega and Kolla covers areas of altitude between 1500-2300 and 500-1500 meters asl,

respectively. The study area does not have Wurch agro ecological zone which is above 3200 meters and Berha which includes areas below 500 meters asl.

From each of the three agro-climatic types and each *wereda*, we selected one *kebele* with the help of the respective *wereda* experts to get a total of six *kebeles* for the study. Table 1.1 shows *kebeles* selected with their respective sample size and agro-ecology conditions.

The total sample size was determined based on Yamane (1967) which is given by Eq. 1

$$n = \frac{N}{1+N(e^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. 1$$

In Eq. 1, n stands for the sample size while N represents the total population and e stands for the desired level of precision which is assumed to be 0.05. By adding a 25% contingency, the total sample size for the survey was determined to be 480 households.

The total sample size (n=480) was then allocated to the six *kebeles* identified in the two *weredas* according to probability proportional to size (PPS), which is given by Eq. 2.

$$S_i = n\left(\frac{k_i}{N}\right) \ and \ n = \sum_{i=1}^{6} S_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 2$$

Where S_i and k_i stand for the sample size and the entire population of the i^{th} *kebele*, respectively. As a result, sample size was determined for each of the six *kebeles*, and this information is provided in Table 1.1.

Table 1.1: Distribution of Samples by the study *weredas* and *kebeles*

Wereda	***Kebele***	**Agro-ecology**	**Sample size**
Ezha	Zigbaboto	Upper Kolla	87
	Yesiray	Weyinadega	45
	Ketane	Dega	103
Cheha	Werdene	Upper Kolla	53
	Wodro	Weyinadega	88
	Girar & Yefermazigibe	Dega	104
Total			480

For the most part, household surveys, KIIs, FGDs, satellite images, and field observations were used to generate the primary data for this study, which was conducted primarily in the months of January and February of 2021. In addition, secondary data obtained from various governmental and non-governmental offices were also utilized.

The sample units for the household survey were selected using systematic random sampling technique from a list of households obtained from the respective *kebele* offices and a structured questioner (See Appendix I) was administered by trained enumerators. The enumerators were recruited by consulting the respective *wereda* level officials and experts and all were graduates of agriculture or related fields with more than two years of working experience in their respective *kebeles*. In addition, information required for assessing food security of households was collected based on the Food and Nutrition Technical Assistance (FANTA) guidelines for HFIAS based on Coates et al. (2007) and FCS based on WFP (2008). The satellite images required to analyze the LULC dynamics of the study area were obtained from United States Geological Survey (USGS) free of charges for year 2000, 2010 and 2021.

KIIs were also undertaken with all the six *kebele* (or their representatives) and the two *wereda* administrators based on the guiding questions given in Appendix II. In addition, *wereda* level experts and development agents (DAs) from all the six sample *kebeles* who were found to be well informed about the socioeconomic conditions of the community were interviewed.

Furthermore, six focus group discussions (FGDs), one in each *kebele*, were conducted in total, with participants drawn from a variety of socioeconomic backgrounds, with the primary goal of generating qualitative data on the pertinent themes. The local DAs assisted in the selection of the participants, who gave their complete consent to participate in the conversation. There were at least three female volunteers in each group, which consisted of seven to eleven heads of households.

1.7.2.2 Methods of Data Analysis

The data collected were analyzed with the help of Stata 14.2 software to achieve the objectives of this study. Descriptive statistics, econometric models and satellite image analysis were used as data analysis tools. For the qualitative data, a technique of content

analysis approach was used. Table 1.2 shows as a summary of the econometric data analysis models used in this study.

Table 1. 2: Econometric Data Analysis Tools Used

Paper	Dependent variable	Model used	Justifications
I	Level of Agreement (1,2,3,4,5)	Ordered Logit Model	Perception is expressed as category which follows a natural order.
II	Proportion of land allocated to eucalyptus tree; ratio [0,1]	Fractional Logit Model	The dependent variable is a ratio taking a value between 0 and 1.
III	Total household's eucalyptus holding (Ln of eucalyptus)	Ordinary Least Square (OLS)	The dependent variable is a continuous variable with no upper limits
IV	Households' food security status (0,1,2)	Multinomial Logit Model	A categorical dependent variable where there is no clear ordering of the dependent variable

1.7.2.3 Variable Definition

A brief explanation of the independent variables used in this study is provided in this section.

Gender of Household Head

This is a dummy variable that refers to the gender of the head of the household which takes a value of 1 if the head is male or 0 otherwise.

Marital Status

This is a dummy variable which refers to the marital status of the households head taking a value of 1 if the head is married or 0 if single (never married, widowed, divorced, separated).

Age of Household Head

This is a continuous variable measuring the age of the household head in years.

Educational level of Household Head

This variable measures the educational level of the household head and it is taken as a continuous variable and is measured in terms of the maximum years of schooling attained by the household head.

Total Land holding of Household

This is a continuous variable which can take any value starting from a minimum value of zero. It refers to the total area of land the household has and farmers usually express their holding in terms of a local unit called *zheng* which in this study is converted and expressed in terms of hectares (ha.).

Availability of Cash Crops

This is a dummy variable which takes a value of 1 if the household is engaged in producing some cash crop such as coffee, khat, or some fruits, or 0 if there is no production of cash crops.

Access to Electricity

This is a dummy variable indicating whether the households has hydroelectric power connection or not and takes a value of 1 if connected or 0 otherwise.

Suitability of Land for crop production

This is a dummy variable indicating whether most of the land held by the household is suitable for crop production or not and takes a value of 1 if most of the land is suitable for crop production or 0 otherwise (marginal land, hill side) which is considered as unsuitable for crop production.

Family Size

This variable measures the total number of individuals living in the household and it is a continuous variable.

Family Members between 15 and 64 years

This refers to the number of family members who are older than 14 but younger than 65 years of age and it reflects the potential labour force the household has for agricultural or nonagricultural activities.

Participation in non/off-farm activities

This is a dummy variable taking a value of 1 if any member of the household was participating in some non/off-farm activities during the interview period or 0 otherwise.

Annual Income of Household

This is a continuous variable representing the gross farm and non-farm income of the households measured in Ethiopian Birr (ETB).

Income from eucalyptus

This is a measure of the total annual income earn by the household from selling eucalyptus products and it is expressed in terms of ETB.

Total Livestock holding (TLU)

This is a continuous variable reflecting the total livestock holding of the household. It is calculated by assigning different weights to the different animals the household owns according to Storck and Dopper (1991). (See Appendix XII).

Proximity to main road/ Distance from the main road

This variable measures the time (minutes) needed to reach the nearest main road from the household and it is used as a proxy variable to market access since eucalyptus products are mainly sold on main roads (farm-gate).

***Wereda* Level Fixed Effect Dummy**

This is a dummy variable included to check the effects of factors which are not included in the estimation such as fertility status of soil, climatic conditions and other unobservable variables which might influence eucalyptus plantation of households in the two *weredas*. The variable takes a value of 1, if the household is found in Cheha *wereda* or 0 otherwise.

***Kebele* Level Fixed Effect Dummy**

Taking a value of 1, if the household is found in a specific *kebele* (e.g. Zigibaboto) and 0 otherwise. This variable helps to check whether there is a variation among households' eucalyptus plantation due to their *kebele* or not.

Livelihood perception score

This continuous variable, which has a value between 1 and 5, reflects the perceived effects of eucalyptus tree on households' livelihood.

Environmental perception score

This continuous variable, which has a value between 1 and 5, reflects households' perception towards the effects of eucalyptus tree on the environment.

1.8 Eucalyptus Tree and its Expansions

1.8.1 Origin and Expansions

Original home being Australia, eucalyptus tree is the most widely planted tree all over the world with more than 800 different species, it belongs to the family Myrtaceae and subfamily Myrtoideae (Hayat et al., 2015). Gum tree (Eucalyptus) is identified by its smooth or stringy bark and lance-shaped leaves. Eucalyptus Oozes gum when the stem is stabbed or damaged. The name eucalyptus was first coined by the French botanist– Jacques Julien Houton in 1799, from two Greek words "eu" and "kaluptos" which together give the meaning of "well-covered" reflecting the hard cover protecting its fruits and flowers (Gil et al., 2010). The

evergreen species range in height from a small shrub or multi-stemmed tree under ten meters to a large single-stemmed tree over sixty meters. It typically grows between sea level and 1,850 m above sea level, while it can reach higher altitudes in Ethiopia (FAO, 1998; Gil et al., 2010; Pukka and Pohjonen, 1989).

Before 400 years ago, the tree was grown outside of its original country for the first time in Portugal. Since that time, the species has flourished and expanded widely throughout Europe, Latin America, Asia, and Africa. Some of the countries where eucalyptus is widely planted include the USA, Colombia, Chile, Ecuador, Spain, China, Israel, Morocco, Ethiopia, Uganda, and South Africa. At the end of 1990, there were over ten million hectares of eucalyptus in the tropics (FAO, 1998).

A small number of species, including Eucalyptus globules, Eucalyptus camaldulensis, and Eucalyptus grandis, account for more than 90% of eucalyptus plantations, and more than 55 of these species are grown in Ethiopia (Friis, 1995). However, Eucalyptus globules and Eucalyptus camaldulensis are the two most significant eucalyptus species that are widely planted in Ethiopia (FAO, 2009).

1.8.2 Eucalyptus tree in Ethiopia

The introduction and widespread use of eucalyptus (Gum tree) by Emperor Menelik II in the 1890s are thought to have been prompted by the low yield and slow growth of native tree species (Yitebitu, 2010; Amare, 2010), as well as the rising demand for tree products as a result of the establishment of the City of Addis Ababa (Mesfin and Wubalem, 2014). It was mostly brought from Australia, and free seeds and seedlings as well as tax incentives were employed as tools to accelerate its dispersal in order to lessen the pressure on the diminishing native forests (Teketay, 2000).

The government's backing for eucalyptus tree plantation as well as the promotion of numerous academic and developmental organizations allowed it to spread slowly but surely throughout the nation (Amare, 2002). It was soon given the local name "Bahirzaf," which means "tree of the sea" in Amharic, signifying that it was brought in from other nations (from beyond the sea). Additionally, the two species that are most frequently planted in the nation have been given the local names *keybahirzaf* and *nechbahirzaf*, which respectively translate to "red" eucalyptus (Red Gum) and "white" eucalyptus (Blue Gum) for the species eucalyptus

camaldulensis and eucalyptus globules, respectively. The distribution of these two species is mainly altitude based where eucalyptus globules is mostly adapted at higher altitudes of *dega* agro ecological zones, while eucalyptus camaldulensis is adapted in lower altitudes of *weyinadega* and upper *kolla* areas (Gill et al., 2010). In addition, *Eucalyptus saligna* is also widely planted in some parts of Ethiopia such as Arsi-Negelle and Shashamane districts.

Given the absence of effective land use policy and various interrelated socioeconomic factors, nowadays eucalyptus plantation has spread almost all over the country leading to a significant change in land use largely as a result of smallholder farmers' plantation on what used to be food producing land (Liang et al., 2016). With more than 500,000 Ha. of plantation, Ethiopia is the largest in the Eastern region of Africa and is thought to be one of the ten countries that introduced the eucalyptus tree to Africa (Mesfin and Wubalem, 2014). With 58% of the plantation cover in Ethiopia being made up of eucalyptus trees; Cupressus, Juniperus procera, and pines come in second, third, and fourth place, respectively, with 29%, 4%, and 2% of the total plantation cover (Gill, 2010).

Gurage zone is thought to have been one of the regions of the country to adopt eucalyptus trees as early as they were introduced to the country because of its proximity to Addis Ababa city. While government officials increasingly view eucalyptus trees as a problem that causes substantial changes in land usage that have an impact on people's livelihoods and the environment, it is becoming the most preferred agricultural enterprise to many smallholder farmers in Gurage Zone. Previously, the majority of those opposed to the planting of eucalyptus trees did so under the guise of "environmental concerns," but nowadays, most of the government officials and agricultural experts openly express their concerns about the negative effects of eucalyptus expansion on the food security of the Gurage people, who are usually regarded by many as "food self-sufficient."

1.9 Eucalyptus Expansion and Perception

One of the most important issues that needs to be taken into account is the perception of stakeholders towards eucalyptus tree. Equally important to the economic benefit of eucalyptus, there is also a growing concern on its wide-ranging effects extending from LULC change to potential losses in food production that could ultimately leads to food insecurity problem as a result of which finding a sustainable solution to the eucalyptus conundrum

should take the knowledge and perception of the local population into account (Finucane, 2009).

One of the key elements influencing a person's decision is perception (Kondalkar, 2007). This indicates that decisions about adoption and the amount of resources, such as land, to be dedicated to eucalyptus trees depend in great part on the decision maker's perception towards eucalyptus trees. In order to develop efficient mechanisms to control the expansion of eucalyptus trees with the complete cooperation of smallholder farmers, it is crucial to understand how farmers feel about eucalyptus tree (Pervin, 2017).

In general, perception is how we interpret and comprehend what is occurring in our surroundings. It is both subjective and objective, as well as being largely the product of our prior experiences. Perception can change through time in response to changes in our settings (Harappa, 2022). Thus, the perceived effects of eucalyptus trees (positive or negative) are expected to vary from person to person and can also change as a result of changes to the pertinent stimuli (Hennessay, 2012).

One of the challenges that need proper attention in order to manage the expansion of eucalyptus trees is the disparity in opinions and perceptions between government authorities and smallholder farmers in the study area. Shaping smallholders view on eucalyptus tree is crucial for fostering mutual understanding and building and maintaining trust between farmers and government officials. Therefore, the understanding of smallholder farmers' perceptions and the factors that influence it will provide vital inputs in devising policies that can better address the needs and concerns of the community with regard to the eucalyptus conundrum.

1.10 Eucalyptus trees and land use and land cover changes (LULC)

LULC changes are global phenomenon that has an impact on the ecology and the livelihoods of millions of people worldwide, despite the fact that the rate and reasons vary from place to place (Nedd et al., 2021). Eucalyptus trees are typically planted on cultivated farmlands (Getachew, 2016; Kebede, 2017; Molla, 2023) as well as, to some extents, as usually recommended on degraded and marginal areas (Zerga and Berta, 2016). As a result, LULC changes are the direct and immediate outcomes of eucalyptus expansion. However, these LULC changes have wide-ranging effects that affect everything from the environment and livelihood to production mix at the farm level (Jaleta et al., 2016; Desalegn et al., 2014).

Land use and land cover are not notions that are mutually exclusive; instead, one implies the other. Land use and land cover can be seen as two sides of the same coin because while land cover is primarily concerned with changes in the physical characteristics of the earth's surface (Rawat et al., 2015), land use refers to changes in the socioeconomic conditions of people as a result of a change in land cover. According to Turner and Meyer (1994) and Briassoulis (2009), human interaction with the environment is the main cause of LULC changes. The causes of these shifts, however, can differ at the international, national, and regional levels. As a result, several demographic, socioeconomic, and institutional factors have an impact on land use decisions at the household level (Briassoulis, 2009). In order to ensure that these changes are consistent with the socioeconomic interests of society and a healthy ecosystem, it is crucial to assess the pace of LULC changes and identify the elements that influence it.

LULC measurements have seen a significant improvement thanks to the advancement of technologies in Geographic Information Systems (GIS) and remote sensing (RM), which offer valuable data on both the current and past LULC status from which the rate of LULC changes can be calculated. In this study, the identification of relevant LULC types, the rate of eucalyptus tree expansion and its contribution to the LULC dynamics in the study area are primarily done based on data obtained from RS and GIS by complementing with data obtained from field observation, FGDs and KIIs.

1.11 Food Security

1.11.1 Concept of Food Security

The concept of food security has evolved over the past 40 years from focusing solely on the problems of food availability and price stability to recognizing its multidimensional aspect in the 1980s and 1990s, which included food utilization and stability issues in addition to the earlier components (FAO, 2006). As a result, at the World Food Summit in Rome in 1996, the term "food security" was broadly defined as "a situation where all people at all times have physical and economic access to sufficient, safe, and nutritious foods to meet their dietary needs and food preferences for an active and healthy life."

According to Maxwell and Smith (1992), this widely accepted definition of food security emphasizes the following crucial ideas. Which are:

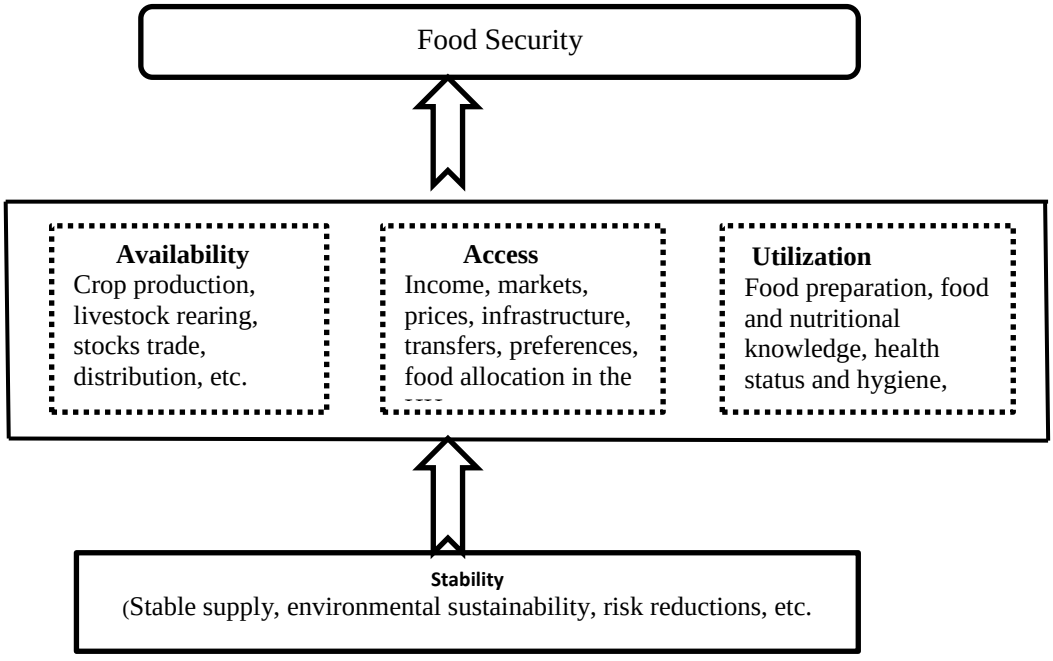
1. Sufficiency: calories requirement for active and healthy life.
2. Access: by means of production, purchase, exchange and /or gift.
3. Security: the balance between vulnerability, risk and insurance.

4. Time: food insecurity can be chronic, transitory or cyclical.

Currently, the four pillars of food security- availability, access, utilization, and stability help us better understand food security. All of these pillars must be sufficiently present for a condition of food security to exist (FAO, 2008).

Currently, the definition of food security has been greatly enlarged to include all elements that affect a society's food system (Maxwell, 2000). The working definition adopted for a particular case, however, should take into account each of the four components of food security (FOA, 2008). In line with this, the definition of food security provided by Degefa (2005), which reads as follows, looks the most applicable for this study.

"The ability to establish access to production resources such as land, livestock, agricultural inputs and family labor combined to produce food or cash".



Source: Adapted from FAO (2008)

Figure 1.1 Pillars of Food Security

From this definition one can understand that food security at farm household level is determined not only by the household's own production of food but also members' ability to purchase food of the right quantity and quality. This, in other words means if rural households can maintain adequate purchasing power, then they can secure their food security. In a society where livelihoods are agriculture based, a productive agricultural sector with the

support of well-established institutions can ensure households with availability and access of quality food through production and exchange with better utilization and stability of food security (Bonnard, 1999). From this one can see the possibilities for eucalyptus trees to enable smallholder farmers in achieving and maintaining food security.

The issues of eucalyptus plantation can also be seen in relation to the newly emerging issues of food system, resilience and food sovereignty since the agricultural sector is where most if not all food originates. Food system which can be defined at different scale ranging from local community to global stage (Von Braun et al., 2021), encompasses all actors and their activities, the processes and the resources involved ranging from food production to its final disposal. A sustainable food system is one which ensures food security for all in such a way that the bases for insuring food security are not compromised for the future generations (Tutwiler et al., 2017). In the context of rural communities building and maintaining resilience to internal and external shocks is an essential component of a sustainable food system. When a household or a community is resilient, it means that they can withstand shocks and difficulties that threaten their food security and bounce back from them (Bullock et al., 2017)

Food sovereignty which initially came as an alternative to the concept of food security emphasizes the right of communities and individuals to control their food system by actively involving on matters of policy formulation and implementation with regard to the use of agricultural resources, food production and consumption (Wittman et al., 2010). Food sovereignty promotes and recognizes the democratic and free choice of farmers and therefore it requires striking a balance between different seemingly conflicting goals (Agarwal, 2014). Consider the conflict between the government's desire to enhance food crop production and farmers' freedom of choice when it comes to selecting between eucalyptus trees and food crops production in the study area.

The broader food system as well as the food sovereignty and resilience of the smallholder farmers in the study area are thus expected to be directly impacted by the use of eucalyptus trees as a livelihood strategy, which has a direct impact on food production (availability), access, utilization, and stability.

1.11.2 Measurement of Food Security

As the concept of food security evolved over the years, so did its measurement (Fawole et al., 2016). There are even more debates on the issue of measurement than its meaning due to lack of universally accepted measurement tools that can serve the specific purpose of the study and the condition of the target communities (Bashir and Schilizzi, 2012). This is why different measures report varying result of food security for a given population (Bashir and Schilizzi, 2012; Maxwell et al. 2013).

While production gap (supply and demand) is primarily used to measure food security at the global, nation and local level (Fawole et al., 2016), age adjusted per capital calorie and anthropometric measures are frequently used for assessing food security at the household level and nutritional status at the individual level, respectively (Hoddinott and Yohannes, 2002). These techniques are time- and money-consuming, and also miss out on crucial aspects of food security like quality (dietary diversity and micronutrient sufficiency), vulnerability and risks, fluctuations, and consumption trends over time (Degefa, 2005).
The use of recall durations of 24 hours, 7 days, or 30 days in dietary intake surveys is growing in popularity (Bashir and Schilizzi, 2012).These techniques heavily rely on respondents' memories of the amount, quality, and other household food-related experiences during the reference period (Maxwell et al., 2013). One of the main advantages of these methods is that they examine the quantity, quality, and current and future patterns of food consumption in the household, rather than only measuring food availability (Bashir and Schilizzi, 2012).

In this study, food security is measured using the Household Food Insecurity Access Scale (HFIAS) and Food Consumption Score (FCS), as well as a composite food security indicator that is created by integrating the HFIAS and FCS using the method proposed by Maxwell et al. (2013). According to Maxwell et al. (2013), employing two or more indicators to quantify food security is preferable than doing so with just one because the former allows for the capture of more aspects of food security.

1.11.3 Eucalyptus trees and Livelihood-Food Security

Studies on the effects of eucalyptus farming on food security status of rural households are scanty in Ethiopia and even some of the studies done did not use standard food security

indicators (e.g. Getachew, 2016). His study indicated that farmers in Bambasi *wereda* of the Benishangul-Gumuz Regional state were converting their crop lands to eucalyptus plantation due to higher returns from the latter as a result of which local food production was on a declining trend. He further reported eucalyptus trees to have negative impact on the growth of neighboring plants due to its shading effects and allopathic chemicals which are produced from the different parts of the tree. He came to the conclusion that the community's level of food security is negatively impacted by the unchecked spread of eucalyptus tree plantations. As a result he proposed a complete ban of planting eucalyptus tree on agricultural lands. In other studies as well (see Betre, 1998; Alemie, 2009), it was found that eucalyptus decreased almost all crops and vegetables yields due to its shading effect, competition for water and nutrients, and production of toxic exudates. These claims imply that eucalyptus expansion can have a negative impact on food security in the long-term because it influences the stability component of food security due to its negative environmental effect which may ultimately decrease agricultural productivity.

Contrarily, some studies have indicated that income from eucalyptus tree is significantly higher than income from agricultural products and other exotic trees, increasing the purchasing power of rural households leading to the improvement of their livelihoods and food security (Amare, 2002). According to Feyisa et al. (2018), 83% of sample households indicated that the adoption of eucalyptus trees had improved their food security by increasing their purchasing power, enabling them to buy both the essential agricultural inputs for their farm work and the food they needed directly from the market.

According to a study by Mekonnen et al. (2007) conducted in Central Ethiopia, declining agricultural productivity and lack of off-farm employment opportunities were the main reasons for farmers to plant eucalyptus trees. Eucalyptus trees were found to be the best coping strategy because of their high rate of biomass production, ease of cultivation, and adaptability to different agro ecological zones. According to the same study, eucalyptus trees contributed significantly to rural households' livelihood in the study area, accounting for 25% of their annual cash incomes and 74% of the firewood sold.

Zerihun (2010) investigated the impact of planting eucalyptus on food security among coffee-producing smallholder farmers around Jimma- Oromiya Region. He discovered that 44.9% of homes had eucalyptus and that their average annual income exceeded ETB 4000. According to him, their average annual revenue would have been between ETB 2000 and ETB 3000

without eucalyptus trees. He came to the conclusion that eucalyptus cultivation is an essential component of the livelihood of low- and middle-income households, and that its discouragement may make those households more susceptible to food insecurity.

In general, empirical research have not come to a clear conclusion regarding how eucalyptus affects the food security of households and whether to encourage or discourage smallholder farmers from planting eucalyptus trees. Hence, this study will serve to clarify contentious issues surrounding the effect of eucalyptus trees on smallholder farmers' food security status and provides suggestions to stakeholders as to how they should manage eucalyptus tree in connection to food security challenges

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1.12 Analytical Framework

Figure 1.2, the analytical framework of the study, shows the interplay between the various factors and the major issues associated with the expansion of eucalyptus tree and the resulting consequence on land use which ultimately influence the livelihood of smallholder farmers in the study area. These issues include the perception of households towards eucalyptus tree, its expansion and drivers, as well as its effects on LULC dynamics and the resulting effect on the livelihood of smallholders which is directly related to the food security of the study area.
As depicted in the figure, eucalyptus expansion, which can be defined as an increase in the number of eucalyptus trees planted (Zerga and Berta, 2016) or increase in land allocated to it (Getachew, 2016) can be influenced by a variety of factors including demographic (gender and age of household head, family size, etc.), socioeconomic (land size, livestock, income, etc.), institutional (extension services, policy regimes, etc.), and infrastructural (access to market, availability of social services like health centers, schools, etc.) factors (Kebede, 2017; Gebreegziabher, 2020). The extent of eucalyptus expansions is also expected to be heavily influenced by the perception of smallholder farmers (Hennessay, 2012; Pervin, 2017).

Despite the fact that eucalyptus trees can improve smallholders' livelihood by meeting their own demand for trees and generating higher income than traditional crop products (Dessie and Erkossa, 2011), it is thought that these benefits come at the expense of food production (Getachew, 2016; Bazzane et al., 2021), which may result in a reduction in household food availability. This is due to the fact that eucalyptus trees are widely believed to take fertile rural land which produces food not only for the farmers themselves but also for the rapidly expanding urban population of the developing world and this raises the issue of sustainable

use of natural resources. Additionally, it is generally accepted that eucalyptus trees contribute to environmental problems by draining ground water (Daba, 2016), depleting soil fertility due to their allopathic effects (Bazzana, et al., 2021), and inhibiting the growth of other plants due to their shading and water competition effects (Betre, 1998; Alemie, 2009). As a result, there are increasing concerns about the net effects of eucalyptus trees expansion on the already fragile food systems of many rural areas of Ethiopia including Gurage Zone.

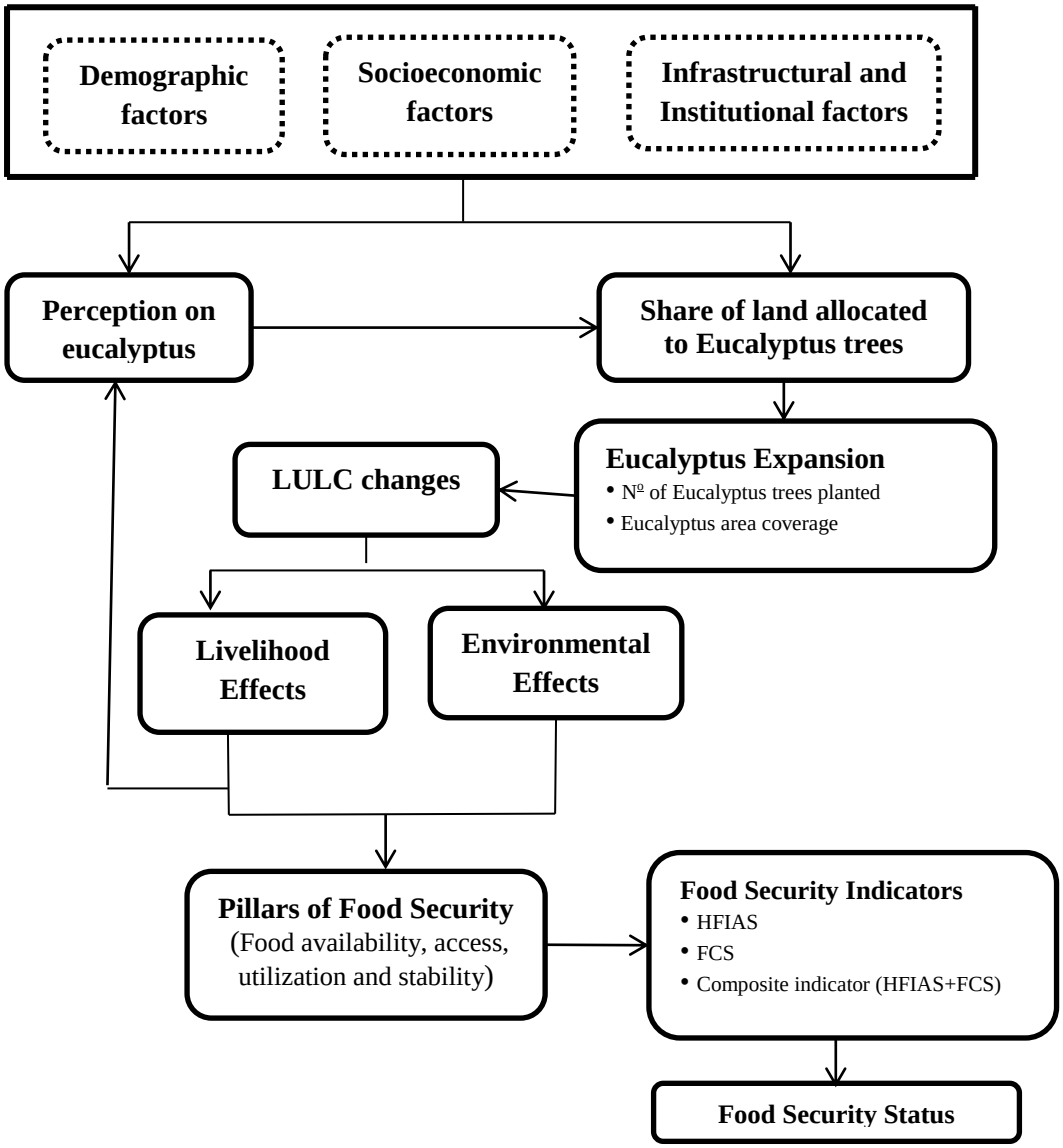

Figure 1. 2: Analytical Framework

In order to obtain crucial policy inputs for a sustainable land use in rural Ethiopia, it is vital to analyze the overall effects of eucalyptus plantations on the livelihood of rural households which highly influence their food security status. The food security status of households in

the study area is determined by using a composite food security indicator which is derived by integrating HFIAS and FCS.

1.13 Organization of the Dissertation

This dissertation is divided into six chapters. Important components such the study's background, the research questions, the problems statement, and the research techniques used to address the research questions are covered in the first chapter of the dissertation. The second through fifth chapters address the four articles that were written based on the dissertation's research objectives. The study's recommendations and conclusion as well as the key findings and the synthesis of this study are part of the sixth chapter.

The first paper, which examines how smallholder farmers perceive the impacts of eucalyptus trees on their livelihood and the environment, is presented in the second chapter. This article which is published by Journal of Sustainable Development in Africa (JSDA) explores the perception of households and other stakeholders towards eucalyptus plantation.

The third chapter presents the second article which is on the livelihood contribution of eucalyptus trees to rural livelihood and the factors that influence the share of land allocated to it. The article assesses the contribution of eucalyptus tree to the income of rural households, its use as source of energy for cooking, lighting and heating the household. This article is also published by Trees, Forests and Livelihood journal which is under Taylor & Francis publisher.

The fourth chapter presents a published article by the Journal of Land Use Policy which is under Elsevier publisher. It is about the expansion of eucalyptus tree and the factors that influence it in Gurage Zone. The fifth chapter presents another published article by Heliyon Journal which is under Elsevier publisher. It assesses factors that affect the food security of smallholders' households who use eucalyptus tree plantation as a livelihood strategy in the study area.

Chapter 2: Smallholder Farmers' Perception on Livelihood and Environmental Effects of Eucalyptus Tree- An Empirical Study in Gurage Zone, Ethiopia[1]

Abstract:

Eucalyptus tree is expanding on farm lands of Ethiopia at an alarming rate and efforts of local authorities to control this expansion have become sources of conflict and wide spread grievances among smallholder farmers in Gurage Zone. Focus Group Discussion, key Informant Interviews as well as Household Survey were used as data collection methods. The result from the ordered logit estimation indicated households' perception to be influenced by demographic and socio-economic factors such as age and educational level of household head and total land holding. Households who have positive perception towards eucalyptus tree, continue planting it despite the negative perception of experts and local officials and their efforts to control its expansion. The formulation and effective implementation of policy regarding eucalyptus trees and undertaking continuous awareness raising programs are essential measures needed to win the support of farmers in regulating the expansion of eucalyptus tree which is essential for a sustainable use of rural lands.

Keywords: eucalyptus expansion, farm forestry, sustainable land use, Likert scale, ordered logit, perception index

[1] Published by: Journal of Sustainable Deveopment in Africa (JSDA):24(4).ISSN 1520-5509

2.1 Introduction

Ethiopia is a country where more than 80% of its population depends on the agricultural sector for their livelihood. However, the performance of the agricultural sector is still very low due to many interrelated factors such as low adoption of modern technologies and inputs, small and fragmented land size and land tenure insecurity (Yigezu, 2021). As a result, the country's ability to feed its population is falling year after year. For instance, the share of food import as a percentage of all merchandise imports has continuously increased from 8.96% in 2014 to 18.40% in 2020 mainly due to continues population growth and decline in per capita food production (World Bank, 2022).

Despite government's efforts to improve the food security of the country by increasing farm level productivity, smallholder farmers in several parts of the country are diverting their land and other resources to the production of cash crops and farm forestry. However, this has not received much attention by both policy makers and practitioners (Getachew, 2016). In relation to food security, an important issue that has to be addressed properly is the rapid expansion of eucalyptus tree at the expense of crop lands in many parts of rural Ethiopia (Tola, 2010; Mesfin & Wubalem, 2014). More and more researchers have come to argue that agroforestry and farm trees to improve households' food security in the face of declining productivity of smallholders' agriculture due to lower labor demand of trees, their capacity to generate more income and also declining access to land in many rural areas (Waldron et al., 2017; Duffy et al., 2021). Though studies on the particular case of eucalyptus tree are scarce, a study by Peralta and Swinton (2009) indicated that farmers in Western Kenya are unlikely to replace food crops by trees in the long-run due to the high cost of getting subsistence household requirement of food grain from the market. However, the case in Ethiopia seems different since empirical studies are showing eucalyptus tree to expand rapidly at the expense of crop lands in most part of the country (Alemie, 2009: Jenbere et al., 2012; Getachew 2016). For instance, a study conducted by Getachew (2016) in Bambasi *wereda* of Benishangul–Gumuz Regional State reported eucalyptus trees have concurred 45.15% of smallholders' fertile crop lands- within few years of its introduction into the area.

Eucalyptus is the most widely planted but also debated tree in Ethiopia (Tekelay, 2000). Its cultivation is believed to be influenced by many interrelated factors and the perception of farmers towards eucalyptus tree is one of the most important factors (Derbe et al., 2018). In many parts of rural Ethiopia, farmers continue to plant it on their limited land despite

concerns about its negative implications on the environment and food security (Alemu, 1998; Alemie, 2009: Getachew, 2016). The various actors, i.e. farmers, experts and local officials do not agree with the benefits and cost of planting eucalyptus trees. As a result, conflicts arise among these actors mainly due to lack of understanding of farmers' motive and perception about the tree. To find sustainable solutions to the eucalyptus conundrum observed in many parts of Ethiopian in general and in the study area in particular, it is crucial to understand smallholder farmers' perception about the livelihood and environmental effects of eucalyptus tree. Moreover, identifying the various factors that influence households' perception of the tree and the extent of their influence will be crucial since smallholder farmers are the major agents of eucalyptus expansion in many rural areas of Ethiopia (Zerga and Berta, 2016; Alemu, 1998). Hence, this study aims at addressing these issues and forwarding some recommendations that might be helpful for future planning and implementation programs in order to achieve a more sustainable use of rural farm lands of Ethiopia.

Oxford dictionary, edited by Stevenson (2010) defines perception as the way in which something is regarded, understood or interpreted and this implies it may or may not fully reflect the reality, but it influences one's opinion, attitudes and response to policies or programs (Pervin, 2017; Yohannes, 2019). The process of perception involves stimuli (inputs) which are transformed into perceptual outputs like feelings, opinion, attitudes, etc., which ultimately determines individual's behavior and actions and this ultimately determines our economic and social conditions (Ochoo et al., 2017). From the process of perception, we can see that one's attitude and action is the result of own perception about that agent or issue and therefore understanding peoples' perception can be a very important input in any development intervention.

One of the reasons for analyzing perception is because it varies from one individual to another due to various demographic and socio-economic factors. A study by Yohannes (2017) indicated that perception of households towards climate change is significantly affected by demographic factors such as sex and marital status of household head in addition to other economic variables. Studies also suggest that the perception of an individual is likely to change over time for various reasons. According to Hennessy (2012) earlier positive perception held by East San Francisco Bay residents on eucalyptus which was reinforced by resource management goals such as lumber, fire wood, oil, etc. and the promotion of wealthy landowners and influential members of society changed to negative perception due to

historical events (massive fire hazard) and environmental education given to society as a result of which during the survey almost 98% of respondents described eucalyptus as ‘invasive species’.

This research is expected to have important contributions to knowledge and policy formulation. First, since we have not found such a study in the study area, the findings of this study are expected to help policy makers understand the local knowledge, opinions and views which can be used as inputs in formulating policies and designing future programs that aim at proper land use and management practices. Second, it adds to the existing but little literature on debate on agriculture-environment tradeoffs with regard to incorporating the perceptions, opinion and views of farmers and other stakeholders in any rural development effort. In addition, nowadays there is an increasing awareness that only formal scientific knowledge will not be sufficient to solve the various problems the rural communities are facing. As a result, there is an increasing interest to incorporate knowledge of the local people and their perception in development programs (Finucane, 2009; Arsiso et al., 2017). However, very little attention is given to views and opinions of smallholder farmers on eucalyptus tree plantation in Ethiopia in general and in the study area in particular.

2.2 Materials and Methods

2.2.1 Study Area Setting

Gurage zone is found in the newly formed Central Ethiopia Region. According to population projection of CSA (2021), the total population of the zone was estimated to be 1,791,034 in 2021 of which more than 80 % were rural residents. The elevation of the zone ranges between 968 meters asl to 3638 meters asl (Damene et al., 2007)

Though most farmers practice mixed farming system, enset (*Ensete ventricosum* or "false banana plant") is the principal crop in the Zone. It is characterized by its massive stem that grows underground and is involved in every aspect of Gurage life. In recent years, there is a

rapid land use pattern change in Gurage Zone due to the rapid expansion of eucalyptus tree which makes the zone one of the leading suppliers of eucalyptus logs to many parts of the country (Zerga and Berta, 2016). Figure 1.1, shows the map of the study area.

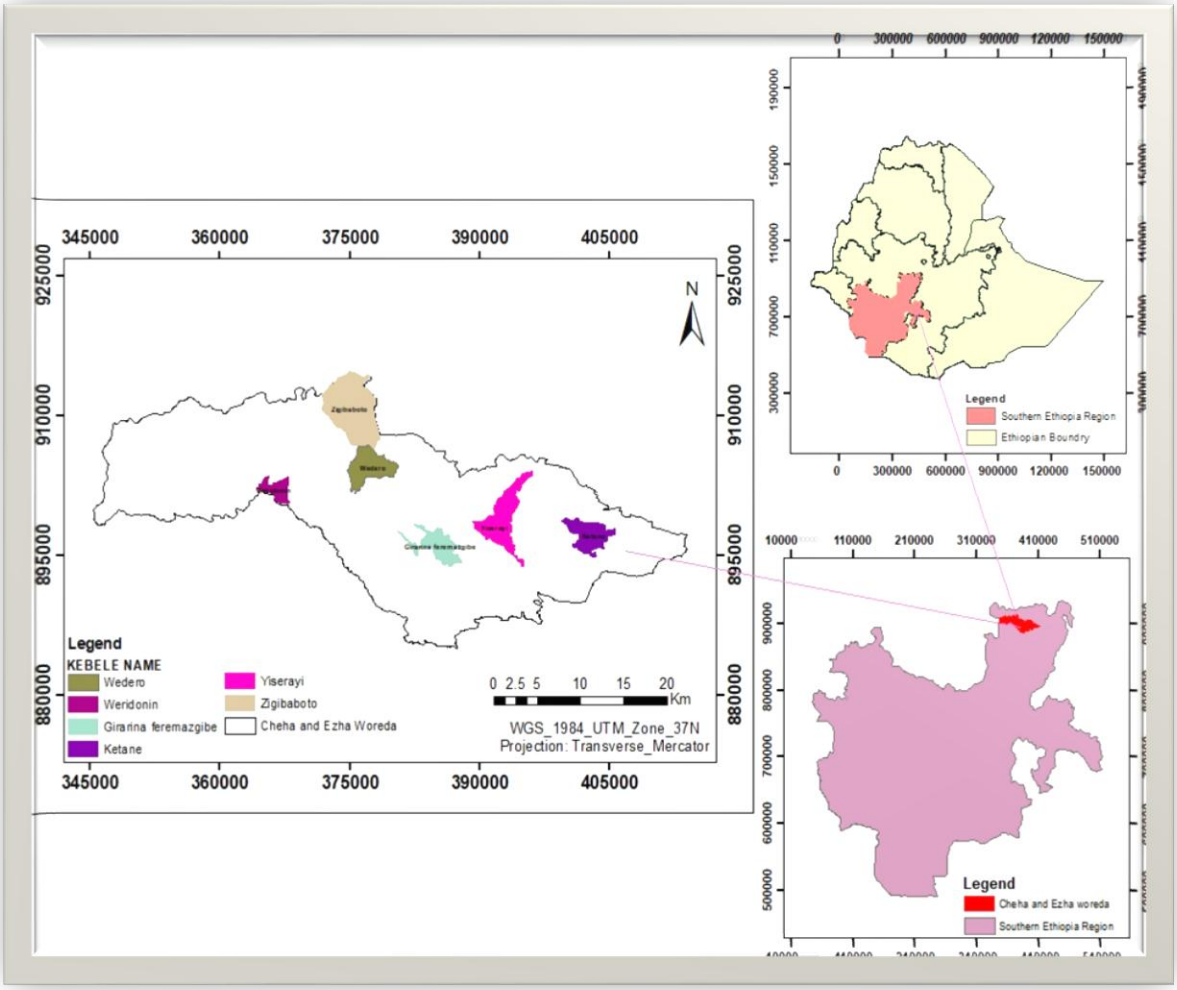

Figure 2.1 Map of Study Area (ESSGSI, 2021)

2.2.2 Sampling Techniques and Data Collection Method

There are sixteen *weredas* in Gurage Zone and each *wereda* is further divided into smaller administrative units called '*kebele'*. The study is done in two purposefully selected *weredas* where eucalyptus plantations are practiced widely. According to Zerga & Berta (2016), there are four *weredas* in Gurage Zone with higher practice of eucalyptus plantation- Enemor and Ener, Cheha, Ezha and Gumer. From these four the study was done in Ezha and Cheha *weredas*.

From each *wereda* three *kebeles* were purposively selected based on the extent of eucalyptus tree expansion and one *kebele* from each of the three agro-ecological Zones- lowland *('Kolla'*), mid altitude ('*Weyinadega'*) and highland ('*Dega'*). Experts from the respective Agriculture and Natural Resource Bureau were consulted in selecting *kebeles* from each *wereda*. The sample households were selected using systematic random sampling procedure in which the first household from each *Kebele* was picked randomly from a list of households obtained from their respective *kebeles* and then every 6^{th} household was taken to get the required sample size from each *kebele*.

Using the formula given by Yamane (1967) for sample size determination, the total sample size for this study was calculated to be 480 households which then were divided to the six kebeles based on their respective household size. As a result 87 from Zigbaboto, 45 from Yesray, 103 from Ketane, 53 from Weredene, 88 from Wodro and 104 from Girar and yefermazigibe sample households were selected.

In addition, information was also collected using Focus Group Discussion (FGDs) and Key Informant Interviews methods. Participants in FGDs were selected in such a way that they represent the youth, elderly and women and a total of six FGDs (one in each Kebele) were undertaken. Key informant interviews at *wereda* and *kebele* level were also held with government officials, experts and DAs (Development Agents) who are more familiar with the socio-economic and environmental conditions of the study area.

2.2.3 Data Analysis

In this section a discussion on how the perception indicators are calculated are presented first then a discussion on econometric model specification follows.

2.2.3.1 Perception Indicators

We used different indicators (indicated by Table 2.1) to calculate a value of perception that reflects the level of agreement of each respondent to the different perception questions. Each perception question had 5 Likert Scale response options reflecting the level of agreement to each of the perception statement provided to the household head in our survey . The questions were presented as follow:

"Eucalyptus trees generate more income than your alternative agricultural produce"

(1) Strongly Disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly Agree

Table 2. 1: Outcome Variables and Perception Indicators Used

Outcome Variables	Indicators
Household Livelihood	(1) Generate more income than alternative agricultural Produce.
	(2) Covering social contribution such as *ekub*[2] and *idir* [3].
	(3) Getting additional income.
	(4) Higher market demand (marketability).
	(5) Source of money during emergency cash needs.
	(6) Serving as a major input in construction.
	(7) Major source of fire wood.
Environmental Effects	(1) Negative effects on the growth of other plants (reduce food grain and forage availability).
	(2) Reduces availability of ground water.
	(3) Negative impact on future soil fertility (productivity).

In our questionnaire, the questions on environmental issues were stated as negative statements like "Eucalyptus tree has negative effect on the growth of other plants (reduce food grain/ forage availability)". So agreement to such statements means holding the opinion that eucalyptus has negative effect on the environment while disagreement means holding the opposite opinion.

2.2.3.2 Econometric Model Specification

An ordered logit model which uses maximum likelihood estimation was employed to evaluate the probability of responding with one of the five categorical response options given to respondents. The use of OLS would treat, for instance, the difference between strongly disagree (1) and disagree (2) as the difference between neutral (3) and agree (4). However, these are only rankings representing the perception of individuals. In addition, when the response items are ordinal like the ones we have in this perception analysis, using OLS will not be appropriate as the estimates can be biased and misleading (Mckelvey & Zavonia, 1975). Using multinomial logit or probit model would also fail to capture the ordered nature of the dependent variables (Green, 2003). Therefore, we have employed ordered logit model to identify factors that influence the level of agreement to the perception statements.

[2] an informal financial institution like Rotating Savings and Credit Association (ROSCA) formed by individuals who usually know each other very well.
[3] an indigenous social insurance formed for the purpose of providing economic and social support to members in the events of unfortunate incidences usually bereavement.

Let Y^* be the feeling (Perception) of a given household about eucalyptus tree. Suppose this unobserved (latent) variable is assigned 0-100% point on a level of agreement on perception statement about eucalyptus but if the possible responses are condensed into five then respondents can express their feelings using the available five choices (ordinal variables) such as strongly disagree, disagree, neutral, agree and strongly agree. This means respondents must decide which one of the five available options best reflects their feelings (perception) about the livelihood and environmental effects of eucalyptus tree.

Let Y be the observed ordinal variable and hence;

$$Y = f(Y^*) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Assuming we have M observed responses (Y_i=1, 2, 3,…,M) from the unobserved latent variable Y^* .

We can state that:

$$Y_i^* = X_i\beta + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$Y_i = j \qquad if \ Y_{j-1} < Y^* \leq Y_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Then for any $Y_j s$ with $Y_0 = -\infty$, $Y_1 = 0$ and $Y_M = \infty$, the probability that alternative j is chosen is the possibility that the latent variable Y^* is between two boundaries Y_{j-1} and Y_j . In Eq 2, X_i refers to vector of independent variables that influence the dependent variable Y_i^* and ε_i $is\ the\ disturbance\ term.$

If we assume ε_i to follow a logistic distribution N(0,1), we have ordered logit model (Williams, 2021). For a five–scaled Likert scale response, there will be four cutpoints (C_i= 1… 4) separating responses from one another, then the ordered response model can be stated as:

$$Y_i^* = X_i\beta + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\begin{aligned} Y_i &= 1, \quad if \ Y_i^* \leq C_1 \\ &= 2, \quad if \quad C_1 < Y_i^* \leq C_2 \\ &= 3, \quad if \quad C_2 < Y_i^* \leq C_3 \\ &= 4, \quad if \quad C_3 < Y_i^* \leq C_4 \\ &= 5, \quad if \quad Y_i^* > C_4 \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Using eq. 5 and the assumed logistic distribution of the disturbance term, the ordered logit model can be used to estimate the probability that the unobserved variable Y^* falls within the various cutoff points.

Two estimations of ordered logit regressions are presented in this study. The first is for the perceived effect of eucalyptus tree on livelihood while the second one is for environmental effects. In our estimation, we have attempted to take both sides of the argument in relation to eucalyptus trees. The livelihood estimation takes those issues raised in favor of eucalyptus plantation (eucalyptus as a 'blessing'). Livelihood perception questions include issues such as income generation, firewood, construction material and marketability of eucalyptus. The estimation on the environmental effect on the other hand, addresses issues raised against eucalyptus tree (eucalyptus as a 'curse'). Those who claim eucalyptus tree to be harmful raises environmental issues such as shading and allelopathic effect of eucalyptus tree which negatively affect the growth of neighboring plants, and also reducing soil fertility and ground water (Bazzana, Gilioli, Simane, & Zaitchik, 2021; Zerga, 2015; Getachew, 2016).

Stata 14.2 software was used to analyze the data.

2.3 Results and Discussions

2.3.1 Reliability of Indicators of Perception

In order to get a better result in a research like this which mainly uses Likert–type questions, undertaking reliability tests is very important. Since the outcome variables used in our perception analysis are latent variables, we use scale (group of questions) to make them measureable. As a result, we need to check to what extent the questions in the scale relate to each other and their degree of reliability. For Likert-type questions the most appropriate measure of reliability is Cronbach alpha (α) which is calculated by taking the variance, covariance and the total number of items included in a scale. Its values lie between 0 and 1 and if all of the items in the scale are entirely independent from one another Cronbach's alpha will be 0 and as it approaches 1, items in the scale have higher and higher covariance and suggests the items tends to measure the same underlying concept (Virginia, 2015).

Cronbach's alpha (α) is calculated for each outcome variable using the expression;

$$\alpha = \frac{K * \bar{C}}{\bar{V} + \bar{C}(K-1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where $K = \text{Number of items in a scale}$

$\bar{C} = \text{average covariance between items}$ and $\bar{V} = \text{average variance}$

A Cronbach's alpha (α) greater than 0.95 may indicate redundancy of items in a scale and when the value is between 0.8 and 0.95, 0.7 and 0.8, and 0.6 and 0.7 shows very good, good

and fair reliability, respectively. A value below 0.6 is unacceptable and needs reviewing (Zikmund, Babin, Carr & Griffin, 2010). Cronbach's alpha was calculated using Stata 14.2 software and the result is shown in Table 2.2.

Table 2. 2: Reliability Status using Cronbach's Alpha

Outcome variables	**Nº of items**	**Scale Reliability Coefficient (Cronbach's Alpha)**	**Reliability Status**
Households' Livelihood	7	0.7521	Good
Environmental Effects	3	0.8234	Very Good

Source: own survey (2021)

The reliability test, in general confirms the questions used to capture each outcome variables are acceptable though at different degree since both Cronbach alpha values are above 0.7. Environmental effect has a higher value (0.82) which shows less variance among the responses given to the three environmental items which suggests that respondents had more or less similar responses to the environmental perception questions compared to that of the livelihood perception questions.

2.3.2 Households' Perception towards Eucalyptus Tree

2.3.2.1 Households' Opinion on Issues related with Eucalyptus Tree Expansion

Though the household may have different motives for engaging in eucalyptus tree farming, it is important to identify their prime pushing factors that lead to the decision to plant the tree. To this end, households were asked about their prime reason for planting eucalyptus trees. The results suggest that income generation is the prime motive for around 66% of the respondents. While nearly 18% of the sampled households reported that immediate cash need was their prime reason. Those who identified household own demand for wood as their prime reason constituted around 11.7% of the sampled households.

Another interesting finding of this study is that unlike the claims made by other local government authorities, only 4% of the sampled households reported that their land holding was unsuitable for regular farm production. This suggests that most farmers are planting eucalyptus trees on lands which are suitable for crops. This is an issue to be explored further in order to find a balance between the forest and food nexus.

To examine the views of households towards the benefits of eucalyptus trees in their locality; we asked them the following question "Do you think eucalyptus tree plantation in your locality has benefited the community more?" The response shows that 61.7% of them responded 'yes' while the remaining 38.3% responded 'no'. From this we can say, though the majority was in favor of eucalyptus tree, there were also some households (more than a third) who had some concern about its expansion in their localities. From those who replied 'no', around 80% of the respondents reported eucalyptus tree's negative impact on local food production as their main reason followed by its negative impact on the growth of other neighboring plants and the environment as second and third reasons constituting 17.4% and 2.7%, respectively.

When asked about government's reaction towards the expansion of eucalyptus trees in their localities, more than 96% of the sampled households responded by saying 'the government discourage eucalyptus plantation', while only 0.83% replied with the option of 'government promote eucalyptus plantation' and the remaining 2.5% reported that they did not know about the reaction of the government. Participants, during the FGDs also stated agricultural experts and other government officials discourage farmers from planting eucalyptus tree especially on farm lands suitable for crop production or *enset* plantation.

Table 2.3 below, presents the response of the respondents to the question on measures the government mainly uses in order to control and discourage eucalyptus plantation and expansion. The three measures mentioned by the sampled households were awareness creations, warnings and forceful uprooting of eucalyptus seedlings.

As summarized in Table 2.3, most households (55.4%) reported 'warning' to be the most commonly measure used by the government to control eucalyptus expansion. Around 43% of the respondents identified 'awareness creation' as another measure to control the expansion of eucalyptus tree. Forceful uprooting is not common and only 2% of the sampled households reported such cases in our study area. *Wereda* level officials mentioned cases of eucalyptus uprooting measures taken by task forces formed for this purpose when found planted on communal lands left for grazing or other purposes. This usually creates grievances among farmers and it does not seem working since eucalyptus tree farming is continuously expanding in the study area.

Table 2.3: Measures Taken by the Government to Control Eucalyptus Expansion

Measures	**Frequency**	**Percentage**
Forceful Uprooting	9	2.0
Warnings	255	55.4
Awareness Creation	197	42.6
Total	460	100

Source: own survey (2021)

According to the *wereda* level experts, the reason for such kind of land use is partly failure in implementing the existing Proclamation 110/2007 (SNNPRS, 2007), issued by the Regional Government which under Article 'Obligation of Rural Land Users' states "A holder of rural land shall be obliged to properly use and protect the land . When the land gets damaged the user of the land shall lose his use right." However, most farmers in the study area believe that it is their right to use their land in any way they like.

DAs and local officials consider eucalyptus tree as a conundrum that threatens future food security of the area due to its continuous expansion despite their efforts to reverse the condition. During one of the interviews held at the *wereda* level an expert responding to the question "Is there any support you provide to those who engage in eucalyptus farming?" replied "let alone giving support, if possible we would be happy to eliminate it from our Zone altogether." This opinion is far from being unique among local government officials and agricultural experts which may also suggest their frustration in controlling the expansion of eucalyptus trees under the existing circumstances. In addition, during the FGDs some participants clearly stated that often DAs advice and warn them not to engage in planting eucalyptus trees. Hence in order to avoid confrontations, eucalyptus tree planting in the study area are usually undertaken when DAs and other government officials are not around. This suggests the need for awareness creation and policy formulation that enable a sustainable use of land that can strike a balance among the various objectives of stakeholders such as the need for food and forest products as well as addressing the environmental issues.

Our survey results further indicated that around 97% of the sampled households believed that eucalyptus tree plantation is expanding rapidly while the balance, that is only 3%, argue against. This indicates that the majority of the farmers themselves support the opinion of local administrators and experts that eucalyptus tree is expanding at an alarming rate in the study area. An attempt was also made to know what farmers feel about the expansion of

eucalyptus tree in their locality, but the finding was inconclusive as those who replied they were happy to see this expansion were almost in equal percentage as those who were not happy (have some concern). However, according to a study conducted by Jenbere et al. (2012) in Arsi Negele, 57.8% of the respondents were found to perceive eucalyptus expansion to cause a series problem to their community in the future who identified the adverse effects of eucalyptus expansion on local food production as their prime concern,

A question was given to the respondents in order to know their perception on the effects of eucalyptus tree expansion on future food security situation of the local community. The majority (around 53%) perceive that it is likely to improve the food security of the local community. This could be the result of expected higher income from selling eucalyptus products which might be used to buy essential agricultural inputs such as fertilizer and seed in addition to enabling them to buy some food items directly from the market (Tola, 2010; Alemie, 2009).

2.3.2.2 Calculating Perception Index

As mentioned earlier 7 and 3 perception questions (indicators) were presented to each household for livelihood and environmental perceptions, respectively. As a result, 7 responses were obtained from each household for perception on livelihood and 3 responses for environmental effects. However, for sake of generalization and summary, only a single value that can give the 'average response' of a particular household is needed. Therefore, a mean value of perception (perception index) was calculated for each household using the following formula.

$$PS_i = \frac{\sum_{j=1}^{N} Q_j}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (7)$$

Where: PS_i= Perception Index (score) of the i^{th} Household (i=1 … 480)

Q_j= Response on the j^{th} perception question (j=1… N),

N= Number of indicators for each outcome variable

The mean perception score from Eq. 7 is a continuous number between 1 and 5. However, we need to assign a categorical ranking that ranges from strongly disagree (1) to strongly agree (5). For this purpose, we need to have five equal class intervals with the lowest and highest possible values being 1 and 5, respectively. Therefore, we used five equal ranges to label the perception indexes into the five categorical rankings. As a result, each household was

neutral and only 9.8% and 5.4% responded with ‘disagree’ and ‘strongly disagree’, respectively.

Based on socio-economic studies on eucalyptus tree in Ethiopia, Dessie & Erkossa (2011) reported eucalyptus tree to have a significant contribution to household income compared to any other agricultural produce. This is in line with the findings of this study and this shows why household in the study area have positive opinion on eucalyptus and are eager to plant the tree. In addition, as part of livelihood strategies eucalyptus is also used as a security tree in many part of Ethiopia. This goes in line with the findings of Adimasu, Kessler, Yirga and Stroosnijder (2010) who argued that eucalyptus tree was considered by farmers in Ethiopia as a security crop in times of crop failure due to draught and pests.

2.3.2.4 Perceived Effects of Eucalyptus Tree on Environment

One of the major issues raised with the expansion of eucalyptus trees is its impact on environmental quality. Some question the expansion of eucalyptus tree from its ‘negative impact’ on the environment due to its allopathic and shading effect and also claims of decreasing soil fertility and ground water (Bazzana, et al., 2021; Alemie, 2009). To address these issues, as shown in Table 2.1, three questions were include in the survey to capture the perceived effects of eucalyptus tree on the environment.

Using equation 7, the minimum and maximum environmental perception index for the sampled households were found to be 1.33 and 5.00, respectively and the mean value was 4.18. The mean perception index indicates that households on average responded with the option of ‘agree’ to the statements that eucalyptus has a negative impact on the environment. From Figure 2.2, the most chosen option was ‘strongly agree’ with 40.4% of respondents and also the majority of the sampled households (78.7%) have responded positively to the statement that eucalyptus has a negative impact on the environment. While only 12.5% responded with ether ‘disagree’ or ‘strongly disagree’. This indicates that sampled households overwhelmingly agree with the claim that eucalyptus trees have negative impact on the environment.

From the descriptive analysis of perception questions, we can conclude that households in the study area plant eucalyptus to make advantage of generating more income, serving as means of fulfilling immediate cash and fire wood demands of the household among other benefits despite their perceived environmental effect of the tree. . This finding is consistent with

Alemie (2009) who claimed that farmers in Koga Watershed in Western Amhara Region of Ethiopia perceived eucalyptus plantation depreciates the potential of the environment but they keep on growing the trees because of the relative short time required to produce wood biomass for fuel, construction and cash.

2.3.3 Econometric Analysis of Households' Perception on Eucalyptus Tree

The results of ordered logit estimations on coefficients and marginal effects are presented in two sections. The first section discusses estimation result of the effects of eucalyptus tree on livelihood while the second one discusses the result of the environmental effects.

2.3.3.1 Estimation for Perceived Effects of Eucalyptus Tree on Livelihood

A summary of result of estimations from Stata 14.2 for coefficients and marginal effects are given in Table 2.5 and Table 2.6, respectively. From the results of estimation, the model as a whole was statistically significant which rejects the null hypothesis that states there are no predictors (the coefficients of all the estimates are zero) since the Likelihood ratio chi-square (97.76) has a p-value of 0.0001. This shows the independent variables included in the model as a whole explains the perception of households. The model also has a pseudo- R^2 of 0.0795.

Coefficients in general indicate the direction of the relationship between dependent and independent variable and their values indicate the log odds of increase or decrease being in a higher level of agreements to the perception statements depending on their signs. However, the interpretation of the numerical value of a coefficient is a bit complicated and its meaning is also somewhat confusing (Mckelvey & Zavonia, 1975; Williams, 2021). For this reason, marginal values are used for numerical interpretation.

From the regression result presented in Table 2.5, we can see that the nature of land (being suitable for crop production or not) is not significant factor in explaining variation in the perception of households. This may somewhat reflect the observation of the researchers and also the opinions reflected during key informants interview that households use all types of lands including fertile crop land to grow eucalyptus tree and this is also consistent with the finding of other research such as Getachew (2016) and Tola (2010).

Table 2.5: Coefficient Estimation of Factors Influencing the Perceived Effect of Eucalyptus on Livelihood

Variables	Description of Variables	Coef.	Std. Err.	p>|z|
Gedr	Gender of Household Head (Male 1; Female 0)	0.3192181	0.2077404	0.124
Mrstt	Marital Status (Married 1; Single 0)	-0.0479539	0.2074002	0.817
Ageh	Age of Household Head (years)	-0.0215709	0.0116118	0.063
Elhh	School year of Household Head	0.0900985**	0.027228	0.001
Lnsz	Total Land of Household (ha)	0.8720645*	0.3733038	0.019
Avcce	Availability of Cash Crops (Yes 1; No 0)	0.4674958*	0.1898679	0.014
Acele	Access to Electricity (Yes 1; No 0)	-0.4219319*	0.1813718	0.020
Sulne	Suitability of Land for crop production (Yes 1; No 0)	-0.10094995	0.177831	0.538
Flit	Family Members between 15 & 64 years	-0.2499401**	0.0833111	0.003
Pnof	Participation in Non / Off-farm activities (1 Yes; 0 No)	0.6712425**	0.199736	0.001

** = significant at 0.01 level; * = significant at 0.05 level
Source: Own survey (2021)

The positive and significant coefficient of the variable years of schooling of household head (elhh) shows that an additional year of schooling increases the probability of having positive opinion on the perceived effects of eucalyptus tree on households' livelihood, if all other variables included in the model remain the same. The marginal value, as indicated by Table 2.6, indicates that education increases the chance of responding with 'Strongly Agree' by 2.1%. In general, households with better education are expected to be more open to adapt themselves to new opportunities and attempt to take advantage of market conditions compared to those with less education. This finding is consistent with Pervin (2017) who studied perception of smallholder farmers' towards eucalyptus plantation in Bangladesh.

The coefficient of the variable total land holding of the household (lnsz) is positive and significant. An increase of land size by one Hectare would increase the probability of responding with option 'Strongly Agree' by 20.4%, if all other factors remain the same. This suggests that households with larger land size have more favorable perception towards the role of eucalyptus for livelihood. Though the role and share of eucalyptus tree is higher in income generation for farmers with smaller land size compared to those with larger land size (Mekonnen, Kassa, Lemenh & Campbell, 2012), but still households with smaller land size tend to prioritize feeding family compared to income generation in the study area. This is because households with smaller land holding are found to be less willing to engage in eucalyptus farming for the purpose of income generation because these households give priority to food /*enset* production. This finding does not agree with Mekonnen et al. (2012)

who claimed that those with relatively smaller land size tend to be more willing to plant eucalyptus trees.

Availability of cash crop mostly *khat* and/or coffee (avcce) is also significant and the marginal effect indicates that having cash crop increases the probability of being in the category of strongly agree by 10.6%, if all other factors remain the same. This positive opinion could be the result of having some exposure to market oriented production system that made those households with cash crop to be positive to eucalyptus tree compared to those who do not have such exposures. The FGDs also revealed that in areas where there are little or no cash crops respondents are not that much enthusiastic about eucalyptus tree compared to areas where there are cash crop production and sell.

Table 2.6: Marginal Effects of Factors on Livelihood for Outcome 5

Variable	**dy/dx**	**std. Err.**	**p>|z|**
gedr	0.72767	0.04611	0.115
mrstt	-0.0112316	0.04872	0.818
ageh	-0.0050372	0.00271	0.063
elhh	0.0210398**	0.00636	0.001
lnsz	0.2036441*	0.08714	0.019
avcce	0.1063458*	0.04186	0.011
acele	-0.0968909*	0.04088	0.018
sulne	-0.0255351	0.0414	0.537
Flit	-0.0583659**	0.01945	0.003
pnof	0.1592179**	0.04763	0.001

** = significant at 0.01 level; * = significant at 0.05 level

Sources: Own survey (2021)

Having access to electricity service (acele) decreases the probability of responding with 'Strongly Agree' by 9.7% as compared to those who do not have access, if all other variables remain as they are. This could be due to the fact that those who have access to electricity are less dependent on eucalyptus tree for lighting and to some extent for cooking.

Another important variable expected to affect the perception of households towards eucalyptus plantation was the availability of work force in the family (flit) represented by the number of household members between the age of 15 and 64. This was used as an indicator for availability of labour force in the household and it was found to have a negative and

significant effect on households' perception as expected and is consistent with the findings of Jenbere et al. (2012). The reason could be due to the fact that eucalyptus farming requires less family labour and attention compared to regular farm works. This was also reflected in the FGDs that absentee farmers and those who have two or more wives tend to engage more in eucalyptus farming due to shortage of labour for regular farm work (Adimassu et al., 2010). The estimates show that one additional family member who is in the working age group is likely to decrease the respondents chance of being in the category of strongly agree by 5.8%, if all other variables remain the same.

The ordered logit model also revealed that those who participate in off/non-farm activities (pnof) are more likely to hold positive opinion about eucalyptus farming. Being participant is associated with a 16% more chance of being in the 'Strongly Agree' category as compared to non-participants, if all other variables remain the same. This could be due to participants having less time to engage in regular agricultural work that demands more labour and attention compared to eucalyptus farming.

2.3.3.2 Estimation for Perceived Effects of Eucalyptus Tree on the Environment

The result of estimation for coefficients and marginal effects on the perceived environmental effects of eucalyptus tree are summarized by Table 2.7 and Table 2.8, respectively. The estimation results showed the model chi-square to be 154.60 with 10 degree freedom and it is highly significant which indicates the independent variables included in the model have significant effect on households' perception of the effect of eucalyptus on the environment since the p-value is 0.0000.

Table 2.7: Coefficient Estimation of Factors Influencing the Perceived Effect of Eucalyptus on Environment

Variable	Description of Variables	Coefficient	Std. Err.	p>|z|
Gedr	Gender of Household head	-0.1185783	0.2161585	0.583
Mrstt	Marital status	0.0448193	0.2070217	0.829
Ageh	Age of Household head	-0.040261**	0.0119692	0.001
Elhh	School year of household head	0.0833003**	0.0274646	0.002
Lnsz	Total land holding of household (ha)	0.6831504	0.3928945	0.082
Avcce	Availability of cash crops	1.766393**	0.2047513	0.000
Acele	Access to electricity	0.424896*	0.1866353	0.023
Suln	Suitability of land for agri. Works	0.3006944	0.181794	0.095
Flit	Family members between 15 & 64 years	-0.1195058	0.0804415	0.137
Pnof	Participation in non / off farm activities	-0.0842112	0.1967876	0.669

** = significant at 0.01 level; * = significant at 0.05 level

Sources: own survey (2021)

From Table 2.7, we see that variables such as age and school years of household head, availability of cash crops and access to electricity to be significant factors while the remaining variables are found to be statistically insignificant at 5%.

Table 2.8: Marginal Effects of Factors on the Environment for Outcome 5

Variable	dy/dx	std. Err.	p>|z|
Gedr	-0.0275286	0.05057	0.586
Mrstt	0.0102885	0.04737	0.828
Ageh	-0.0092714**	0.00277	0.001
Elhh	0.0191828**	0.00632	0.002
Lnsz	0.1573194	0.0905	0.082
Avcce	0.3531613**	0.03401	0.000
Acele	0.0989316*	0.04382	0.024
Sulne	0.0693859	0.04164	0.096
Flit	-0.02775204	0.01854	0.138
Pnof	-0.0193201	0.04498	0.668

** = significant at 0.01 level; * = significant at 0.05 level

Source: own survey (2021)

Table 2.8 above, indicates that age of household head (ageh) is negatively associated with households' perception regarding the negative impact of eucalyptus on the environment. That is, when age of the household head increases by one year, the probability of responding with

'Strongly Agree' on the negative impact of eucalyptus on the environment decreases by 0.9%, if all other factors are held constant. This could be the result of younger people being more exposed to information from mass media and other sources of information on environmental issues. In addition, higher school year is positively correlated with higher perception of households regarding the negative environmental effects of eucalyptus. This could be the result of better awareness of the more educated about the alleged negative environmental effects of eucalyptus tree (Hennessy, 2012).

The result of estimation further showed that availability of cash crop and access to electricity to be positively and significantly correlated with the perceived effects of eucalyptus tree on the environment. The positive coefficient of the variable access to electricity indicates that those who have access to electricity hold stronger position on the negative impact of eucalyptus tree on the environment which could be the result of their exposure to mass-media and other sources of information about the negative effects of eucalyptus tree on the environment compared to those who do not have access to electricity.

2.4 Conclusion

This study indicated that 'income generation' is the prime motive for planting eucalypts tree in the study area. The study further showed that farmers are planting eucalyptus trees mostly on lands which are suitable for food production which implies that eucalyptus is expanding at the expense of food production as was the case in other parts of the country (Getachew, 2016; Jenbere et al., 2012). The study also indicated that some households have concerns about the long-run effects of eucalyptus expansion on local food production capacity. This suggest that it is essential to undertake a continuous awareness creation programs in order to shape the perception and attitude of smallholder farmers towards eucalyptus expansion so that they can give their cooperation and support to any future plans that aim at controlling and managing the expansion of eucalyptus tree in order to make the best use of rural land in the most sustainable manner.

One of the main findings of this study is that eucalyptus tree is a source of confrontations between farmers who believe they can plant it anywhere on their land and local officials and experts who want to prevent them from planting the trees on farm lands. In relation to this, one important issue that needs to be addressed is the issue of law with regard to eucalyptus trees plantation and use. The existing general law on 'the proper use of agricultural land' is

not strong enough to give local authorities to exercise their power in controlling eucalyptus expansion. This is because it does not clearly mention where eucalyptus trees can and cannot be planted in relation to the nature of the land and also with respect to the production of other essential agricultural products such as food crops and '*enset'* in addition to other important issues.

Sample households have responded positively to both perception questions. This means households have favorable opinion on the role of eucalyptus trees for their livelihoods. This clearly indicates that households in the study area continue to plant eucalyptus trees as it provides them with wide range of benefits such as generation of more income and fire wood in addition to serving them as a means of construction material. The study also finds that most households are fully aware of its claimed negative environmental consequences. Furthermore, the perception of households toward eucalyptus tree was found to be affected by various demographic and socio-economic factors such as education, land size, availability of labour force and cash crops. Thus, efforts to control eucalyptus expansion in the study area should take these factors into account to get the desired results.

To sum up, while experts and local government officials have unfavorable perception on eucalyptus trees and are also attempting to stop its expansion on farm lands by taking different measures. Smallholder farmers, on the other hand, have favorable perception due to its benefits as a result of which they show strong desire and commitment to plant it, though they are aware of its claimed negative environmental consequences. Therefore, based on the findings of this research, we recommend the formulation and effective implementation of rural land use policy so that authorities can have full legal right to control and manage rural land in a way that can generate the maximum economic, social and environmental benefits through a sustainable use of rural land. In addition, a continuous awareness creating programs have to be launched in order to build and maintain mutually understanding and trust among the different stakeholder especially between smallholder farmers and local authorities.

Chapter 3: Determinants of Share of Land Allocated to Eucalyptus Tree and Its Livelihoods Contribution to Rural Farm Households: empirical evidence from Gurage Zone, Ethiopia[4]

Abstract

Smallholder farmers are increasingly planting eucalyptus trees as an important farm product in many rural areas of Ethiopia including the study area- Gurage Zone. This study analyzed the contribution of eucalyptus trees to rural households' livelihood and factors that influence the share of land allocated to eucalyptus by smallholder farmers in the study area. The study mainly used household survey, key informant interviews as well as Focus Group Discussions to generate the required data for the study. The descriptive analysis indicated that eucalyptus tree to be important farm product as a source of households' energy in addition to other economic and social benefits. The study revealed that close to 98% of households use eucalyptus tree products for cooking their meals in addition to serving as an important source of heat especially during cold seasons. In addition, almost 92% of the respondents reported to use their own plantation to meet own tree demands. When it comes to income, in addition to being the most reliable source of finance during times of emergency, it contributes almost 31% to the total annual household income. Furthermore, the fraction logit estimation indicated factors such as total household income, household heads' perception towards eucalyptus trees, livestock holdings as well as distance from main roads to be important factors in determining the share of land allocated to eucalyptus trees. The study recommends government officials and experts to recognize eucalyptus trees as an important integral component of the farming system and hence assist smallholder farmers to use rural land in the most sustainable way by developing and implementing appropriate land use policy.

Keywords: Land allocation, livelihoods**,** forest products, fractional logit model, land use policy, Gurage

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3.1 Introduction

Achieving rural development goals is unlikely if not impossible without proper utilization of rural resources, especially land (Van Lier, 1998; Liu, 2018). The proper utilization of rural land is one of the most important determinants of the outcomes of development efforts ranging from the microeconomic goals of improving the living standards of rural households to the macroeconomic goals of price stabilization and increasing export earnings in agriculture dominated economies of developing countries (Daly, 1991). However, land in many rural areas of Ethiopia is used without much consideration to its best environmental, economic and social contribution. This had been attributed mainly to the absence of national land use policy (Gebeyehu et al., 2017). As a result, smallholder farmers use their land in a way that maximizes their short-term benefits without due consideration to the future implications which usually leads to controversies and even in some cases to conflicts between local authorities and farmers in many place of rural Ethiopia (Mesfin and Wubalem, 2014; Getachew, 2016; Gebeyehu et al., 2017).

One of the most common problems mentioned in line with land use practices of smallholder farmers is the rapid expansion of eucalyptus trees not only as homestead trees but also as farm forestry practices (Gizachew, 2017; Alemayehu and Melka, 2022). This is believed to be mainly due to the absence of well-articulated and effective land use policy which makes eucalyptus expansion a demand driven phenomenon where long-term consequences, including its ecological impacts, are not taken seriously into account (Jenbere et al., 2012; Bazzana et al., 2021).

The Eucalyptus genus includes more than eight hundred different species and is believed to be the most widely planted tree genus in the world. In Ethiopia, where *Eucalyptus camaldulensis* and *Eucalyptus globulus* are the two most widely planted species (Gil et al., 2010), it has been expanding in the highlands since its introduction in the 1890s by Emperor Menelik II (Turnbull, 1999; Teketay, 2000). . The decline of natural forests and the demand for wood products are believed to be the major factors that contributed to the rapid expansion of eucalyptus trees on cultivated farm land in Ethiopia (Jenbere et al., 2012; Dessie, Abate, et al., 2019).

Eucalyptus trees provide direct economic benefits to the rural community, (Zerga and Berta, 2016; Dessie, Abtew, et al., 2019) and act indirectly as an economic safety net in case of crop

failure (Gizachew, 2017). According to Alemayehu and Melka (2022), eucalyptus tree is believed to generate more income than any other alternative agricultural produce under the current circumstances in many rural areas of Ethiopia. As a result, eucalyptus tree is increasingly becoming an essential component of smallholders' farming systems, leading to a substantial change in land use patterns (Jenbere et al., 2012; Getachew, 2016; Bazzana et al., 2021). Subsequent to these changes, development stakeholders are becoming more and more concerned about potential food security and environmental issues linked to eucalyptus growing (Paralta and Swinton, 2009; Getachew, 2016).

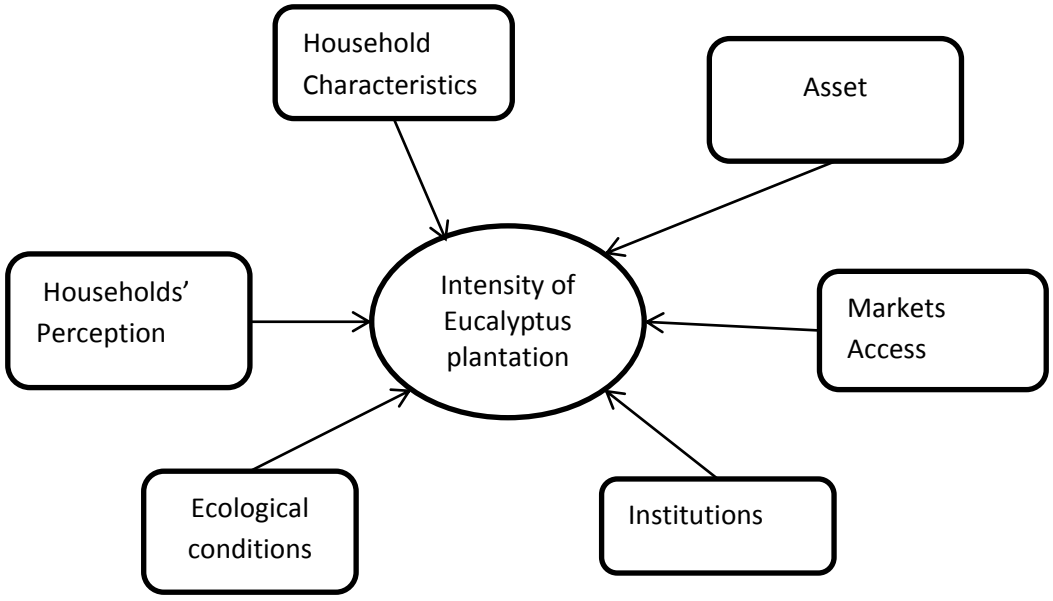
For a smallholder farmer, the decision to plant eucalyptus trees is an economic decision which given external factors such as land use policies, climatic and other natural factors, can be influenced by many interrelated demographic, socioeconomic as well as institutional factors (Rathmann et al., 2010; Mwaura and Adong, 2016; Musara et al., 2019; Damene et al.; 2020; Gebreegziabher et al., 2020). We may think that, in a given region, the higher the intensity of eucalyptus planting by smallholders, the higher the social and economic importance of eucalyptus for smallholders. In this study, we estimated the intensity of eucalyptus planting by smallholders by the share of their farmland devoted to eucalyptus planting. This study aims to broaden the empirical knowledge regarding the role that eucalyptus trees play in smallholders' livelihoods and the factors that affect their decisions regarding land allocation.

The study addresses the following three research questions:
i) To what extent does eucalyptus tree contribute to the livelihoods of smallholder farms?
ii) What is the share of land allocated to eucalyptus trees in smallholders' farmland? And
iii) What are the different demographic, socio-economic and institutional factors that influence farmers' decision on land allocation?

In the next section the conceptual framework of the study is presented; the study area and the methods used are presented in section three; section four is devoted to the presentation and discussion of our findings, while the final section highlights the conclusion and recommendations of the study.

3.2 Conceptual framework

The decision of farm households on what amount of land to allocate to eucalyptus trees can be influenced by different socioeconomic factors (Musara et al., 2019, Gebreegziabher et al., 2020). These may include household characteristics, households' assets endowment, market access, institutions, ecological conditions and households' perception on eucalyptus trees. Figure 3.1 presents the various factors that may influence the proportion of land allocated to eucalyptus trees (intensity of eucalyptus plantation).



Source: adapted from Musara et al. (2019)

Figure 3. 1: Conceptual Framework

As illustrated in the conceptual framework given by Figure 3.1, the intensity of eucalyptus plantation (land use decision) is influenced by various interrelated factors. Households' demographic and socioeconomic characteristics can influence the extent of land allocation through its influence on resources availability such as labour force, cash and non-cash cash income and their ability to make decisions (Gebresilassie and Bekele, 2015; Ahimbisibwe et al., 2019, Gebreegziabher et al., 2020, Hajjar et al., 2020). In this study land size, livestock holding and educational level of the household head are expected to have positive influence on the share of land allocated to eucalyptus trees. While younger household heads are anticipated to allocate more of their land to eucalyptus trees rather than regular farm work at which they may lack the experience. Male-headed households are expected to allocate less

land to eucalyptus trees due to the likelihood that they may have the necessary farm labour for regular farm work. This is because most of the female-headed households are those who are widowed or those whose husbands are living in cities who usually come to their village once a year during *Meskel*[5] or *Arefa* celebrations.

It is anticipated that market accessibility will positively influence the proportion of land allocated to eucalyptus trees. In this study distance from the main road is taken as a proxy to market access and households are asked to estimate the time they need to reach to the nearest main roads. This means the shorter the time they need, the better access the households will have to the market since usually the trucks will be available to load the tree products on the main roads. Households' perceived effects of eucalyptus tree can also influence the extent of eucalyptus tree plantation (Getachew, 2016; Pervin 2017; Kerbo et al., 2022). Households having higher perceived livelihood effects of eucalyptus trees are expected to allocate more of their land to it. Since this higher positive livelihood perception is likely to make them more willing to allocate more of their land to eucalyptus trees as was the case in the study of Getachew (2016) and Kerbo et al. (2022). However, the higher perceptions households have about the negative environmental consequences of eucalyptus tree, the less land they will be expected to allocate and hence it is expected to have a negative sign in the estimation.

The influence of institutional and ecological factors on land allocation is expected to be captured by *wereda* dummy which is expected to capture the difference between households found in the two *weredas.* This difference was first reported by *wereda* level experts during interviews and also confirmed by the researchers' observations. These differences include variations in soil fertility, weather patterns, and the development of infrastructure, among other things.

3.2 Material and Methods

3.2.1 Study Area Setting

We selected Gurage zone for conducting this study because it is one of the central highlands of Ethiopia where eucalyptus tree is expanding at alarming rate mainly at the expense of other agricultural products (Gizachew, 2017). The study area has broad variations of altitude

[5] Meskel is a religious as well as a cultural celebration of Orthodox Tewahedo Cristian followers in Ethiopia which commemorates the finding of the true cross.

which covers areas of elevation above 3000 meters and below 2000 meters. The three primary agro-ecological types, Kolla (lowland), Weyinadega (mid-elevation), and Dega (high elevation), are consequently found in the Zone. According to Dendir and Birhanu (2022), the zone's mean annual temperature varies from 13° C to 30° C while its mean annual rainfall varies between 600 mm and 1600 mm. The overall population of the zone was estimated to be 1,791,034 in 2021, with more than 80% of residents living in rural areas, according to the CSA (2021) population forecast.

Although most farmers use diversified agricultural system, the main crop in the Zone is enset (*Ensete ventricosum)* or "false banana plant"), which is an integral part of Gurage life. It is characterized by its enormous underground stem. Enset is a stable starch crop for millions of smallholder farmers in the Southern part of Ethiopia which includes the study area (Borrell et al., 2019). Another important cash crop in Gurage Zone is khat which belongs to the family celastraceous. It is widely cultivated in the mid altitude of the zone. Its ability to resist draught has contributed to its wide cultivation under different climatic conditions (Binalfew, 2017). However, Gurage Zone's land use pattern has been changing rapidly in recent years as a result of the expansion of eucalyptus tree plantations, making the area one of the top suppliers of eucalyptus logs for various regions of the nation (Zerga and Berta, 2016).

3.2.2 Sampling Techniques and Data Collection Method

There are sixteen *weredas* in Gurage Zone and each *wereda* is further divided into smaller administrative units called '*kebele'*. The study is done in two purposefully selected *weredas* where eucalyptus plantations are widely practiced. According to Zerga and Berta (2016), there are four *weredas* in Gurage Zone with higher practice of eucalyptus plantation- Enemor and Ener, Cheha, Ezha and Gumer. From these four the study was done in Ezha and Cheha *weredas*.

From each *wereda* three *kebeles* were purposively selected based on the extent of eucalyptus tree expansion and one *kebele* from each of the three agro-ecological Zones. Experts from the respective Agriculture and Natural Resource Bureau were consulted in selecting sample *kebeles.* The sample households were selected using systematic random sampling procedure in which the first household from each *Kebele* was picked randomly from a list of households obtained from their respective *kebeles* and then every 6^{th} household was taken to get the required sample size from each *kebele*. A face-to-face interview was held with the head of

each household or a member of the household who has the required information about the household's socio-economic conditions.

The total sample size for this study was determined to be 480 households based on the method provided by Yamane (1967) for determining sample size, which was then distributed among the six *kebeles* according to the proportion of their respective population to the total population. As a result the samples from each *kebele* was determined to be 87 from Zigbaboto, 45 from Yesray, 103 from Ketane, 53 from Weredene, 88 from Wodro, and 104 from Girar and yefermazigibe.

The survey for this study was conducted in the months of January and February of 2021 with the help of six enumerators who were recruited with the help of local experts and administrators. The selection was made based on their educational level and work experience in the study area. Accordingly, all enumerators selected had a degree in agriculture or related fields with a minimum of two years of working experience in their respective *wereda*. Before the main survey was launched, they received training on how to conduct it and took part in the pilot survey.

In order to supplement the survey results, additional information was gathered through the use of Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). A total of six FGDs (one in each *Kebele*) were conducted, with participants chosen to include women, the young, and the elderly. Local government officials, experts as well as DAs (Development Agents) were also the subjects of KIIs.

3.3 Data Analysis

3.3.1 Descriptive Analysis

The study employed descriptive analysis and statistics such as frequency, mean and standard deviations were used to evaluate the livelihood contribution of eucalyptus trees to smallholder households in the study area.

3.3.2 Econometric Model Specification

For the purpose of identifying factors that influence the share of land allocated to eucalyptus tree, fractional logit model was used since the dependent variable is a fraction that ranges between 0 and 1.

When the dependent variables are fractional values using OLS, logit and two-limit Tobit model is not appropriate (Ramalho et al., 2011). According to Ramalho et al. (2011), using linear models to estimate the influence of explanatory variable may not guarantee fractional values for the dependent variables and also not appropriate to expect the effect of any explanatory variable to be uniform throughout its entire range between 0 and 1. To make sure the dependent variables are restricted between the two limits, this study used logistic estimation. The estimates of the odds ratio from the logistic estimations however, have two shortcomings. The first is the difficulty to interpret the coefficients directly and secondly the predicted values of the dependent variables not being well defined for boundary values of 0 and 1 (Ramalho et al., 2011).

When there are many observations at the upper and/or lower limits of the response variable, it is relatively common to use Tobit models for data censored at one and/or zero. Again, there are some problems with this approach. First, only in the two-limit Tobit model are in fact the predicted values of *y* are restricted to the unit interval. However, this model can only be applied when there are observations in both limits, which is often not the case. Second, conceptually, as suggested by Maddala (1991), Tobit is suitable to describe *censored* data with [0, 1] interval but its application will be difficult in case data is located only in that interval. This is because in cases of fractional variables, values at the boundaries are the result of individual decisions rather than being the result of any form of censoring. Third, the Tobit model is very stringent in terms of assumptions, requiring normality and homoscedasticity of the dependent variable, prior to censoring (Ramalho et al., 2011).

In case where a simultaneous decision is made- whether to plant and what amount of land to allocate, it is appropriate to apply double hurdle estimation. Musara et al. (2019) used it to identify the determinants of sorghum adoption and land allocation intensity in the smallholder sector of semi-arid regions in Zimbabwe. In this case, there are two decisions to be made- a decision to adopt and what amount of land to allocate.

Given the shortcomings of these models, certain alternate approaches that take into consideration the bounded nature of the relevant variable have been proposed by various writers, including Papke and Wooldridge (1996). While some of these models can be applied when either both or just one border value is seen, others can be applied when neither boundary value is seen. However, they all need that the E(y|x) be inside the range [0,1].

This study used a fractional logistic model (FLM) to find the variables that affect the proportion of the household's total land holding that is allotted to eucalyptus trees (the intensity of eucalyptus plantation). This model was used by Mwaura and Adong (2016) in Uganda to analyze factors influencing land allocation to crop production, Adjimoti (2016), to analyze crop land allocation in rural Benin, as well as Misango et al. (2022) to evaluate the intensity of pest management practices in Rwanda. Hence, based on the recommendations of Papke and Wooldridge (1991), the FLM model for the study is defined as shown by Eq. 1.

$$E\left(y_i/x_i\right) = Q(px_i) \quad \text{..... Eq. 1}$$

In Eq. 1 y_i represents share of land allocated to eucalyptus trees and x_i refers to a vectors of independent variables and $Q(.)$ is a cumulative distribution function that follows a logistic distribution function representing a non-linear link function where $0 \leq Q(.) \leq 1$.

Eq.1 is approximated using a quasi-maximum likelihood (QML) estimation technique where the likelihood for an observation is specified by Bernoulli likelihood which is given by Eq. 2.

$$L_i = [F(Bx_i)]^{y_i}[1 - F(Bx_i)]^{1-y_i} \quad \text{..... Eq. 2}$$

The estimation for fractional logistic model is done with Stata 14.2 software.

3.3.3 Description of Variables

The variables used and their expected signs as well as their summary statistics are given in Table 3.1. As shown in the questionnaire, 7 and 3 perception questions (indicators) were presented to each household for livelihood and environmental perceptions, respectively. By calculating the average score of each household on their perception of livelihoods and environmental effects of eucalyptus tree we measured perception as a continuous variable taking a minimum value of 1 and a maximum value of 5. Stronger perception or agreement with the perception questions is indicated by higher scores (see Kerbo et al., 2022).

Table 3. 1: Variable lists, associated statistics and expected signs in FLM estimation

Var.	Description	Unit	Sum. Stat.		Ex.
			Mean	S. D.	Sig.
Dependent Variable					
Slae	Share of land allocated to eucalyptus trees	Proportion	0.31	0.17	
Independent Variable					
Gedr	Gender of Household Head	Dummy (male 1, female 0)	0.76	0.43	-
Mrstt	Marital status of Household Head	Dummy (mar. 1, single 0)	0.75	0.43	+
Ageh	Age of Household Head (years)	Continuous	47.17	9.17	-
Elhh	School year of household Head	Continuous	5.11	3.45	+
Lnsz	Total landholding (Hectares)	Continuous	0.75	0.27	+
Lgieh	Ln of total household's annual income	Continuous	10.47	0.28	+/-
Htlu	Livestock ownership (TLU[6])	Continuous	3.25	2.18	-
Pnof	Participation in non/off-farm employment	Dummy (yes 1, no 0)	0.35	0.48	+
actr	Distance from main road (minutes)	Continuous	43.78	22.00	-
flt	Household members between the age of 15-64	Continuous	3.62	1.22	-
wedm	*Wereda* of the household	Dummy (Cheha 1, Ezha 0)	0.51	0.50	-
Suln	Suitability of land for crop production	Dummy (yes 1, no 0)	0.39	0.49	-
psli	Perceived effects of eucalyptus tree on livelihood	Continuous	3.78	0.39	+
psee	Perceived effects of eucalyptus tree on environment	Continuous	4.18	0.63	-

The *wereda* dummy is expected to be negative since households in Cheha *wereda* are expected to be allocating less of their land to eucalyptus tree compared to households in Ezha *wereda*, since households in Cheha *wereda* have better agricultural inputs in terms of land fertility and climatic conditions as well as infrastructural facilities which are likely to make them less eager to allocate more of their land to eucalyptus trees.

[6] TLU is a measure of total livestock ownership which is calculated based on Storck et al. (1991).

3.4. Results and Discussion

3.4.1 Contribution of Eucalyptus Tree to Households' Livelihood

3.4.1.1 Contribution of Eucalyptus Tree to Household Energy

Eucalyptus trees give a wide range of service to the rural households beyond serving as a source of income. In this section, a discussion on how eucalyptus tree contributes to the livelihood of households by providing energy for lighting and heating the house and cooking in comparison to other possible energy sources is given. Table 3.2 provides a summary of the data gathered from the survey on households' energy sources for lighting.

Table 3. 2: Households' Sources of Energy for Lighting

Sources of Lighting	Frequency	Percentage	Cumulative
Biogas	3	0.6	0.6
Solar Energy	291	60.6	61.3
hydroelectric	78	16.3	77.5
Kerosene/Candle	51	10.6	88.1
Wood	57	11.9	100
Total	480	100	

Source: Own Survey (2021)

As we can see from Table 3.2, the majority of household (60.6%) identified solar energy to be their major source of energy for lighting while 16.3% reported hydroelectric power to be their major source. Wood, kerosene/candle and biogas were reported by 11.9%, 10.6% and 0.6% of households, respectively. The survey result further indicated that eucalyptus tree to be the only tree used by all the 57 households who reported wood as their major sources of energy for lighting. Due to the frequent blackouts, the majority of households that reported hydroelectric power as their primary source of lighting also mentioned cases of using solar and wood products. This is why, as observed by the researcher, solar panels are installed on the roofs of nearly all households who have connections to hydroelectric power.

The energy sources used by households to cook their meals are listed in Table 3.3, and as can be seen, wood was cited as the primary source of energy for cooking by nearly 98% of respondents. Additionally, all but only one respondent identified eucalyptus tree as their primary source of firewood for cooking.

Table 3. 3: Households' Sources of Energy for Cooking

Sources of Lighting	Frequency	Percentage	Cumulative
Animal Dung	1	0.2	0.2
Wood	471	98.1	98.3
Charcoal	7	1.5	99.8
Hydroelectric power	1	0.2	100.00
Total	480	100	

Source: Own Survey (2021)

The study result further showed the majority of households (91.7%) gets the wood they need from their own plantation, while only 5.7% said they buy eucalyptus wood from the nearby market and the remaining 2.6% claimed they gather wood from nearby forests.

Participants in the FGDs also mentioned eucalyptus tree as the only sources of heating the household especially during cold seasons. They also added that eucalyptus have a high social value for *meskel* celebration with which the Gurage people are highly attached to. The preparation of eucalyptus tree logs, which are visible practically in every homestead's compound, marks the commencement of *Meskel* celebration. Eucalyptus woods and leaves are also used to make the d*amera*, the torch that marks the *Meskel* celebration. In general, we can say that nowadays, eucalyptus trees are part of every aspect of smallholders' lives in the study area.

3.4.1.2 Contribution of Eucalyptus Tree to Households' Income

The contribution of eucalyptus to household income is summarized in Table 3.4. As indicated in the table, the mean annual cash income from eucalyptus is US$ 285.5, which is almost 31% of the mean total annual households' cash income (US$ 921.4). The findings of this study exceed those of Mekonnen et al. (2007) who indicated that eucalyptus trees contributed around 25% of households' total income from their study in central Ethiopia.

Table 3. 4: Households Annual Cash income of Sample *Kebeles* (US$)

Wereda	Ezha			Cheha			
Kebeles	Zigibaboto	Yesray	Ketene	Werdene	Wodro	Girar & Yefermazigibe	Total
Agro-eco. Zone	Upper Kolla	Weyina dega	Dega	Upper Kolla	Weyina dega	Dega	
Annual Household Cash income from Sale of Eucalyptus products							
Mean	275.8	261.9	280.4	295.9	293.3	297.3	285.5
St. Dv.	213.4	127.0	114.3	152.7	183.7	116.3	155.3
Min.	37.6	89.7	87.7	135.4	42.6	145.4	37.6
Max.	1,729.6	576.5	737.0	812.2	1,453.9	726.9	1,729.6
Annual Total Household Cash income							
Mean	845.6	830.5	865.7	914.1	1,023.0	771.7	921.4
St. Dv.	260.4	250.5	208.2	224.6	331.35	275.58	273.1
Min.	383.5	466.2	443.7	546.5	518.9	585.8	383.5
Max.	2,419.0	1,541.6	1,356.1	1,456.4	2,571.9	1,781.0	2,571.9
Share of eucalyptus products from total household cash income(%)							
Share (%)	32.6	31.5	32.4	32.4	28.7	38.5	31.0
Total	87	45	103	53	88	104	480

Source: Own Survey (2021)

Note: The conversion of ETB to US$ was done by using the exchange rate which prevailed during the survey (1 US$ = 39.90 ETB, NBE 2021).

Based on the information obtained from experts during the interviews from the two *weredas* and our own observations, Wodro *kebele* found in Cheha *wereda* had a conducive agro ecological climate and irrigation facilities compared with the rest. This might have led to its highest mean total household cash income (US$ 1023.0) and lowest share of cash income earned from eucalyptus trees (28.7%). This may suggests that if farm level production and marketing difficulties are properly addressed farmers could generate adequate income from their farms and this may contribute to control the rapid expansion of eucalyptus trees in the study area.

Table 3.5 shows sample households' ranking of seven important agricultural cash income sources and 60.4% of surveyed households identified eucalyptus as their first source of cash income showing how crucial eucalyptus is to households' income.

Table 3. 5: Households' Ranking of Agricultural Cash Income Sources

	1st Rank		2nd Rank		3rd Rank		Total 1st-3rd Rank	
Sources of Cash income	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Food crop	85	17.7	209	43.5	155	32.3	449	93.5
Eucalyptus	290	60.4	116	24.2	37	7.7	443	92.3
Khat	64	13.3	56	11.7	33	6.9	153	31.9
Livestock	2	0.4	45	9.4	135	28.1	182	37.9
Enset	8	1.7	26	5.4	49	10.2	83	17.3
Coffee	26	5.4	25	5.2	29	6.0	80	16.7
Fruits and vegetables	5	1.0	3	0.6	42	8.8	50	10.4
Total	480	100	480	100	480	100	-	-

Source: own Survey (2021)

The survey result further showed crop and *khat* taking second and third places as first source of cash income for 17.7% and 13.3% of households, respectively. While coffee and *enset* took the fourth and fifth places and fruits and vegetables, and livestock took the sixth and seventh places, respectively. In addition, Table 3.5, indicates that 443 (92.3%) of households have ranked eucalyptus trees as either first or second or third important source of cash income which means only 7.7% (37 households) did not rank it as either 1st or 2nd or 3rd important source of income.

Information was also collected on the source of finance when households face emergency cash need. This emergency cash need can arise due to various reasons including in case of sickness or death of a household member as well as debt repayment. For such instances households need to have some liquid asset as much as possible or rely on some other sources such as borrowing or requesting assistance from family members or relatives. In this study, we wanted to examine the contribution of the different agricultural products in case of emergency cash demands. Table 3.6 summarizes the ranking of different cash income sources according to their relative importance in cases of emergency cash need.

Table 3. 6: Rank of Agricultural Cash Income Sources for Emergency Cash Needs (%)

Sources of Cash income	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Total 1st-3rd**
Food crop	9.1	23.5	38.5	15.2	4.6	9.4	71.2
Eucalyptus trees	57.1	32.3	8.8	1.7	0	0.2	98.1
Coffee	0.2	3.1	6.7	16.3	51.3	22.5	10.0
Khat	20.5	4.71	1.3	2.9	11.9	58.8	26.5
Enstet	0.21	2.3	12.5	52.5	24.6	7.9	15
Livestock	12.9	34.0	32.3	11.5	7.8	1.7	79.3

Source: Own Survey (2021)

Eucalyptus tree is identified by 57.1% of household as their first source. In addition, it is cited by 98.1 % of respondents as among the first three ranked sources, which means that eucalyptus is by far the major source of household emergency cash needs. This is why some researchers such as Peralta and Swinton (2009), Dessie and Abtew et al. (2019) and Tesfaw et al. (2022) described eucalyptus tree as a 'Living Account' for rural communities where formal financial services are not available. The fact that eucalyptus products are sold on the farm by negotiating with the buyers who come to the villages with their own truck has increased the liquidity of eucalyptus tree, as a result of which farmers prefer to grow eucalyptus tree in the study areas where financial services are not easily accessible.

Livestock served as the second most important source of finance in cases of emergency cash needs next to eucalyptus trees with 79.3% of household identifying it as either first or second or third source. The third most important source of cash income to cover emergency cash needs was sale of food crops which includes both cereals and pulses and this accounted for 71.2% of households relaying on it as either first or second or third sources. Khat and *enset* took the fourth and the fifth places while coffee took the last spot in financing emergency cash needs of the households in the study area.

In general, the contribution of eucalyptus trees to the livelihoods of household in the study area was found to be very critical and it seems to be indispensable having no visible agricultural enterprise to replace it not only as an essential source of cash income but also as an important tree to meet households' own tree demands.

3.4.2 Econometric Results

The result of fractional logit regression estimation from Stata 14.2 is show in Table 3.7. The estimation result showed chi 2 of 281.91 with a p-value of 0.0001, which suggests the null-hypothesis that the coefficients of estimates are all simultaneously zero is rejected. As indicated in the Appendix V, the VIF for the entire variable included is below 5, indicating no serious multicolinearity issues to exist.

Table 3.7: Coefficient Marginal Effect estimation of Fractional Logit Model

Var,	Description of variables	Coef.	M. Eff.	Robust St. E	p>|z|
Slae	Share of land allocated to Eucalyptus (Dependent Variable)				
gedr	Gender of Household Head	0.0095	0.0014	0.0741	0.899
mrstt	Marital Status	-0.0531	-0.0081	0.0796	0.505
ageh	Age of Household Head	-0.0162	-0.1528	0.0043	0.001**
elhh	School year of Household Head	0.0176	0.01912	0.0097	0.070
lnsz	Total land holding	0.2064	0.0329	0.2668	0.439
lgieh	Ln of Annual Cash income of Household	0.6748	1.4462	0.1277	0.001**
htlu	Total Livestock holding (TLU)	0.0845	0.0611	0.0250	0.001**
psli	Perceived effect of eucalyptus on livelihood	0.2778	0.2345	0.0723	0.001**
psee	Perceived effect of eucalyptus on environment	-0.0864	-0.0738	0.0565	0.126
flit	Family members between 15 & 65 years	-0.0122	-0.0092	0.0288	0.672
actr	Distance from main roads	-0.0030	-0.0267	0.0013	0.024*
pnof	Part. in Non / Off-farm activities	0.0612	0.0048	0.0690	0.375
sulne	Suitability of Land for crop	0.0483	0.0037	0.0652	0.458
wedm	Dummy for *Wereda*	-0.0756	-0.0078	0.0661	0.253
Con.	Constant	-8.2391		1.3277	0.001

** = significant at 0.01 level; * = significant at 0.05 level

Source: Own Estimation (2021)

From the estimation results summarized in Table 3.7, we can see that age of household head, total cash income of households, livestock ownership, perceived effects of eucalyptus on households' livelihood and distance from main roads are the variables which were found to significantly influence the proportion of land allocated to eucalyptus tree in the study area. However, it was revealed that the amount of land owned by the household as a whole, which has a positive coefficient, was not a significant factor in determining the share of land allocated to eucalyptus trees. This could be an indication that households, regardless of the amount of their land, are committed to having their own eucalyptus plantation.

Age of households head was found to be one of the demographic factors to significantly influence land allocation. This was also the case in the study of Mwaura and Adong (2016). From the coefficient of the variable age of household head, we can see that higher age of the head of the household leads to lower proportion of land allocated to eucalyptus tree, if all other factors remain as they are. The marginal effect value -0.15, indicates that for every one percent increase in age of household head, the proportion of land allocated to eucalyptus tree is expected to decrease by 15%. This result suggests that younger household heads tend to allocate more proportion of lands to eucalyptus compared to older household heads. This could be due to younger people's general tendency to engage in cash income maximization activities than the common practice of crop production.

Household's total cash income influences the intensity of eucalyptus plantation positively, and a 1% increase in ln value of cash income is expected to increase the proportion of land allocated to eucalyptus by 144.6%, if all other factors remain as they are. This implies that households are more inclined to dedicate a larger percentage of their land to eucalyptus trees, the more total income they receive from various sources. This in other words means the richer the households, the higher the proportion of land they are likely to allocate to eucalyptus trees. This result is consistent with the findings of Gebreegziabher et al. (2020) who studied the effects of eucalyptus trees in Ethiopia as well as the findings of Van Khuc (2020) who concluded that planted forests benefited wealthier households more than it benefited the poor households from their studies in Vietnam. Livestock ownership also has a positive and significant effect on the dependent variable. The marginal effect value of 0.0611 indicates, for a 1% increase in TLU, the proportion of land allocated to eucalyptus tree increases by about 6.1%. The positive influence of variables such as cash income and livestock ownership in general suggests that better-off farmers allocate larger share of their land to tree growing as was the case in the study of Sikor and Baggio (2014).

Distance from main road, which may be used as a proxy variable to market access, has a negative effect on the dependent variable, and for a 1% increase in the time needed to reach the nearest main road from the household, the proportion of land allocated to eucalyptus tree decreases by 2. 7%, if all other variables remain unchanged. This, in general indicates that the further away a household is located from the main road, the smaller the proportion of land allocated to eucalyptus tree. This could be because, as eucalyptus logs are sold on the farm, the easier the access to the farm, the more land could be allocated by households to eucalypts.

This suggests market access to be another driving force for eucalyptus intensification in the study area in addition to the total income households' receive and their perception. This finding is consistent with the findings of Mulu et al. (2022) who indicated that the share of land allocated to trees by smallholder farmers in the Northwestern part of Ethiopian highlands is significantly influenced by distance from market centers.

Finally, households' perception of the effect of eucalyptus on their livelihood tends to affect the share of land allocated to eucalyptus positively. A marginal effect of 0.2345 indicates that for a 1% increase in perception score of households, the proportion of land allocated to eucalyptus increases by 23. 5%, if all other factors remain constant. This goes in line with the studies of Getachew (2016) and Pervin (2017) who concluded that the perception of household is one of the most crucial factors that influence households' decision on the adoption of eucalyptus tree as well as the amount of land allocated to it.

3.5. Conclusion and Recommendation

The results of this study have confirmed how important eucalyptus trees are to the livelihoods of smallholder farmers in the study area. This suggests that eucalyptus trees are crucial component of the farming system, acting as a dependable source of energy and cash income for households in addition to being crucial for social events like *meskel* celebration and night coffee ceremony, where neighbors congregate around an eucalyptus wood fire.

Eucalyptus trees constitute the prime source of energy for cooking, getting heat during cold seasons in the nights and also to some extent for lighting households in cases of the absences of light from other sources. More than 90% of households reported using their own plantation to obtain eucalyptus products, indicating that the vast majority of households are self-sufficient as far as tree products are concerned. This indirectly reveals the amount of resources, such as land, each household has allocated to it.

One of the most important reasons to plant eucalyptus trees is to generate income, and this study has confirmed that eucalypts are a very important source of income to the smallholder farm households in the study area. This is the primary source of annual cash income for 60% of our sampled households and the primary source of income used in case of emergency needs for 57% of our sampled households. Furthermore, households in the study area allocate on average almost 31% of their total land holding to eucalyptus trees. This indicates the high level of eucalypt adoption and importance to the smallholder farmers. Since

eucalyptus tree is becoming increasing an important integral part of smallholders' livelihoods in the study area due to its immense contribution in meeting households' demand for energy as well as its significant contribution to income; experts and government officials need to evaluate their stands with regard to eucalyptus trees.

The proportion of land allocated to eucalyptus tree was found to be significantly influenced by five socio-economic factors, including household's age (household characteristics), perception of the effects of eucalypts on livelihood (household perceptions), distance from main roads (market access), as well as amount of livestock ownership and total annual cash income of households (household assets). Experts and authorities need to focus on these issues in order to achieve a more balanced land use between the demand for tree products and other agricultural products such as food production.

This study concludes that eucalyptus trees in the study area provide an indispensable contribution to smallholders' livelihood. Consequently, we suggest development stakeholders to recognize eucalyptus tree growing as an important agricultural activity and to play a constructive role in supporting smallholder farmers in getting the best use of eucalyptus tree while minimizing its alleged negative effects on the food production of smallholder farmers and the environment since there are no viable options to replace eucalyptus trees under the exiting circumstances that can meet both the income generation and own tree demand of the rural communities.

Chapter 4: Eucalyptus Tree Expansion and Land Use and Land Cover Dynamics in Ethiopia- empirical evidence from Gurage Zone, Ethiopia[7]

Abstract

Gurage Zone is one of the areas of Ethiopia experiencing rapid land use and land cover (LULC) changes over the past few decades. This study assessed the contribution of eucalyptus expansion to LULC changes based on a detailed household level survey, key informant interviews, focus group discussions and a set of Landsat imageries. Both descriptive statistics and econometric model were employed for the analysis of drivers of eucalyptus plantation. LULC change detection technique was used to examine the changes in LULC over time. This study achieved a mean classification accuracy of 89.17% and 0.83 overall Kappa statistics for the tree LULC maps. The result of descriptive analysis revealed that more than 42% of the sampled households have planted eucalyptus trees on crop land. The study indicated that eucalyptus plantation which was fourth in LULC ranking in 2000 has increased by 68.3% in 2021 to become the second largest land cover next to crop land. On the other hand, from 2010 to 2021, the area covered by crops showed a decline. This indicates eucalyptus tree to be the major cause of LULC change in the study area. The econometric estimation identified the micro-level drivers such as land size and access to market to be important factors influencing eucalyptus plantation. This study suggests that the rapid expansion of eucalyptus plantation on fertile soil requires an immediate policy response in order to balance food crop production and eucalyptus plantation in Gurage Zone.

Keywords: Eucalyptus Expansion; Land use land cover change; Crop land; Micro-level drivers, Gurage Zone

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4.1 Introduction

Land is the most important natural resource on which all of our economic and social activities are undertaken. The issues of land use and land cover (LULC) change which could be the result of natural process and/or human activities has been identified as top priority at local, national and global levels due to its direct implication on livelihoods and the environment (Adhikari et al., 2017). Analyzing changes of the earth's surface features enable us to realize the interactions between humans and their environment and the use of natural resources (Singh, 1989). One of the most important issues that may come to the minds of many experts dealing with LULC issues in Ethiopia is presumably eucalyptus tree.

Despite widespread criticisms by experts and government authorities, eucalyptus tree has continued to expand covering wider geographic areas both in highland and lowland of Ethiopia due to the rising demand for fire wood and construction material. The main criticism comes from its claimed adverse effect on the environment (Hennessay, 2012; Bayle 2019; Bazzana et al., 2021). This negative impact is said to come not only through its effects on decreasing soil fertility and groundwater but also through its allelopathic and shading effects on neighboring plants which diminishes both the productivity of the land and the biodiversity of the area. Bazzana et al. (2021) argued that the allelopathic characteristics of eucalyptus strongly affect the soil fertility and hence inhibiting the possibility to switch to food crops in the future. Another important issue raised by the critics on the uncontrolled expansion of eucalyptus tree is its effect on LULC change with its own implication on food production systems in many parts of Ethiopia especially in highly populated areas such as Gurage Zone (Belay, 2015; Getachew, 2016; Mulatu et al., 2019)

Despite the perceived negative impacts of eucalyptus on the environment in general and soil productivity and exhaustion of once productive crop lands in particular, farmers continue to plant it. The main factor for the expansion of eucalyptus tree is its fast biomass production in a relatively short period of time from which economic and ecological benefits are generated (Belay and Muluneh, 2016; Gebreegziabher et al., 2020). Gurage zone is one of the areas of the country where the planting of eucalyptus tree is spreading rapidly for the past few decades (Belay, 2015; Belay and Muluneh, 2016). In areas such as Gurage Zone where land is becoming more and more fragmented due to population pressure, the increasing tendency of planting eucalyptus trees for cash income and other purpose is likely to change the land use patterns with its own implications on available land and other scarce resources for food

production. Since Ethiopia does not have land use policy yet, assessing land use and land cover (LULC) dynamics and investigating its implications will be essential inputs for future policy formulation and implementation (Gebeyehu et al., 2017). Therefore, the main objective of this study is to examine the extent of LULC changes in Gurage Zone and identify the micro-level factors responsible for eucalyptus expansion in the region. .

There are related empirical works in Ethiopia which tried to examine LULC dynamics. The works of Belay et al. (2021), Hailu et al. (2020), Desta and Fetene (2020) and Mulatu et al. (2019) are some of the empirical studies on LULC dynamics conducted in different parts of the country. To the best of our knowledge, there are no empirical works that considered the expansion of eucalyptus trees as one of the land use category and examined the microeconomic drivers of its expansion using econometric models. In addition, this research will be the first of its kind in the study area to examine the expansion of eucalyptus tree by taking multiple indicators such as number of eucalyptus trees planted, land allocated to it and LULC changes observed at different points in time. Furthermore, unlike other similar studies (e.g. Belay et al., 2021; Hishe et al. 2022), this study employed econometric tools to assess micro level variables that affect the expansion of eucalyptus trees at household level which according to Gebeyehu et al. (2017) leads to land cover and land use changes of a given area. Therefore, this study aims to address the following research questions: i) What are the major micro-level variables that affect eucalyptus trees plantation in the study area? ii) What is the extent and rate of expansion of eucalyptus in the region? And iii) To what extent does the expansion of eucalyptus tree contribute to LULC changes in the study area?

Since smallholder farmers are the major agents in eucalyptus trees expansion in the study area (Belay and Muluneh, 2016), assessing the micro-level factors influencing farmers' decision regarding eucalyptus expansion will be of great value to policy makers by providing relevant information in future planning to balance food crop production and eucalyptus plantation. Moreover, understanding the nature and extent of eucalyptus expansion and its effect on LULC can be an important input for the country's land use plan and policy formulation in general and the study area in particular.

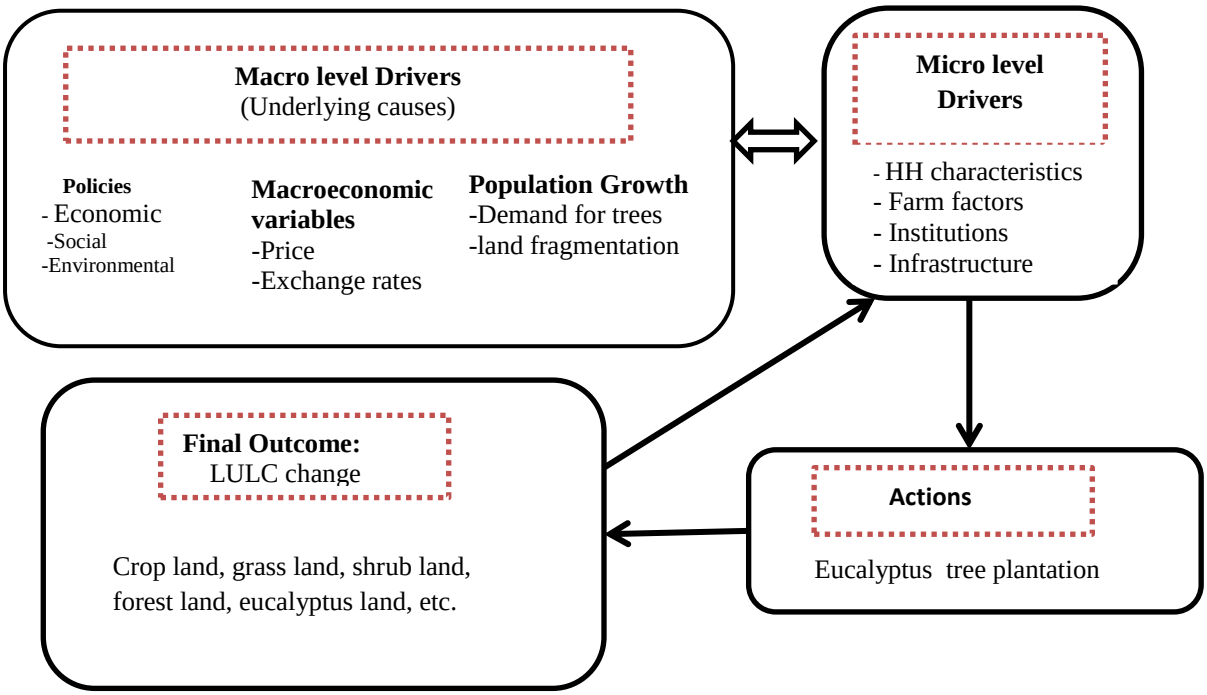
4.2 Conceptual Framework

In this study, eucalyptus expansion is measured by the number of eucalyptus trees planted, the amount of land allocated to it and the change in eucalyptus land coverage obtained from LULC changes observed in the study area over the specified time period. In addition, the share of land allocated to eucalyptus plantation can also be used as an alternative way of measuring eucalyptus expansion.

The expansion of eucalyptus tree is affected by various socioeconomic and institutional factors that play a role in the decision of smallholder households who are the major agents in expanding eucalyptus trees. The expansion of eucalyptus tree usually leads to LULC changes with its own implication on the food security of the rural community.

According to Rawat and Kumar (2015), land cover is the physical characteristics of the surface of the earth such as soil, vegetation, water and other physical features which are the result of human activities like settlements, while land use refers to land used by humans for residence and economic activities. Land is one of the scarcest resources in the rural economy and in most cases it can be put to alternative uses. As a result, the more land used for eucalyptus plantation the less land that will be available for alternative uses. Given backward technology and low level of input use accompanied by limited institutional support in smallholders' farming in Ethiopia (Gemechu, 2014; Getu and Almas, 2022), less land in general means less production and vice versa. Therefore, a shift of land from food production to eucalyptus production would generally mean a decline in food production. For this reason, the use of land needs to be guided by appropriate policy so that it can be used in the most sustainable and efficient manner.

The conceptual framework adopted for the analysis of the drivers of LULC is presented in Figure 4.1. As shown in Figure 4.1, macro level drivers are the underlying causes of LULC change which underpin the micro level drivers (Bosselmann, 2012; Hetting et al., 2016). These include various economic, social and environmental policies which influence smallholders' decision on how to use their land. Some of the policies that may impact farm decisions include agricultural policies, land policies and market policies which may influence both agricultural input and output prices. Population pressure has an impact on farm decisions due to its direct impact on decreasing farm size as well as the increase in demand for forest products both in rural and urban areas (Hetting et al., 2016).



Source: Adapted from Hetting et al. (2016) and Bosselmann (2012)

Figure 4.1: Conceptual Framework of LULC

The focus of this study is on the micro-level drivers. Household level land use decisions are highly dependent on the specific household's demographic and socioeconomic condition given the macro level derivers (Hetting et al., 2016). For instance, household labour, size and quality of land as well as their educational level can influence their decision on land use (Gebreegziabher et al., 2020). In addition, local infrastructural development and institutions play a critical role in influencing the decision of farm households. This may come in the form of affecting production and/or input and output markets (Bosselmann, 2012). The different types of land uses included in this study are crop land, grass land, shrub land, forest land, eucalyptus land (woodlots), settlement land, water body, wet land and bare land. There could be feedback effects between the micro level drivers and the underlying causes. Therefore, this study attempted to examine the effect of micro level drivers to eucalyptus trees plantation which ultimately influence LULC changes in the study area.

4.3. Research Methods

4.3.1 Study Area

Gurage zone is found in what is now called Central Ethiopia Region in Ethiopia. Geographically, the study area is positioned between 37.766259 – 38.144136N latitude and 8.274112–8.082874' E longitude (ESSGSI, 2021). Gurage Zone shares border on the Southwest with Hadiya zone and Yem special *wereda*, on the west, north and east with Oromia region and on the Southeast with Silt'e Zone. There are sixteen *Weredas* in Gurage Zone and each *Wereda* is further divided into smaller administrative units called '*Kebele'*.

In recent years, there is a rapid land use pattern change in Gurage Zone due to the expansion of eucalyptus trees, making the zone one of the leading suppliers of eucalyptus tree products to many parts of the country (Belay, 2015; Belay and Muluneh, 2016).

4.3.2 Sampling Technique and Data Collection Methods

According to Belay and Muluneh (2016), Enemor and Ener, Cheha, Ezha and Gumer are the four leading *weredas* in eucalyptus plantation practices in the zone. Since Ezha and Cheha *weredas* exhibit all the three agro- ecological zones, the study was conducted in six *kebeles* selected from these two *weredas*.

The selection of *Kebeles* was based on the extent of eucalyptus tree expansion and one *kebele* was taken from each of the three agro-ecological Zones- lowland ('*kolla'*), mid altitude ('*weyinadega'*) and highland ('*dega'*). Experts from the respective Agriculture and Natural Resource Bureaus were consulted in selecting the *kebeles* from each *wereda*. The sample households were selected using systematic random sampling technique where the first household from each *kebele* was picked randomly from lists obtained from the respective *kebele* offices and then every 6^{th} household was taken to get the required sample size from each *kebele*.

Using the formula given by Yamane (1967) for sample size determination, the total sample size for this study was calculated to be 480 households which were then divided among the six kebeles based on their respective population size.

4.3.3 Data Sources, Description of Variables and Hypothesis

The data required for this study were obtained from both primary and secondary sources. Data on socio-economic variables were obtained from field survey. For key informant interviews (KIIs), individuals who know what is going on in the community with regard to land use and land cover change were identified for the interview. The purpose of KIIs is to collect information and better understand the nature of eucalyptus expansion, the associated problems and measures to be taken to address those problems. For FGDs, efforts were exerted to incorporate participants from different segments of the society. As a result, women and poor as well as both young and elderly farmers were included in the discussion. The purpose of FGDs was to gather qualitative data on the drivers of LULC in the community and other related information based on a list of guiding questions. A total of six FGDs, one in each *kebele,* were undertaken.

Satellite images together with ground truth data were used to examine the LULC dynamics of the study area. The data obtained were also triangulated with the data obtained from secondary sources at local, regional and national sources in addition to the observation of the researchers.

Descriptive, econometric and LULC changes analyses methods of data analysis were used to examine the LULC dynamics of the study area and to identify the micro level drivers of these changes.

What follows is a discussion of the variables included in the econometric estimation and their hypothesized relationship with the dependent variable (the number of eucalyptus trees owned).

Gender of household head (gedr): a dummy variable with a value of 1 for male household heads and 0 for female heads. Female-headed households are more likely to choose eucalyptus plantations because they are less likely to have the labour force to engage in conventional agriculture, but they are also more likely to grow food crops to feed their families. As a result, the influence of this variable can be either positive or negative.

Marital status (mrstt): this is a binary variable which has a value of 1 for married households and 0 otherwise. Married households are more likely to demand more trees and tree products and hence positively related with the decision to plant trees.

Age of household head (ageh): this variable is continuous and expressed in years. Since younger households are anticipated to have less expertise in conventional agriculture while older households tend to focus on maintaining adequate food for their families, age in general is expected to negatively affect eucalyptus plantation.

School year of household head (elhh): this variable measures the household head's educational attainment in terms of school years. Education is expected to enhance eucalyptus plantation because educated people are more aware of the importance of eucalyptus for the purpose of generating income and satisfying household's own demand for tree products.

Total land holding of household (lnsz)[8]: all agricultural outputs, including the production of eucalyptus trees, are basically determined by the availability of land. Hence, it is expected land size to positively influence eucalyptus plantations, all other factors being the same.

Proximity to main roads (actr): households were asked to report the amount of time it took to get to the closest main road, and this variable is used as a proxy for household's access to market. The reason for this is because eucalyptus products are usually sold on the farm to people who use their own transportation to take the products. It is expected that households closer to the main roads are more likely to have more eucalyptus trees and vice versa.

Access to electricity (acel): this dummy variable has two possible values: 1 if the household has an electric connection and 0 otherwise. Households with electric connections are less reliant on eucalyptus as a source of energy, and hence less demand for eucalyptus as a source of energy which in turn leads to lower interest for eucalyptus plantation.

Suitability of land for crop production (suln): this is a dummy variable taking a value of 1 if the land is suitable for crop production and 0 if it is not (hillside, marginal land, etc.). This is expected to have a negative effect on eucalyptus plantation as the opportunity cost of planting eucalyptus on lands suitable for crop production is high, compared to those households whose land is unsuitable for crop production, i.e. those who have more of marginal land, hill side, types of lands.

Number of household members in the working age group (flit): this is a continuous variable which refers to the number of household members who are in the working age group- between 15 and 64 years of age. In general, due to lower labour demand requirement of eucalyptus plantation compared to crop production, households with less labour force are expected to prefer eucalyptus plantation to conventional agriculture. As a result, the coefficient of this variable is expected to be negative in the econometric estimation.

[8] *Zheng* is the local unit used to measure land holding. For the purposes this study, we convert it to hectares (Ha).

Participation in non/off-farm activities (pnof): this dummy variable has a value of 1 when the household participates in non/off-farm activities and 0 when it does not. Since households who participate in non-farm activities are expected to have less time for routine farm work as a result of which they are likely to have more eucalyptus trees, if all other factors remain as they are. .

***Kebele* level fixed effects** are included in order to capture *kebele*/village aspects such as soil fertility, *kebele* level leaders' capacity, and climatic conditions which may have some influence on the dependent variable.

4.3.4 Methods of data analysis

4.3.4.1 Descriptive statistics

Descriptive statistics are used to assess the extent of eucalyptus plantation, land allocated to it as well as relevant households level socioeconomic variables.

4.3.4.2 LULC changes analysis

The expansion of eucalyptus in the study area and its implication on change in land use pattern is analyzed using satellite images for year 2000, 2010 and 2021. The satellite images were analyzed using thematic mapping and change detection techniques. A wide variety of techniques are employed in change detection analysis to recognize, explain, and measure variations in images taken of the same scene at various periods or with various circumstances. In contrast, a thematic map displays the geographical distribution of one or more particular data topics for pre-selected regions. On the other hand, thematic mapping is the process of assigning a certain topic to a geographical location.

In Ethiopia, researchers have used satellite images to examine the dynamics of LULC and to assess the resulting impact on the environment and natural resources in addition to identifying the drivers of those changes. For example, Desta and Fetene (2020) and Hailu et al. (2020) used satellite images to study LULC changes in Lake Ziway watershed of the Ethiopian Rift Valley and Jimma Geneti District in Western Ethiopia, respectively.

The LULC maps were analyzed by classifying LULC of the study area into nine different types based on satellite images and ground truth data collected by the researchers. LULC types used for this study were bare land, eucalyptus land, grass land, forest land, crop land,

shrub land, wet land, water bodies and settlement land. Table 4.2 presents the definition of each LULC type as used in this study.

In this study, image gaining dates were chosen based on the availability of cloud-free imageries in the months of the dry season period to minimize classification mistakes. For the purpose of LULC assessment Landsat Thematic Mapper (TM) imagery for 2000 (Andualem and Demiss, 2018), one set of Enhanced Thematic Mapper Plus (ETM^{+}) for 2010 (Wakjira et al., 2020), and one set of Landsat Operational Land Imager (OLI) 2021 (Mohajan et al., 2018) having a pixel size of 30 m × 30 m spatial resolution with the cloud cover less than 0.05% were downloaded free of charge from the United States Geological Survey Center for Earth Resources Observation and Science (USGS, 2021).

Table 4.1: Description of LULC Types in the Study Area

LULC Type	**Description**
Bare land	Land which is not covered by any vegetation and is not currently in use.
Eucalyptus land	Land on which eucalyptus tree is planted by households. This does not take those planted along side roads or areas which are not inhabited by people.
Grass land	Area of land covered with grass, i.e. be it private or communal grazing land.
Crop land	Land covered with food crops such as barely, teff, wheat, beans, potatoes, etc.
Shrub land	Land covered with *enset*, khat, and other such sized plants (not longer than two meters)
Forest land	Land covered with different type of trees not owned by households and not close to homesteads. It includes trees planted road sides and areas not close to farm households.
Settlement land	Areas of land used for houses, roads and other such built infrastructures.
Water body	Surface of the earth covered with water such as lake, river, pond, etc.
Wet land	Marshes (swamps) that are covered often with shallow water (land having soils saturated with moisture usually have some plants on them).

The study area was completely contained within a single Landsat scene (168 and 169) paths and (054 and 055) row. Three Landsat scenes for the three acquisition periods were attained for January and February. The assortment of suitable image acquisition dates is a prerequisite for clear identification of the LULC types from satellite imageries (Mulatu et al., 2019). The detailed properties of Landsat data used in this study are shown in Table 4.2.

Table 4.2: Imagery Statistics and Sources

Nº	Imagery Type	Imagery Date	Path	Row	Resolution(m)	Source	Bands/ color
1	Landsat TM	18/01/2000	168 And 169	54 And 55	30*30	USGS	Multi-spectral
2	Landsat ETM+	18/01/ 2010	168 And 169	54 And 55	30*30	USGS	Multi-spectral
3	Landsat OLI	18/01/2021	168 And 169	54 And 55	30*30	USGS	Multi-spectral
5	Topo-sheets		_	_	1:50,000	GII	_

The following three preprocessing activities were undertaken.

I) Radiometric correction

- Correction for atmospheric effects, sensor calibration, and other radiometric distortions to ensure consistent pixel values across images.

II) Geometric correction

- Rectifying the images to a common geographic coordinate system and correction for sensor distortions, terrain effects, and other geometric distortions.

III) Cloud and shadow removal

- Identifying and masking out any cloud cover or shadow areas that could interfere with the LULC analysis.

Satellite images obtained were ortho rectified to Universal Transfer Mercator (UTM) Zone 37N, WGS 1984. Image processing and GIS data analysis were done using remote sensing and GIS software comprising ERDAS (Earth Resource Data Analysis System) Imagine version 14 and ArcGIS 10.5, respectively. Initially, images were transformed into UTM and Geo-referenced to a datum in which Ethiopia has been selected by WGS-84. The delineated study site was digitized in ArcGIS 10.5 to overlay the view on spatial databases generated from the photographs and the satellite image.

Once the demarcated study area was in ArcGIS 10.5, then superimposing the view on the spatial database was created from satellite image. To improve image quality and accuracy assessment, ground truth points (160 points) from nine land cover classes, i.e. 0 bare land, 0 water body, 104 crop land, 11 shrub land, 7 grass land, 2 wet land, 2 settlements, 15 eucalyptus land and 19 forest land areas were used. After doing geometric adjustment and radiometric corrections, images of both dates were geo-referenced with admiration to each

other by collecting high-quality ground control points (GCP) and the Root Mean Square Error (RMSE) of geo-referencing that was kept below 0.2 pixels.

Appendix VI shows the flow of activities undertaken for the purpose of image classification and getting the final LULC maps of the study area based on which changes in LULC of the study area were analyzed. The images for 2000, 2010 and 2021 were analyzed together with the data obtained from field observation for the purpose of image classification. Image classification simply involves turning remote sensory data (reflectance) into different categories representing some ground features (Mohajan et al., 2018).

There are two types of image classifications in LULC analysis– unsupervised and supervised classifications. Unsupervised classification is done by software in which the researchers determine only the number of classes to be used and summit the image to the software which does the rest of the work- classifies the area based on its reflectance (pixel values). However, for a better result of classification supervised classification is recommended (Kaul and Sopan, 2012). It requires the direct involvement of the researchers and knowledge of the study area (Kaul and Sopan, 2012). Hence, in supervised classification LULC types are determined based on the reflectance and the ground truth of the study area.

After getting the initial LULC images for the three periods, accuracy assessments need to be made by comparing the classified images to another data sources which is regarded to be more accurate (Kaul and Sopan, 2012; Mohajan et al., 2018). In our case, accuracy assessment for 2000 and 2010 were made by comparing the LULC maps with the actual images obtained for those periods from satellite while for 2021 we used Google earth maps and data collected from GCP.

Once the final LULC maps are obtained, the next step is analyzing the changes based on the final LULC maps of the study area. Singh (1989) identified two groups of change detection approaches. The first one is Bi-temporal altered detection which is a direct comparison, post-analysis comparison, and uniform modeling which measures changes based on a simple two periods timescale comparison while the second one is temporal trajectory analysis which is a time series analysis and the changes are based on a continuous timescale, focusing on both changes between dates and the progress of the modification over the period. In this study, to obtain the information of LULC dynamics in terms of pattern and rate of conversion, post-

classification change detection analysis was carried out in ERDAS Imagine 2014 using classification images of 2000, 2010 and 2021.

According to Lu et al. (2004), accuracies of change detection is used when someone is interested to know changes that have taken place in a particular region provided that satellite data over that area can be easily attained. The key objective of the change detection technique is to obtain the alteration in two or more images of the identical sites captured at different point in time. Different approaches have been adopted for change detection depending on its application such as algebra-based, transform-based, classification-based, neural network and fuzzy-based and other change detection approaches (Asokan and Anitha, 2019).

The LULC change was obtained using the following formula:

$$L = \frac{\text{AFY} - \text{AIY}}{\text{AIY}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. Eq.1$$

Where L= Percentage Change in LULC

AFY = Area at final year

AIY = Area at the initial year

Accuracy assessment is used to set up an error matrix which extensively used for examination of change detection outcomes. Accuracy assessment was conducted by matching the classified image with the land cover classes on the topographic maps and the GCP on the map. Therefore, positive values propose an increase but the negative once indicate a reduction in the extent of the particular LULC type. For the first comparison, accuracy assessments in 2000, 2010 and 2021 classified images were conducted through visual interpretation and the guidance of topographic maps. For each of the classified cover types, 160 random sampling points were established and accuracy checked by using Google earth and ground truth data by comparing remote-sensing generated classification and reference sample generated data.

Overall Accuracy (OA) is the ratio of the altered and unchanged pixels which are properly sensed pixels. The accuracy measures are worked out based on the confusion matrix that comprises the Producer's and User's accuracy (Asokan and Anitha, 2019). Producer's Accuracy (PA) denotes a measure of the omission error whereas User's Accuracy (UA) denotes a measure of the error. User's accuracy is the result obtained by dividing the number

of properly categorized pixels in each class by the entire classified pixels in the same class (Asokan and Anitha, 2019).

Another convenient parameter is the Kappa Coefficient (KC). A non-parametric Kappa test was also executed to calculate the degree of classification accuracy. Kappa coefficient is a metric that evaluates the performance of the detection algorithm. Kappa denotes an agreement between the classified LULC and the observed land use category. It was evaluated following Kaul and Sopan (2012) and Butt et al. (2015).

$$\text{Keppa} = \frac{\text{P(A)} - \text{P(E)}}{1 - \text{P(E)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 2$$

Where P(A) is the number of times the K raters agree and P(E) is the number of times the K raters are expected to agree only by chance. P(A) and P(E) are calculated using equations (3) and (4), respectively.

$$\text{P(A)} = \frac{\text{(CP+UP)}}{\text{(TP)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 3}$$

$$\text{P(E)} = \frac{\text{(CP+MA) (CP+FA)+(FA+UP) (MP+UP)}}{(TP)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 4}$$

Here changed pixels (CP) signify the pixels that were found as changed and are properly recognized as altered. Unchanged Pixels (UP) denotes the pixels that were found as unchanged and are appropriately known as unchanged. TP denotes the total number of pixels; while MA and FA represent missed alarms rate and false alarms rate, respectively. TP is the sum of CP, UP, MA, and FA. The greater the kappa coefficient, the better is the classification accuracy (Asokan and Anitha. 2019).

The rate of LULC conversion for the three periods from 2000–2010, 2010–2021 and 2000-2021 was computed using the formula,

$$r = \frac{Q_{2} - Q_{1}}{t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 5}$$

Where: r = rate of change, Q_2 = Final year LULC in Ha, Q_1 = Initial year LULC in Ha. and t = interval year between initial and final year.

4.3.4.3 Econometric estimation

We initially took the dependent variable to be the actual number of eucalyptus trees planted by the household. However, after undertaking the necessary diagnostic tests, the final estimation was made using the log value of the number of eucalyptus trees planted for the

sake of convenience in interpreting the results of the analysis. The test result for multicolinearity of the variables used in the estimation is given in Appendix VII.

Equation 6 shows the OLS econometric model used to examine the factors that influence the dependent variable (Green, 2003).

$$Y_i = \beta_0 + \beta_k X_{ki} + \in_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. (6)$$

Y_i stands for the log value of the number of eucalyptus trees owned by the i^th household, X_{ki} stands for explanatory variables, while β_k stands for the coefficient of the k^th variable for the i^th household and $\in_i$ represents the error term.

4.4. Results and discussion

4.4.1. Number of eucalyptus trees planted

In addition to the number of eucalyptus trees a household had at the time of the survey, data on the number of trees it had before five and ten years was also gathered. Respondents were encouraged to give their best estimates of the eucalyptus tree they planted. However, it is important to acknowledge the problem of recalling the exact number of trees before ten or five years. This information can complement the information obtained from LULC maps showing the situation of eucalyptus and the resulting change in the patterns of land use at different point in time in the study area.

Table 4.4 indicates the total number of eucalyptus trees planted in each *kebele*. Wodro *kebele* had the highest number of eucalyptus before 10 years with a value of 435.63 while Werdene *kebele* had the highest mean eucalyptus holding with 648.11 mean value before five years. However, when it comes to the current number of eucalyptus holding, it is Yesray *kebele* which had the highest mean eucalyptus trees (1121.2) and Wodro *Kebele* had the minimum eucalyptus plantation (997 trees) during the time of the survey. As we can see from Table 4.4, before five or ten years there were some households who reported not to have even a single eucalyptus tree. However, during the survey all the sample households had some trees on their land, the minimum being 530.

In addition, the null hypotheses that all mean values of eucalyptus plantation by the six *kebeles* are all the same $(H_0: X_1 = X_2 = \cdots = X_6)$ was strongly rejected with 1% significance level [Hotelling F(1,479)=1549.83, prob. > F=0.0001)] which means statistically, the mean values of eucalyptus planted by each *kebele* do vary from each other.

This could be the result of variations in agro-ecological condition, proximity to markets and presence of irrigation and other agricultural facilities.

Table 4. 3: Summary statistics of the number of eucalyptus trees planted

Kebele		Time Periods		
	Statistical values	**Before 10 Year**	**Before 5 Years**	**Current**
Zigibaboto	Mean	348.45	604.83	1053.23
	St. Dv	269.05	300.38	167.13
	Min.	0	0	700
	Max.	1100	1050	1400
Yesray	Mean	332	515.56	1121.22
	St. Dv.	286.50	327.35	225.81
	Min.	0	0	720
	Max.	1000	1100	1500
Ketene	Mean	388.74	647.57	1100.54
	St. Dv.	295.89	348.62	284.85
	Min.	0	0	600
	Max.	1100	1500	1580
Werdene	Mean	421.70	648.11	1090
	St. Dv.	286.31	323.00	268.68
	Min.	0	50	580
	Max.	1500	1500	1540
Wodro	Mean	435.63	602.72	997.61
	St. Dv.	322.99	318.35	250.74
	Min.	0	0	540
	Max.	1050	1200	1480
Girar&Yeferemazigbe	Mean	375.72	587.02	1057.74
	St. Dv	268.70	331.66	281.60
	Min.	0	0	530
	Max.	1000	1200	1620
Total	Mean	385.63	606.17	1064.60
	St. Dv.	289.31	326.69	254.55
	Min.	0	0	530
	Max.	1500	1500	1620

Source: Own Survey (2021)

When we look at the mean value for the entire sample, it showed an increment from 385.63 before ten years to 606.17 before five years and then to 1064.60 during the time of the survey; which indicates a 57.19% and 75.63% increase in the first and second five years, respectively. The average rate of increase in eucalyptus plantation in the study areas in the past decade was found to be almost 68 trees per household per year. While the annual rate of increase was almost 17.6% over the past 10 years and this shows how fast eucalyptus tree is expanding in the study area.

Households were also asked about their desire to increasing eucalyptus plantation and 94.4% reported that they want to expand their eucalyptus plantation in the future while the remaining 5.6% said they do not have any plan of expanding their eucalyptus plantation from its current level. This finding is consistent with Dereje et al. (2012) who claimed 92.2% of

farmers in Arsi Negele district reported future plans to continue planting eucalyptus tree. Participants in the FGDs also emphasized the prospect of further eucalyptus expansion due to its perceived higher economic returns compared to conventional farming in the study area.

4.4.2. Households' allocation of land to eucalyptus tree

Land is the most critical resource in the rural economy and the amount of it allocated to eucalyptus tree can be used as an indicator for eucalyptus expansion in a given area (Tegegne et al., 2018). The summary of land allocated by households in the study area is presented in Table 4.5.

Table 4. 4: Summary statistics of land allocated to eucalyptus tree by *Kebele* (Ha)

Statistics	***Kebele***						**Total**
	Zigibaboto	**Yesiray**	**Ketene**	**Werdene**	**Wodro**	**Girar&Yeferemazigbe**	
Mean	0.28	0.26	0.25	0.24	0.25	0.23	0.25
St. Dv.	0.15	0.14	0.18	0.16	0.18	0.19	0.17
Min.	0.04	0.05	0.01	0.01	0.0075	0.01	0.0075
Max.	1.10	0.65	0.80	0.60	0.62	1	1.1
Total	87	45	103	53	88	104	480

Source: own survey (2021)

Zigibaboto has the highest mean land allocated for eucalyptus with 0.28 Ha and Girar&Yeferemazigbe has the smallest with a mean value of 0.23 Ha. While the mean for the entire sample was found to be 0.25 Ha.

It is a well-known fact that in the study area, while some households own land which is totally suitable for crop production, some other may also own land which is fully or partially unsuitable for crop production and hence they describe it as marginal or hill side land which they can use for eucalyptus plantation. As a result, we collected data on the nature of land the household is using for eucalyptus plantation. The survey result showed that about 42.3% of the sampled households use crop land while 48.1% and 9.6% use hillsides and waste/marginal lands for growing eucalyptus tree, respectively. From this, we can conclude that farm households are substituting eucalyptus tree for food crops production and this is likely to have its own implication on food production and food security of the study area.

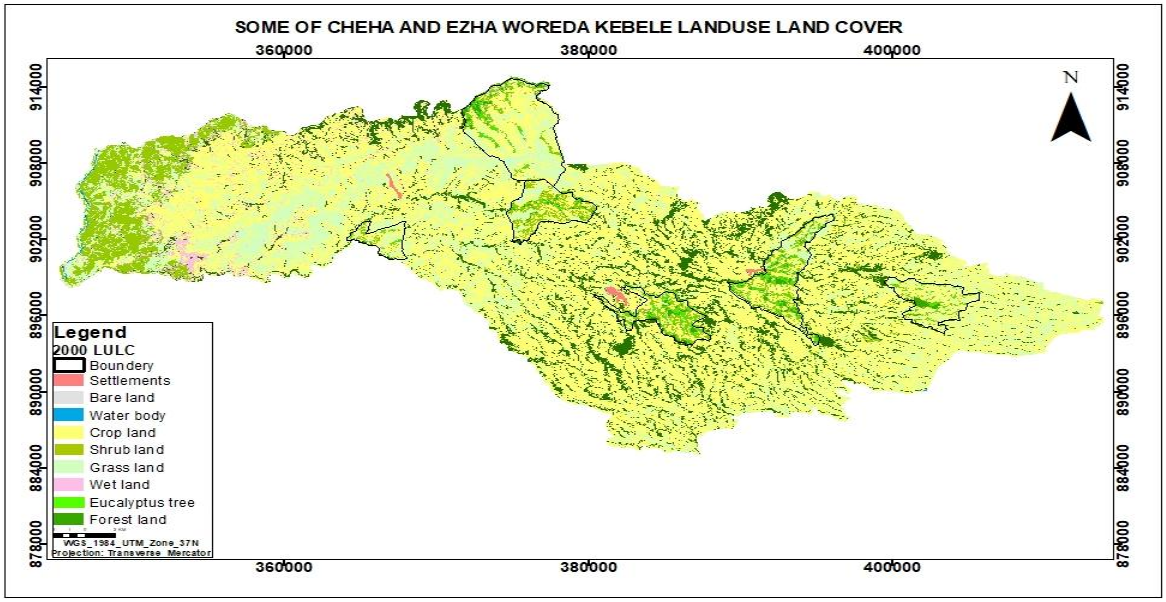
It is important to remember that though households overwhelmingly agree with the fact that eucalyptus is expanding at the expense of local food production, 52.04% of respondents have agreed with the statement that eucalyptus tree expansion improve food security. During the FGDs, participants expressed that the income obtained from the sale of eucalyptus trees have helped many farm households to buy oxen, improved seeds and other essential

agricultural inputs necessary for their farm works in addition to providing them the ability to purchase food directly from the market.

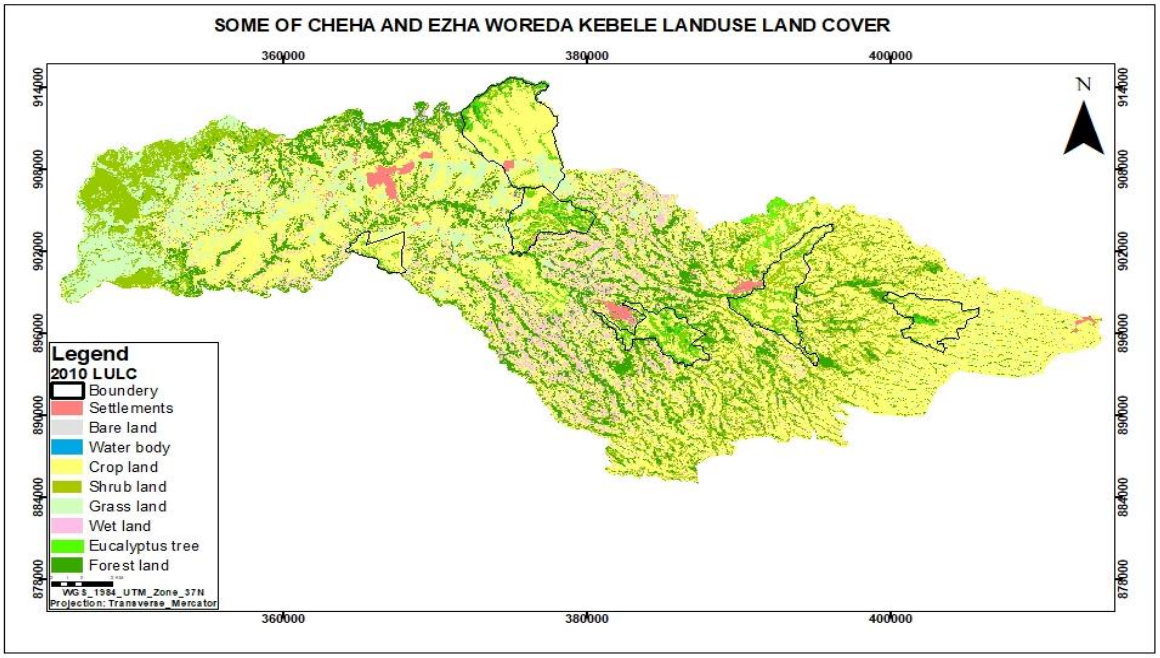
4.4.3. Land use and land cover patterns in Ezha and Cheha *weredas*

The final LULC maps of the study area for 2000, 2010 and 2021 are presented in the following three Figures 4.2 (a-c). The map obtained for accuracy assessment is given in Figure 4.3.

(a)



(b)



(c)

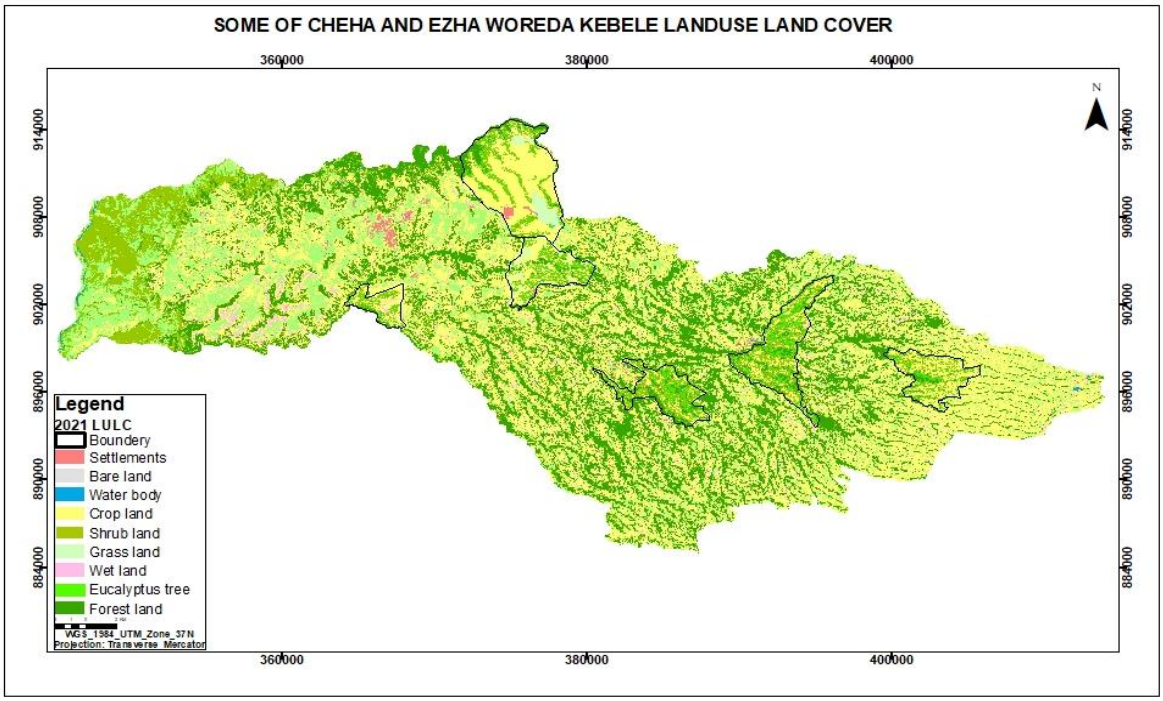


Figure 4.2: LULC Maps for 2000(a), 2010(b) and 2021(c)

The overall classification accuracy is weighted by the number of samples in each class, i.e. the sum of all samples on the diagonal divided by the total number of cells (0+0+6+26+1+15+93+2+0) / 160 which equals 89.37% while the overall Kappa statics was found to be 0.8143 for the classification of 2000.

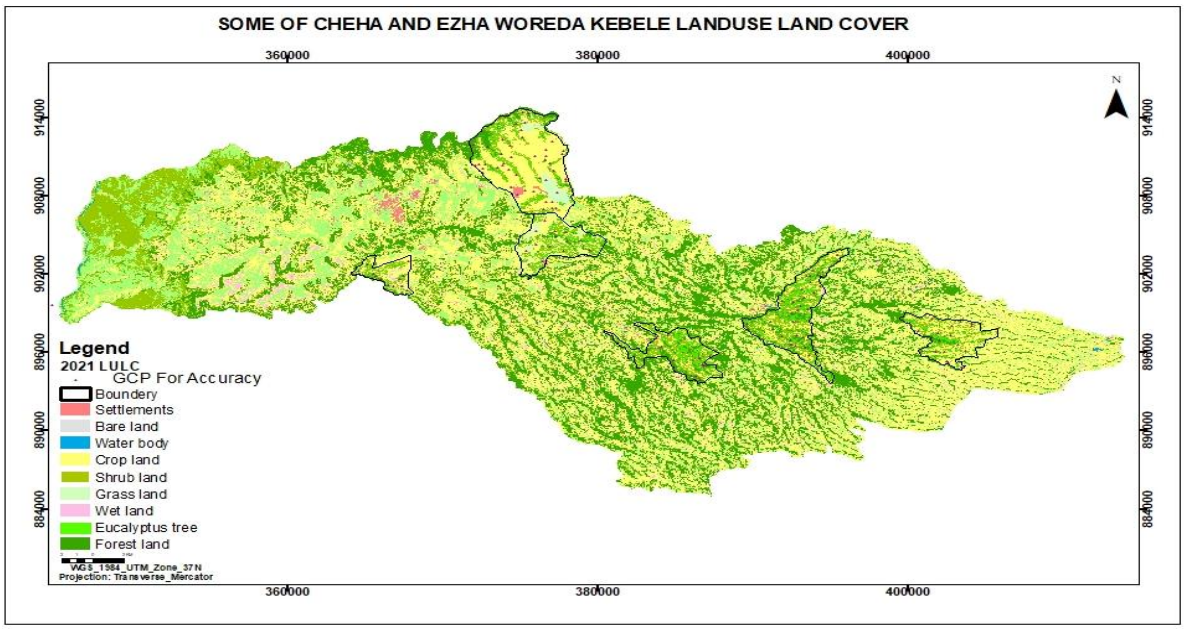


Figure 4.3: Accuracy Assessment map for 2021 LULC

According to the study's error matrix analysis, the categorization had an overall accuracy rate of 89.38%, 89.38% and 88.75% and kappa statistics of 0.814, 0.83 and 0.853 for year 2000, 2010 and 2021, respectively. Accuracy tables for the three periods are given in Appendices part (VIII to X).

From the final LULC maps shown in Figure 3(a-c), the actual areas of each LULC class and their extent of changes for the three periods are summarized in Table 4.6.

Table 4. 5: Summary statistics on LULC of the study area in 2000, 2010 and 2021.

	Area (Ha.)			Comparing 2000 to 2010		2010 to 2021		2000 to 2021		Share from total change in 2021 compared to 2000
LULC type	2000	2010	2021	ha	%	Ha	%	Ha	%	
Bare land	3.15	2.8	0.18	-0.36	-11.4	-2.6	-93.6	-2.97	-94.3	-0.08
Water body	0.54	5.67	1.08	5.13	950	-4.6	-80.95	0.54	100	0.02
Eu. Land	1288.3	1653.7	2168.5	365.4	28.36	514.8	31.13	880.2	68.3	23.8
Grass land	2328.7	571.2	591.0	-1757.4	-75.48	19.8	3.47	-1737.6	-74.6	-47.0
Wet land	114.6	6.93	65.3	-107.6	-93.95	58.3	841.6	-49.3	-43.1	-1.3
Forest Land	646.9	647.9	1180.2	0.99	0.15	532.3	82.2	533.3	82.4	14.4
Crop land	4781.9	6690.9	4723.8	1909.0	39.9	-1967.1	-29.4	-58.1	-1.2	-1.6
Shrub land	1762.3	1287.1	2110.3	-475.2	-27.0	823.2	63.9	348	19.75	9.4
Settlement	4.86	65.7	91.5	60.8	1251.9	25.8	39.32	86.7	1783.3	2.4
Total	10931.8	10931.8	10931.8	4682	42.8	3948.5	36.1	3696.7	33.8	

Source: Own analysis based on satellite data (2021)

among FGD participants in Yesrayi *kebele* that farmers nowadays prefer eucalyptus tree plantation to crops cultivation. In addition, the increase in shrub land could be due to the increasing tendency of farmers to engage in khat cultivation which is the second most important component in the shrub LULC type next to *enset.*

When we compare LULC of 2000 and 2021, eucalyptus plantation has shown the largest increase from the major land use types with almost 68% and experienced the highest gain of share in the changes which is 23.8% (880.2 Ha from 3696.69 Ha of total area of LULC changes), while grass land showed the largest loss (-47.0%). The second largest gain was recorded by shrub land with a 9.4% share. From this, it is possible to take expansion of eucalyptus tree as the leading cause of LULC changes in the study area.

Both *wereda* and *kebele* level experts also expressed their observation that the area is experiencing rapid LULC changes mainly due to the expansion of eucalyptus trees and they blame the absence of strong land use policy to be the main hurdle in tackling the problem. Most participants in our FGDs also expressed the same idea and even in Yesrayi *kebele* participants mentioned increasing cases of attacks on people and crops by dangerous wild animals which use eucalyptus plantations very close to homesteads as hiding places.

By taking the ratio of the total area of land that went through some sort of LULC change and the total study area, we can examine how fast the study area is experiencing LULC changes. Between 2000 and 2021, from the total study area of 10,931.85 Ha, 3,696.7 Ha (34%) experienced some sort of LULC change which is almost a third of the total study area.

The rate of eucalyptus plantation expansion is calculated using equation 5. The average annual rate of eucalyptus plantation expansion of the study area was found to be 36.54 Ha between 2000 and 2010 and 46.80 Ha between 2010 and 2021. For the entire study period (from 2000 to 2021), the average annual rate of eucalyptus plantation expansion was found to be 41.9 Ha.

In summary, the LULC assessment has confirmed that eucalyptus is continuously expanding and given land is limited this expansion is obviously happening at the expense of other land uses types. Between 2000 and 2010 eucalypts was expanding at the expense of grass land and shrub lands. However, between 2010 and 2021 eucalyptus was expanding at the expense of crop land. This may suggest that farmers gradually moving to converting cropland into

eucalyptus after exhausting other sources. This study, therefore, has confirmed eucalyptus tree to be the major driver of LULC change in the study area and if eucalyptus expansion is left unchecked, it is likely to cause a huge decline in local food production since crop land is used to produce food products such as cereals, legumes and potatoes which are important sources of food to households in the study area together with *enset* products. These food production loses may ultimately lead to food insecurity problems in Gurage zone which is more or less a food self-sufficient region.

4.4.4 Factors influencing the number of eucalyptus trees planted

Table 4.7 presents the result of the final OLS estimation indicating how the various socioeconomic factors affect the number of eucalyptus trees planted by the sample households in the study area.

The value of R-square shows the proportion of the variation in the dependent variable explained by the regression model. The p-value shows that the null hypothesis that all the coefficients of the variables are simultaneously zero is rejected at 1% level of significance which means the estimation in general is sound.

We found that most of the household characteristics have an influence on the number of trees planted. Age of household head was found to be negatively and significantly related with the number of eucalyptus trees planted. The coefficient -0.0033 indicates for a one year increase in the age of household head, the number of eucalyptus trees decrease by 0.0033%, keeping all the other variables constant. This means younger household heads tends to have more eucalyptus trees than older once. This could be the result of younger individuals tending to be more interested in exploring better opportunities and increasing their income by diverting their land to eucalyptus trees. Young people may also choose to engage in eucalyptus farming because it does not require as much experience as conventional farming in addition to being less risky in the production as well as marketing activities.

More educated households are more interested to plant eucalyptus trees. The coefficient estimates show that the number of eucalyptus tree planted increases by 0.0092% as the level of education increase by one grade level. This could be due to the general effect of education enabling households to be more aware of market opportunities to produce more of marketable products than producing traditional agricultural products. This finding is consistent with the finding of Dereje et al. (2012) who claimed that school year positively and significantly

affects land allocated to eucalyptus in Arsi Negelle and Gebreegziabher et al. (2020) who concluded that more educated household heads are less likely not to be engaged in planting eucalyptus tree species from their studies of smallholders tree plantation in Tigrai region of Ethiopia.

Table 4. 6: Estimation results of factors influencing the number of eucalyptus trees planted

Variable	Descriptions of Variables	Coef.	Std. Err.	T	P > | t|
Gedr	Gender of HH head (1 male , 0 female)	-0.0162	0.0205	-0.79	0.430
Mrstt	Marital Status of HH head (1 married, 0 single)	-0.0061	0.0206	-0.30	0.768
ageh	Age of HH Head (in years)	-0.0033	0.0011	-3.03	0.003**
elhh	School year of HH head	0.0092	0.0028	3.28	0.001**
lnsz	Total land holding of HH (Ha)	0.3998	0.0365	10.95	0.000**
actr	Proximity to roads (minutes to main road)	-0.0012	0.0042	-2.74	0.006**
acel	Access to electricity (1 yes, 0 otherwise)	0.0077	0.0212	0.36	0.718
suln	Suitability of land to crop production (1 yes, 0 otherwise)	0.0252	0.0180	1.40	0.162
flit	Nº of persons in the HH in the working age group	-0.0376	0.0082	-4.59	0.000**
pnof	Participation in off/non-farm activities (1 yes, 0 otherwise)	0.0457	0.0196	2.33	0.020*
dzgb	Dummy for Zigbaboto Kebele (1 Zigb., 0 otherwise)	0.0387	0.0294	1.32	0.189
dyes	Dummy for Yesray Kebele (1 Yesr., 0 otherwise)	0.0887	0.0359	2.47	0.014*
dket	Dummy for Ketane Kebele (1 Ketn., 0 otherwise)	0.0791	0.0279	2.83	0.005**
dwor	Dummy for Worden Kebele (1 Word., 0 otherwise)	0.0744	0.0333	2.23	0.026*
dgyz	Dummy for Girar & Yefer. Kebele (1 Gryf, 0 otherwise)	0.0649	0.0278	2.33	0.020*
Con.	Intercept	6.8506	0.0753	91.01	0.000
R2		0.4226			
N(No. 0bs)		480			

** = significant at 0.01 level; * = significant at 0.05 level;

Number of household members in the working age is the other variable having significant effect on the dependent variable. For every additional family member who is in the working age group, the number of eucalyptus tree planted decreases by 0.0376%. This further suggests that eucalyptus is widely planted by those who have relatively fewer work forces at their disposal as was the case in the study of Dereje et al. (2012) and Tegegne et al. (2018). This is also in line with the findings obtained in the interviews held with agricultural experts that absentee farmers who usually have less labour force for farm work tend to prefer eucalyptus farming over regular farm works since the later requires more labour and attention.

Households' wealth indicator such as land size was included in the analysis. As expected, the total land holding has positive impact on the number of eucalyptus trees planted. Since land is the major input for eucalyptus tree growing, more land means having extra land for eucalyptus after allocating it for other essential agricultural productions such as food particularly for *enset*. This result is consistent with the findings of the study by Tegegne et al. (2018).

Participation in off/non-farm activities is also a significant variable. Those who participate in off/non-farm activities tend to have more eucalyptus plantation than those who do not participate, if all other variables remain unchanged. This shows those who engage in some form of off/non-farm activities tend to give less attention to regular agricultural works and engage more in eucalyptus plantation which requires less labour and attention.

Access to infrastructure is also important in making tree products available for market. The negative coefficient of the variable proximity to main roads shows that as the household is located far from the nearest main road (the longer it takes to reach the main road), the less will be the amount of eucalyptus tree planted, all else being the same. This variable can be considered as a proxy to access to the markets since eucalyptus products are sold usually at the farm gate to those who come with their own trucks. This could be due to the provoking nature of the market to plant more eucalyptus trees as the farm household comes closer and closer to the main roads and this result is consistent with the literature on LULC (see for example, Belay et al., 2021; Tegegne et al., 2018; Adhikari et al., 2017; and Kebede, 2017).
Finally, the result on the *kebele* level fixed effect shows that there are variations in terms of the number of trees planted by households which might be due to differences in factors such as the fertility status of the soil, climatic conditions and other unobservable factors which were not captured in the analysis. .

4.5. Conclusions and policy implications

Households in the study area on average allocate nearly a quarter of a hectare of land holding to eucalyptus tree mainly due to the perceived higher economic returns compared to conventional farming. The findings also revealed households' intentions to expand their eucalyptus plantations in the future. The study also showed that eucalyptus plantation is carried out on fertile crop lands in addition to waste land and hillsides, contrary to what is typically claimed by local authorities and experts.

The study identified eucalyptus plantation by smallholder farmers to be the prime cause responsible for LULC changes in the study area which is the result of shifting land from crop production and other uses to eucalyptus plantation and this is expected to have a huge implication on local food production capacity and hence future food security.

The econometric estimation showed various socioeconomic factors to be the micro level drivers of eucalyptus plantation in the study area. Compared to the base *kebele* Wodro except Zigbaboto all the remaining *kebeles* were found to be statistically different from the base. This indicates households in Wodro *kebele* which has better irrigation facilities; fertile soil and better climatic conditions were found to have less eucalyptus plantation compared to the other *kebeles*. This suggests that if farmers can get adequate income from food crop production their desire to increase eucalyptus plantation is not expected to grow. Hence solving farm level productivity and market related hurdles can be considered as potential instruments to control eucalyptus expansion in the study area.

This study has found out that farmers in the study area are still eager to increase their eucalyptus plantation and any further uncontrolled expansion of eucalyptus is likely to have a negative effect on local food production. This is because crop and *enset* lands are the only remaining sources of land to accommodate the demand for additional lands for eucalyptus plantation by smallholder farmers. Therefore, if eucalyptus expansion is left unchecked, it is likely to cause a huge decline in local food production since crop land is usually used to produce food crops such as cereals, legumes and potatoes which are important source of food to households in the study area next to *enset* cultivation from which the local staple food known as *Kocho* and other food products are produced. This may ultimately lead to a decline in food production and consequently food insecurity problem unless and otherwise it is offset by technological advancement that can increase farm level productivity. For this reason immediate policy based intervention is needed in order to save the people from impending harmful consequences of uncontrolled expansion of eucalyptus plantation.

To sum up, experts and government officials in the study area are in dilemma between supporting and taking controlling measures on the rapid expansion of eucalyptus tree mainly due to the absence of clear policy guidelines with regarded to eucalyptus tree. In particular, the draft land use policy should be finalized and implemented as it guides the land use type and reduce the conflicts that arise between farmers and local level officials since the land use policy will give authorities the legal power to control any illegal use of rural land. Therefore,

there is a need for an immediate policy formulation and implementation with regard to rural land use and eucalyptus tree plantation in Ethiopia. In addition, to help smallholder farmers reach some sort of balance among the different objectives they seem to pursue, i.e. getting sufficient food for their family, generating adequate income and satisfying own tree demands, continuous awareness creation campaigns should be undertaken to help them make an informed decision with regard to using their most valuable asset in the most sustainable and efficient manner. This may include providing them with timely and scientific production and marketing information on the relevant alternative farm production activities. There is a need to encourage farmers to plant eucalyptus trees on marginal and unproductive lands which cannot be used for crop or grazing lands. This can be enhanced by providing continuous training and increasing the awareness of farmers and all other relevant stakeholders in the region.

Further studies on the cost-benefit analysis of different types of land uses by smallholder farmers in the study area may be necessary as it enables all stakeholders to make an informed decision about the optimal use of rural land. Moreover, a dynamic analysis using panel data on the micro-level drivers of LULC is necessary.

Chapter 5: Analysis of food security among eucalyptus tree farming smallholder farmers in Gurage Zone, Ethiopia: an application of a composite food security indicator[9]

Abstract

This study examines the contribution of eucalyptus tree expansion on rural households' food security status, focusing on the specific context of Ethiopia. Eucalyptus trees pose a significant challenge to the rural food system, warranting investigation. A composite food security indicator was used, and data were collected through household surveys, Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs). Descriptive analysis and multinomial logistic regression models were employed for data analysis. The findings reveal that among the sampled households, 31.2% were classified as food secured, 24.8% as intermediate food secured, and 44.0% as food insecured. Econometric estimations highlight the positive influence of variables such as total land holding and livestock on the likelihood of being in the food secured category. Moreover, a unit increase in income earned from the sale of eucalyptus trees leads to an 8.5% higher probability of falling into the intermediate category, while decreasing the likelihood of falling into the categories of food insecurity by 8.1% and food security by 0.4%. Importantly, this study uncovers the diverse consequences of eucalyptus trees across different food security categories, suggesting that the planting of eucalyptus trees for improving rural livelihoods and food security must be tailored to specific household conditions. The research outcomes provide valuable insights for guiding future policies, practices, and research endeavors aimed at achieving a sustainable food system in rural Ethiopia.

Keywords: Eucalyptus farming, Composite food security indicator, *enset* cultivation, Food system, Food availability, Multinomial logit, Food access, Central Ethiopia.

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5.1 Introduction

With respect to food security and the problem of hunger, the world community has set a Zero Hunger target for SDG 2030. Target 2.1 states: "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round". However, due to various factors, global food insecurity and hunger is rising and around 821 million people (approximately one out of every nine people in the world) are undernourished (FAO, 2018a). The same source indicated that 31.4% of the population of East Africa (132.2 million) was undernourished which was much more than the average of sub-Saharan countries (23.2%). The problem of food insecurity and malnutrition is even worse in Ethiopia which has experienced some of the worst famine of the 20th century- late 1970s and early 1980s. In recent years, the problem seems even to get worse due to prolonged draught and internal conflicts as a result of which the number of people needing food assistance is increasing year after year (FEWS NET, 2023). This is why the issue of food insecurity is still at the center of economic, social and political debates in the developing world including Ethiopia. Besides, ensuring food security has always been one of the basic national policy agenda in many developing countries and it is considered as the foundation of national security (Benson, 2004; Zou and Guo, 2015). This suggests that the issue of food insecurity deserves a special attention in developing countries like Ethiopia. In line with this, the analysis of food security and the factors that influence it will provide important inputs to development stakeholders.

FAO (2003) described food security as a situation that exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This means food security encompasses fulfilling sufficient nutrients such as energy, protein, vitamins and minerals that our body needs for healthy and productive lives in a sustainable manner. To ensure food security at household level in a sustainable manner we need to build a sustainable food system which FAO (2018b) defines it as "a system that delivers food security and nutrition for all in such a way that the economic, social and environment bases to generated food security and nutrition for future generation are not compromised".

The food system encompasses all activities and relationships that exist in food production, processing, marketing, consumption and its final disposal (Van Berkum et al., 2018). However, to the rural communities, the agricultural sector is the most critical sector in

building a sustainable food system. Hence, maintaining a productive and efficient agricultural sector in general and the smallholders' agriculture in particular is crucial in order to build a sustainable food system in the rural economy (Capone et al., 2014; Rutten et al., 2011). With this regard, this study examined the contribution of eucalyptus trees and other socioeconomic factors on the food security conditions of eucalyptus tree farming households in the Gurage highlands located in the central part of Ethiopia.

The expansion of eucalyptus trees has received both supports and criticisms (Duba, 2016). Some take eucalyptus as a curse believing that it can reduce local food production with its own risk of turning once surplus producers to food deficit areas in the future due to its excessive consumption of soil nutrients and ground water (Duba, 2016; Getachew, 2016). Some others take it as a blessing for its significant economic and social benefits. Among others, the cash obtained from eucalyptus sale assists smallholder farmers to bridge the food shortage gap at household level (Jaggar and Pender, 2000; Zenebe et al., 2012; Mesfin and Wubalem, 2014).

Though, food insecurity is the result of many interrelated factors, own productive capabilities play essential roles for rural communities (Degefa, 2005; Getachew, 2018). Degefa (2001) pointed out demographic, economic, infrastructural and social problems to be the causes of seasonal food insecurity in Amhara Region. Among the demographic factors, rapid population growth and the resulting declining landholding of households was found to be the most important factor. This reveals that household own food production play a critical role in rural food system. This is also consistent with the study of Getachew (2018) who identified own production of rural households' to be the major sources of food (44%) for family consumption from his study in East Shewa- Ethiopia. This suggests that improving the food security status of rural farming communities should focus mainly on enhancing their food production capabilities. This involves among other things controlling the shift of productive resources such as land away from food production. In relation to this, one of the most important issues demanding the attention of policy makers and experts in Ethiopia is the alarming expansion of eucalyptus trees farming on fertile food producing land of smallholder farmers in the different parts of the country (Tola, 2010; Getachew, 2016). The analysis of the influence of eucalyptus tree on the food security status of smallholder farmers will provide important inputs in future policy formulation with regard to rural land use, eucalyptus plantation as well as food security issues.

Tough eucalyptus tree is increasingly becoming one of the livelihood options to smallholder farmers in many parts of rural Ethiopia (Getnet et al., 2022). Literatures do not have a clear cut conclusion about the implication of eucalyptus on food security. Some studies indicate eucalyptus trees may reduce crop yields and income of households not only due to its direct impact of occupying scarce smallholders' land (Tola, 2010; Getachew) but also as a result of its shading effects and competition for water and soil nutrients when planted adjacent to food crops (Jaggar and Pender, 2000; Bazzana, 2020). Though studies on the particular case of the impact of eucalyptus tree on smallholders' food security are scarce, some studies argue that cash crop and agro-forestry have positive impact on food security (Magcale-Macandong et al., 2010; Achterbosch, 2014; Kiptot, 2014). This suggests the need for investigating the contribution of eucalyptus trees on rural households' food security status using standard food security measures.

In Ethiopia, there are very few rigorous studies done on the relationship between eucalypts tree and food security. Most of the available studies such as Getachew (2016) did not use standard food security measurement tools and considered only the availability component of food security. This is clearly leaving aside the other components of food security- access, utilization and stability. For instance, eucalyptus trees planted on crop land may reduce own food production (a decline in food availability) but income from its sale can increase the access component of food security which WFP (2009) defines it as "a household's ability to acquire adequate amount of food regularly through a combination of purchases, barter, borrowings, food assistance or gifts". Therefore, food security assessments should attempt to consider as many food security components as possible in order to get a more accurate result (Maxwell et al., 2013).

In Gurage Zone, the focus of this study, the increasing tendency of planting eucalyptus for cash and other purpose is likely to reduce land and other scarce resources available for food production. Hence, assessing the implication of these trends on the food security status of the rural households is crucial. This study will, therefore investigate the implication of eucalyptus tree farming and other socioeconomic factors on food security status of rural households in Gurage zone by using a food system approach of analysis in which all the four components of food security- food availability, access to food, food utilization and stability are considered and for this we use a composite food security indicator which is derived from two food

security indicators- Household Food Security Access Scale (HFSAS) and Food Consumption Score (FCS).

Though some researchers such as Getachew (2018) and Dereje (2021) have used two different food security indicators simultaneously to assess the food security status of their respective target population, using a combination of two or more indicators by merging them together as used in this study are very rare in Ethiopia. Therefore, applying a composite food security indicator in Ethiopia will be one of the contributions of this study. Moreover, this study will contribute to the debate on food versus trees (i.e. eucalyptus) by adding scientific information on the influence of eucalyptus tree on rural households' food security. As a result, it will contribute its share to the proper utilization of rural land and other scarce resources in order to achieve food security in rural areas through building and maintaining a sustainable food system.

In general, this study aims to address the following research questions: i) how do the food security situation of households in the study area look like? II) How do the various demographic, socio-economic and institutional factors influence farm households' food security in the study area? And iii) How does eucalyptus tree influence households' food security status in the study area?

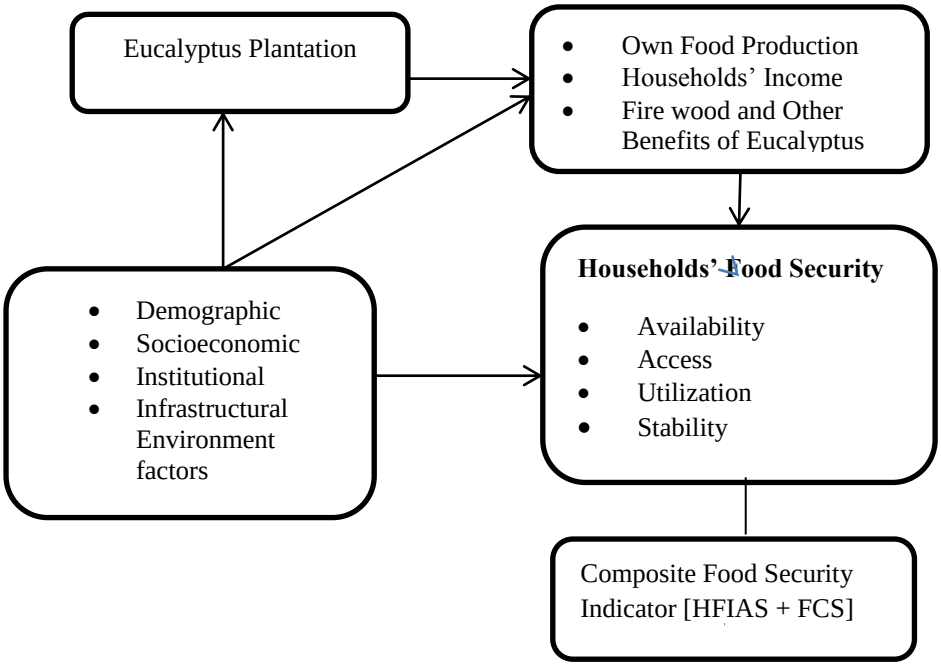
5.2 Material and methods

5.2.1 Analytical framework

The analysis of the contribution of eucalyptus tree on food security is undertaken based on the analytical framework given by Figure 5.1 which shows the basic issues addressed in this study. These issues are associated with the rapid expansion of eucalyptus plantation and their implication on households' food security in the study area. This study also bases itself on food system theoretical framework since this theory allows a comprehensive and holistic approach to analysis the food security status of rural households by considering all aspects of food security- availability, access, utilization and stability (Van Berkum et al., 2018; Rosenzweig et al., 2020).

The plantation of eucalyptus trees is influenced by many interrelated demographic, socioeconomic, institutional and environmental factors (Tefera and Lerra, 2016; Gebreegziabher, et al., 2020). These plantations are primarily undertaken to get higher

income and to satisfy own fire wood demands (Belay and Abraham, 2016; Getnet et al., 2022). However, these benefits are likely to come at the cost of households' own food production. Empirical studies indicate that there is a trade-off between food production and eucalyptus plantation in an area where land is highly fragmented, agricultural inputs are in short supply and there is lack of technological innovations (Tigre and Heshmati, 2022; Gemechu, 2014). This expansion of eucalyptus tree is expected to influence the food production of the area in many ways not simply as a direct loss of food crop but also from a decline in livestock holding of households since eucalyptus tree can also occupy grazing lands (Getachew, 2016).



Source: Adapted from Rosenzweig et al. (2020) and Van Berkum et al. (2018)

Figure 5. 1: Analytical Framework on Eucalyptus and Food Security

Eucalyptus trees can also provide both ecological and economic benefits to the households (Bayle, 2016; Gebreegziabher, et al., 2020) and its expansion may not necessarily lead to a fall in the food security status of households. This is because increased purchasing power from the sale of tree products may give rural households the opportunity to purchase more food (increasing food access) and improve food security (Bazzana et al., 2020). On the other hand, given the poor development of marketing facilities and ever increasing price of food, it

is very difficult to ensure access to adequate food at household level at affordable prices in such rural settings (Jagger and Pender, 2000; Peralta and Swinton, 2009). Therefore, the implication of eucalyptus tree on rural households' food security status requires a rigorous investigation.

The four components (pillars) of food security (FAO, 2003) suggest that households' food security is influenced by multiple interconnected factors as suggested by the food system approach. As a result, no single indicator is capable of fully capturing all aspects of food security (Maxwell et al., 2013; Wolfe and Frongillo. 2016). In this study, therefore, we used a composite measurement derived from two prominent food security indicators- HFIAS and FCS. HFIAS mainly measures the access components of food security and to some extent the stability component (Coates et al., 2007) while FCS examines the availability and the utilization component of food security (WFP, 2008).

5.2.2 Study area setting

Gurage zone is found in the central part of Ethiopia. It is characterized by various land forms such as plateaus, mountains and valleys. The zone covers wide ranges of altitude below 2000 meters and highlands of more than 3000 meters - its highest point being mount Gurage which is 3719 meters above sea level. As a result, all the three main agro-ecologies are found in the zone - *Kolla* (lowland), *weyinadega dega* (mid altitude) and dega (high altitude). The annual mean temperature of the zone ranges from 13^0C to 30^0C. Its mean annual rainfall ranges from 600 to 1600 mm.

Most smallholders in the study area practice mixed farming and *ensete* (enseteedulis, äsät or "false banana plant") is the most important sources of food for the Gurage people. In addition, barely, pulses, potatoes and vegetables especially cabbage are widely cultivated. Wheat and *teff* are also cultivated in some of the mid altitude areas of Gurage zone. *Khat* (catha edulis), a perennial crop is also widely cultivated as cash crop in many areas of Gurage land. However, the rapid expansion of eucalypts tree in Gurage zone could be the most critical challenge due to its effect on changing land use patterns from food production to the production of tree products (Kebede, 2017).

5.2.3 Sampling Techniques and Data Collection

Zerga and Berta (2016) stated that the top *weredas* in Gurage zone's eucalyptus plantations are Enemor and Ener, Cheha, Ezha, and Gumer. Due to resource limitations and the need to consider households in all the tree climatic conditions, the study was undertaken in Ezha and Cheha *weredas* only. Three *kebeles* from each *wereda* were purposively selected based on the extent of eucalyptus tree expansion and one *kebele* from each of the three agro-ecological Zones. Experts from each *wereda* were consulted in selecting *kebeles*. We used systematic random sampling procedure to select sample households from each *kebele* from a list of households obtained from their respective *kebele* offices. .

Based on Yamane (1967), the total sample size of the study was determined to be 480 households which then were divided to the six *kebeles* proportional to their respective population size. As a result, 87 from Zigbaboto, 45 from Yesray, 103 from Ketane, 53 from Weredene, 88 from Wodro and 104 from Girar and Yefermazigibe households were selected. A face-to- face households' survey was undertaken to get the relevant data to achieve the objectives of this research from the households and their farms. Enumerators who were familiar with the study area and those who speck the local language 'Guragigna' were selected and given a day-long training based on FANTA guidelines. A pilot survey was undertaken in three *kebeles* with 50 households to test the reliability of the questionnaire and the effectiveness on the enumerators. The feedbacks obtained from the pilot survey were used to further refine the questionnaire.

The field survey was undertaken in January and February during which there were no fasting of both Orthodox Christianity and Muslim religion followers in the study area. This period was selected because especially information on food consumption can be highly biased in rural Ethiopia during festive and fasting seasons (Sibhatu and Quim, 2017). Especially, the FCS measurement will be irrelevant during fasting months of Orthodox Christians who refrain from consuming any animal products such as meat, eggs, milk and milk products. In addition, these months are less likely to represent neither extreme case of food shortage (like months of March to August) nor food abundance (like the months of September to December) which probably makes them the ideal months to take the average picture of the food security situation of the study area.

In addition, qualitative data were collected using FGDs and KIIs methods using structured guiding questioners. Participants in FGDs were selected to represent the youth, elderly and women. In total, six FGDs (one in each *kebele*) were undertaken. KIIs at *wereda* and *kebele* level were also conducted with government officials, experts and DAs (Development Agents) who are more familiar with the socioeconomic conditions of the study area. The findings from the descriptive and econometric analysis were triangulated with the results obtained from FGDs and KIIs.

5.2.4 Data Analysis

5.2.4.1 Food Security Measurement Tools

Although there are agreements on some aspects of food security, due to its complexity and multidimensional aspect, the absence of standardized measure of food insecurity has been one of the controversies in the discussion of food security (Coates et al., 2007, Maxwell et al., 2013; Wolfe and Frongillo, 2016). For many years, age-adjusted per-capita caloric intake was considered as "the golden standard" for access to food at the household level, and anthropometric measures of nutritional status at the individual level (Hoddinott, 2002). In addition to being very costly and time taking, this method does not reflect all components of food security (Degefa, 2005) and it reflects only one aspect of nutritional status (Yong and Jaspers. 2009).

Even though, there are a number of food insecurity measurements, the most commonly used indicators are quite a few, and it is advisable to use more than one indicator in order to have a better reflection of food security status of the target population (Maxwell et al., 2013). For this reason, we have used a composite food security indicator derived by combining HFIAS and FCS. HFIAS mainly captures the element of food quantity (sufficiency) and quality (diversity) as well as to some extent the issues of stability and acceptability (Coates et al., 2007; Maxwell et al., 2013). On the other hand, FCS attempts to objectively capture issues of food diversity for checking the availability of the required nutrients from the food actually consumed by the household not from the psychic of the respondents unlike HFIAS (Maxwell et al., 2013; WFP, 2008).

I) Household Food Insecurity Access Scale

This method was designed to capture households' behavior as a result of uncertainty to assess sufficiency of food in quality and quantity as well as the resulting anxiety. It is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale (Coates et al., 2007). It involves providing nine occurrence questions- whether the condition in the questions have happened at all in the past 30 days. If the respondent answers 'yes' to the occurrence question, then frequency of occurrence questions will follow to know whether the specific condition happened 'rarely' (once or twice), 'sometimes' (three to ten times) or 'often' (more than ten times) in the reference period of the past 30 days. Based on their responses, it is possible to examine three important food insecurity domains and determine households' food security status as food secured, mildly food insecured, moderately food insecured and severely food insecured. It is also possible to get a continuous number (0-27) reflecting the extent of food insecurity which is called household's food insecurity access scale score. Getachew (2018), Dereje (2021), Garedew (2017) and Adane (2018) are some of the researchers who used this method in Ethiopia.

II) Food consumption score (FCS)

This is a composite score calculated based on dietary diversity, food frequency and nutritional importance of different food groups. Extensive testing and applications have proved this tool to be valuable to the context of developing countries (WFP, 2008). FCS is calculated by collecting data from households who are asked about the number of days they consumed food items which are grouped in to 8 standard groups with different weights reflecting their nutritional importance. FCS is calculated for each household based on the number of days the household consumed the particular food group items in the past seven days and multiplying each by its corresponding weight (WFP, 2008). A continuous food consumption score with a maximum value of 112 is obtained based on which households can be categorized as 'poor', 'borderline' and 'acceptable' reflecting their food security status.

Since every food security indicator has its own limitations, using two or more indicators to predict the food security status of a given target population will provide a better result [25]. Hence, using these two indicators, we derived a composite food security indicator to get more accurate information about the food security status of households in the study area.

5.2.4.2 Econometric Model Specification

To identify factors that influence the food security status of households and evaluate the contribution of eucalyptus farming to household food security, we first categorized households into different groups based on their food security status. For this purpose, the composite food security indicator enabled us to have three categories of households- food secured, intermediate group and food insecured. As a result we have a categorical dependent variable with three categories.

The model, we used for the purpose of identifying factors that influence the probability of falling into one of the three food security categories is the multinomial logit model (MLM). When the dependent variable is more than two categories and where there is no clear ordering of the choice, the most appropriate model is the MLM [46]. MLM uses maximum likelihood estimation to predict the probability of categorical membership. Dereje (2021), Pakravan-Charvadeh et al. (2022), Jackson et al. (2019) and Singh et al. (2014) are some of the researchers who used multinomial logit model to identify factors that influence households' food security status.

To evaluate the contribution of eucalyptus tree to food security status of households, we used the log value of the annual income earned from sale of eucalyptus tree as a proxy variable to capture the extent of eucalyptus plantation by households. We used income earned because, when we use land allocated to eucalyptus or number of eucalyptus trees planted or share of land allocated to eucalyptus, these variables were found to be highly correlated with the total landholding of the household which we have included as one of the most important explanatory variable in the model. In addition, income earned from sale of eucalyptus tree is likely to be directly proportional to the amount of land and other resources allocated to it since smallholders farmers are usually price takers who receive farm gate prices set mainly by middle men (Peralta and Swinton, 2009). Therefore, we took the log value of the annual income earned from the sale of eucalyptus products as one of the independent variables in our MLM to assess the influence of eucalyptus tree on food security status of households. We made initial tests including univariate, bivariate, and multivariate assessments. More specifically, a multicolinearity test was undertaken and the result is shown in the Appendices part (Appendix XI) and based on the results some independent variables were excluded from the final estimation.

The dependent variable in the multinomial logistic regression was assumed to take a value of 0, 1 and 2 for food insecured, intermediate and food secured categories, respectively while the various socio-economic variables as well as the log of annual income obtained from eucalyptus sale were considered as the explanatory variables. Eq.1 shows the expression used to estimate the coefficients of the independent variables.

$$\mathrm{pro}(\mathrm{Y_{ki}}) = \frac{e^{\beta_k^l X}}{\sum_{k=0}^{2} e^{\beta_k^l X}} = 0,1,2 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (1)$$

In Eq. 1 X represents the vector of explanatory variables and Y= 0 for food insecured, Y=1 for the intermediate group and Y= 2 for food secured group. The coefficients in multinomial logit are difficult to interpret and not intuitive, though they do tell us the direction of influence a given explanatory variable has on the dependent variable [46].

By differentiating Eq. 1 with respect to the explanatory variables, we get Eq. 2- the marginal effect equation which is more meaningful for numerical interpretation.

$$m_i = \frac{\partial Y_j}{\partial X_i} = Y_j \left[\beta_j - \sum_{k=0}^{2} Y_k \beta_k \right] = y_j \left[\beta_j - \bar{\beta} \right] \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

Marginal effect measures the probability of falling into the j^{th} categories as a result of a unit change in an independent variable, keeping all other variables constant.

5.2.4.3. Description of variable and Hypothesis

A summery statistics on the variables included in the estimation and their expected influence on the dependent variable is given in Table 5.1.

Gender of Household Head: This is a dummy variable which takes a value of 1 if the household head is male and 0 otherwise. Cultural practices and economic deprivation are expected to make female headed households to be less food secured compared with male headed households.

Marital Status: This is a dummy variable taking a value of 1 if the household head is married and 0 if single. This means all individuals who had no partner during the time of the survey which include those who were divorced or separated or widowed or those who were never married will be considered as 'single' in this analysis. Married household heads are expected to be more food secured than single once because of the likelihood of the contribution of both partners for the wellbeing of the household. On the contrary, married

household heads are likely to have more children who are not yet old enough for work. As a result the effect of the variable marital status can be positive or negative.

Age of Household Head: This is a continuous variable measured in years. In this study, age is expected to influence food security status negatively since older people are expected to be less economically active and more risk averse than younger households and therefore they are expected to be less food secured (Kahsay and Mulugeta, 2014). On the other hand, older household heads are expected to have more experiences in agricultural works and decision making and this is likely to make them more food secured than younger household heads (Gebre, 2012). As a result, in this study we expect the influence of age on food security to be either positive or negative.

School Year of Household Head: This variable measures the educational level of household head in terms of school year. In this study, school year is expected to have a positive impact on food security since more educated people are likely to make better decision in production and consumption. Though, some studies such as Gebre (2012) claimed education to have either insignificant or negative impact on food security; in our study we expect educational level of household head to have positive contribution to households' food security as was the case in the study of Dereje (2021).

Annual Income Earned from Sale of Eucalyptus Products: Higher income increases the purchasing power of households, enabling them to buy food which may improve their food security status (Bazzana et al., 2020). However, this higher purchasing power may come at the expense of households' own food production, with its own negative implication on food security (Getachew, 2016). As a result, we expect the influence of this variable to be either positive or negative.

Total Livestock Holding: This is a continuous variable, reflecting the livestock resource a given household has measured in Tropical Livestock Unit (TLU)[10] as proposed by Storck and Dopper (1991). Livestock holding is expected to influence food security positively since it serves as a direct source of food in addition to being sources of income to purchase consumption and productive inputs in addition being a capital input in farm production (Kahsay and Mulugeta, 2014; Bedek, 2012).

[10] We converted and expressed the total number of livestock in tropical livestock unit (TLU), which is a composite index of livestock ownership calculated by assigning different weights to different types of domesticated animals as proposed by Storck and Dopper [46]. The conversion factors used for this study are given in Appendix XII.

Table 5. 1: Summery statistics of explanatory variables used in the multinomial logit estimation

Variables	Descriptions	Statistics	Expected Sign
Wereda of Households	Cheha	245 (51.04%)	+
	Ezha	235 (48.96%)	
Gender of Household Head	Male	367 (75.63%)	+
	Female	117 (24.38%)	
Marital Status of Household Head	Married	359 (74.79%)	+/-
	Single	121 (25.21%)	
Participation in non/off-farm activities	Participant	167 (34.79%)	+
	Non-participant	313 (65.21%)	
Suitability of Land for crop production	Suitable	293 (61.04%)	+
	Not suitable	187 (38.96%)	
Age of Household Head (years)	Mean	47.17	+/-
	Min.	23	
	Max.	87	
Educational Level of Household Head (years of Schooling)	Mean	5.11	+
	Min.	0	
	Max.	14	
Total Land Holding (Ha.)	Mean	0.75	+
	Min.	0.25	
	Max.	3	
Annual income from eucalyptus (ETB)	Mean	11,391.3	+/-
	Min.	1,500	
	Max.	69,000	
Livestock ownership (TLU)	Mean	3.25	+
	Min.	0.26	
	Max.	9.46	
Family size	Mean	7.65	+/-
	Min.	3	
	Max.	12	
Distance from main roads (minuets)	Mean	43.78	-
	Min.	0	
	Max.	120	

Total land holding of household: Land is locally measured in a unit called zheng. However, for our analysis we converted it to Hectare (Ha.). Land which is, the major critical resource in a farming community, determines all agricultural outputs including the production of eucalyptus trees. In this study, land size is expected to have a positive contribution to food security of households as was the case in the study of Kahsay and Muluget (2014) and Dereje (2021).

Suitability of land for crop production: This is a dummy variable taking a value of 1 if the land is suitable for any type of crop production and 0 if it is not (hillside, marginal land, etc.). This is expected to have a positive influence on food production since suitable lands are more conducive not only for crop production but also for tree planting. We expect this variable to have positive impact on food security.

Family size: This variable represents the total number of persons living in the household and this determines both the productive capacity of households (labour force) and the number of mouths to be feed. We expect this variable to be either positive or negative.

Participation in non/off-farm activities: This is a dummy variable taking a value of 1 if the household involves in a non/off-farm activities and 0 otherwise. This variable is expected to have positive impact since those who engage in non/off-farm activities are expected to generate additional income compared to non-participants (Alem, 2007).

***Wereda* Dummy:** This is a dummy variable which takes a value of 1 if the household is in Cheha *wereda* and 0 if it is in Ezha *wereda*. Economic infrastructures and climatic conditions play an important role in determining the food security status of rural households (Aklilu et al., 2023). We expect households in Cheha *wereda* to be more food secured than household in Ezha *wereda* due to better environmental and economic conditions in the former *wereda*.

Distance from main roads: This variable is taken as a proxy to access to market and households were asked to report the time needed to reach the nearest main road. This means the shorter it takes, the closer they are to the main road. The location of households relative to markets can influence the food security status of households. For instance, Pakravan-Charvadeh et al. (Pakravan-Charvadeh et al., 2022) in their study of food insecurity among Afghan refugees living in Tehran-Iran, indicated that the further away households were located from the central market, the more food insecured they were found to be. This variable is expected to take a negative coefficient in our estimation which means the longer the time households need to reach the main roads, the less food secured the households are expected to be.

5.3 Results and discussions

Aklilu et al. (2023) provides the data set used for calculating the results and drawing the conclusion of this research.

5.3.1 Food security as measured by HFIAS

The results of analysis from HFIAS indicator for conditions, domains, scale score and prevalence are discussed in this section. Condition refers to percentages of households that responded ‘yes’ to each of the nine occurrence questions and the results are summarized in Table 5.2 which shows more than half (54.2%) of the households not to be worried at all about having enough food for their family in the past 30 days. While the remaining 45.8%

of the surveyed household have experienced problem of access to food at various degrees- 35% 'rarely', 9% 'sometimes' and 1.9% 'often'. From Table 5.2, we can also see that out of the total score of 1999, 1277 (63.9%) of them experienced access problem 'rarely' while 27.4% and 8.8% experienced the problem with frequency of 'sometimes' and 'often'.

The result obtained from HFIAS can also be used to calculate food insecurity related domains. There are three domains- anxiety and uncertainty domain, insufficient quality domain and insufficient food intake and its physical consequences domain (Coates et al., 2007). When it comes to the first domain, 45.8% (the ratio of respondents who responded 'yes' to Q1 (240) to the total number of respondents responding to Q1 (480)) experienced anxiety and uncertainty about food availability. While those who felt the food they eat was insufficient in quality (the ratio of those who replied 'yes' to Q2 or Q3 or Q4 (465) to the total number of respondents responding to Q2 or Q3 or Q4 (480)) made 96.9% of the total households. This in general, reflects low quality and monotonous type of households' food consumption in the study area. Our observations and FGDs also reflect food variety to be a common problem in the study area. Most household consume *kocho* and other *enset* products day in and day out, potatoes, roasted barley and pulses. When it comes to the third domain which is on the quantity of food intake and its physical consequences (the ratio of those who responded 'yes' to Q5 or Q6 or Q7 or Q8 or Q9 (224) to the total households responding to Q5 or Q6 or Q7 or Q8 or Q9 (480)) made 46.7% of the total respondents, which indicates the existence of food quantity problem as well though not as severe as the quality problem.

Table 5. 2: Results on Access Related Condition of HFIAS

No.	**Questions**	**Never**		**Yes with severity status of**					
				Rarely		**Sometimes**		**Often**	
		(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
1	Worry about enough food	260	54.17	168	35.00	43	8.96	9	1.88
2	Unable to eat preferred food	22	4.58	264	55.00	146	30.42	48	10.00
3	Eat limited variety of food	95	19.79	215	44.79	114	23.75	56	11.67
4	Eat what you didn't want to eat	64	13.33	305	63.54	92	19.17	19	3.96
5	Eat smaller meal than you want	200	41.67	166	34.58	87	18.13	27	5.63
6	Eat fewer meals in a day	332	69.17	96	20.00	40	8.33	12	2.50
7	No food at all to be accessed	432	90.00	28	5.83	16	3.33	4	0.83
8	Go sleep hungry at night	450	93.75	21	4.38	9	1.88	0	0
9	Eat no food for a whole day	466	97.08	14	2.92	0	0	0	0
	Total			**1277**	**63.9**	**547**	**27.4**	**175**	**8.8**

Source: Own Survey (2021)

The household food insecurity access scale score (HFIASS) is a continuous variable which measures the degree of food insecurity, and it has a minimum value of zero for those who

answer ‘no’ to all the nine questions and a maximum of 27 for those who answer ‘yes’ to all the nine questions with a frequency of ‘often’. The household's level of food insecurity increases with the score's value, and vice versa. The value of the HFIAS score for our study was found to have a minimum value of 0 and a maximum value of 21 with a mean value of 6.03 which is below the half point mark of 13.5 and this in general suggests the score for the study area to be fairly satisfactory.

One important outcome from HFIAS indicator is the determination of households’ food security status which is done by categorizing households into different food insecurity prevalence categories based on the degree of food insecurity. Based on the recommendation given by Coates et al. (2007), households were categorized in to four food security statuses. The categorization is based on households’ responses to the prevalence and frequency of occurrence questions which categorizes them in order of increasing food insecurity as they reply ‘yes’ to more severe conditions of food insecurity and/ or experience those condition more frequently (see Appendix XII).

Based on the analysis, we discovered that 3.12%, 30.42%, 54.58%, and 11.88% of the study area's households were found to be food secured, mildly food insecured, moderately food insecured and severely food insecured, respectively. In order to classify the households into the more common dichotomous classification of food secured and food insecured households, we followed the recommendation of Maxwell et al. (2013) and households in the category of food secured and mildly food insecured were taken to be food secured which were found to be close to 34% of the total sample households while those in the category of moderately and severely food insecured were taken as food insecured household which were almost 66%.

5.3.2 Food security as measured by FCS

The food groups used in our analysis and the proportion of households consuming each group are shown in Table 5.3 which indicates all sampled households to have consumed main staples for 3 or more days. The major food items were *kocho* and other *enset* products together with potatoes and some cereals like barley which is usually consumed in the forms of roasted barely *(kollo)*- served during coffee ceremony. Cereals are also used to prepared *injera* by mixing with *teff*. Households in the study area also consume pulses next to main staples with 25.1% of the households reporting to have consumed it at least for 5 days.

Table 5. 3: Share of Food Groups Consumed by Households (%).

	Days eaten in the past 7 days			
Food Groups	**0**	**1-2 days**	**3-4 days**	**>=5 days**
Main Staples (Cereals & starchy tubers & roots)	0	0	2.9	97.1
Pulses	0	17.5	57.4	25.1
Vegetables	0	31.8	53.5	14.7
Fruits	92.8	4.8	2.4	0
Animal Protein	67.2	26.2	4.3	2.3
Milk and milk products	7.5	42.2	38.9	11.4
Sugar	90.8	8.6	0.6	0
Oils, fats & butter	3.5	60.6	34.2	1.7

Source: Own Survey (2021)

The consumption of vegetables is also fairly good as 31.8% of the household consumed it once or twice in the past 7 days before the interview, while 14.7% of the households consume vegetables for 5 days or more. The problem with vegetables consumption is that they mostly consume cabbage by cooking it sometimes with other food items such as meat. The consumption of fruit is almost nonexistence. The consumption of animal products is not satisfactory since almost 67.2% of households reported not to have consumed it even for one day in the past 7 days. With respect to protein nutrient, the good news is households' common practice of pulse consumption which is also a source of protein. From Table 5.3, we can also see that almost 50% of households consumed milk and milk products for two or less days which is very low, though better than the consumption of animal protein. The consumption of sugar is also very poor since 90.8% of the households did not consume sugar even once in the reference period. In general, the result of assessing the consumption of food groups indicates that households in the study area were not getting balanced diet due to low consumption frequency of animal protein, milk and milk products as well as fruits and vegetables.

The value of FCS is a continuous variable and reflects the level of food insecurity the household faces. The household's level of food insecurity will decrease with increasing FCS value and vice versa. The mean food consumption score of the sample was 50.6 with standard deviation of 26.41. The minimum and maximum values were found to be 16 and 103, respectively. It is also possible to categorize households into different categories of food security based on the recommendation of WFP (2008). We classified households into three categories in which FCS value of 21 and less are considered as 'poor; while a score between 21 and 35 is considered as 'borderline', and a score above 35 is considered as 'acceptable'. Accordingly, 259(54%) of the households were found to be in the acceptable range, while 139 (29%) and 82 (17%) of them were found to be in the borderline and poor categories,

respectively. To classify households into food secured and food insured categories using FCS, we used the suggestion of Maxwell et al. (2013), according to which those who are in the category of acceptable rage are taken as food secured while those in the range of borderline and poor are considered as food insecured households. Accordingly, food secured and food insecured households were found to be around 54% and 46%, respectively.

5.3.3 A composite Food Security Indicator

Households' food security statuses obtained from the two measurements are not quite the same. As expected the more conservative measure HFIAS showed larger proposition of food insecured households than FCS. This is also what Maxwell et al. (2013) obtained in their study of food insecurity in Tigray region of Ethiopia. They found the proportion of food insecured households to be 49.7% from HFIAS indicator which was the highest of all the seven indicators used in the study including FCS which gave only 11.7%. Though, the two measurements give different figures of food insecurity, they are both widely used. In order to examine the consistency of these measures, we calculated the Pearson's correlation coefficient of the two indicators and the Stata output showed a correlation coefficient of -0.73 and a p-value of 0.001, indicating a strong negative correlation implying the two indicators tell almost the same "story".

As mentioned earlier to capture more dimensions of food security, a composite indicator which is derived from HFIAS and FCS is used in this study. Using either of the two indicator alone may lead to capturing less dimensions of food security and also a misclassification of a large segment of households as either food secured while in the other measures they are categorized as food insecured and vice versa. Hence, based on the suggestion of Maxwell et al. (2013), we used a composite indicator in which households were categorized into three distinct categories of food security- food insecured, intermediate group and food secured. Table 5.4 shows the cross tabulation of households into the three distinct food security groups based on the results obtained from HFIAS and FCS indicators.

In Table 5.4, let C_{ij} represents the cell of the n^{th} household who is having a status of i and j from HFIAS and FCS indicators, respectively. According to Maxwell et al. (2013), the green color (C_{11}, C_{12} and C_{21}) includes those households who fall in the category of food secured when we use both indicators, and it constitutes households who are doing well from both indicators- food secured from HFIAS and acceptable or borderline from FCS or mildly food

observe that Ezha *wereda* has higher proportion of households in the food insecured category and lower proportions of households in the intermediate and food secured categories than Cheha *wereda.* From this, we can conclude that Cheha *wereda* is more food secured than Ezha *wereda*. This is also consistent with the information obtained from DAs who claimed that Cheha *wereda* is better-off in resources availability than Ezha *wereda*. This issue is further examined using econometric model in the coming section.

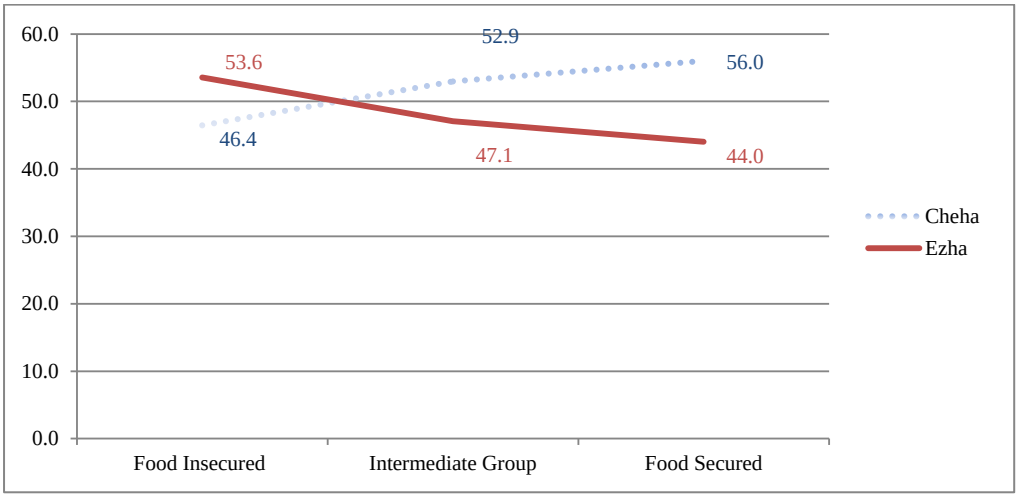


Figure 5. 2: Proportion of Households in Food Security Categories by *Wereda.*

5.3.4 Food Security and Eucalyptus Tree

In the discussion of food security, the issue of input diversion is a very critical issue (Rutten et al., 2011). This diversion is observed mainly on the limited land smallholder farmers have. According to the result obained from KIIs, ecualypsut tree is taking lands meant not only for crops but also *ensent* cultivation. We also observed eucalypsut trees planated on fertile lands which are suitable for all kinds of crop production and also grazing lands.

Table 5.5 provides statistics on total land holding and annual income earned from sale of eucalyptus products by the sample households for the three food security groups. As indicated in Table 5.5, the mean of total land holding for the sample households was around 0.75 hectares (Ha.) while the minimum and maximum land holdings were 0.25 Ha and 3 Ha, respectively. From our FGDs and KIIs, it was learnt that especially absentee farmers who live in towns and cities such as Addis Ababa allocate larger proportion of their land to eucalyptus trees and earn higher amount of income. These individuals usually come to their villages

once in a year for *Meskal* or *Arefa* celebration and they are not that much interested in regular farm works.

As was the case in the study of Belay and Abraham [30], all sampled households reported to have earned some income from the sale of eucalyptus products in the past 12 months. The minimum annual income earned was ETB (Ethiopian Birr) 1,500 while the maximum was ETB 69,000. The mean annual income from eucalyptus was found to be around ETB 11,391.3. Participants in the FGDs also stressed the contributions of income households get from eucalyptus tree to be critical for buying farm inputs and also sometimes food from local markets in case of food shortage. They claimed eucalyptus tree to be like their 'cash' that they can sell it whenever they face cash shortage to meet household demands. This means eucalyptus tree is also serving them as a security tree against cash and food shortage to households in the study area. From this, we can conclude that eucalyptus tree can affect the access components of food security and this is likely to have a positive contribution to households' food security by enabling them to get food from the market. This is consistence with the findings of Zenebe et al. (2012) and Jagger and Pender (2000).

Table 5. 5: Land Size and Annual Income from Eucalyptus Trees by Food Security Groups

Variables	Statistics	Food Security Status			Total
		Food secured	Intermediate group	Food Insecured	
Total landholding (Ha)	Obs.	150	119	211	480
	Mean	0.99	0.80	0.54	0.75
	Std. Dev.	0.25	0.13	0.14	0.27
	Min.	0.75	0.45	0.25	0.25
	Max.	3	1.1	1	3
Annual income from sale of eucalyptus products (ETB)	Obs,	150	119	211	480
	Mean	13,062.9	13,015.5	9,286.8	11,391.3
	Std. Dev.	6,147.2	8,696.4	3217.4	6197.1
	Min.	3,500	3580	1500	1500
	Max.	36,000	69,000	20,000	69000

Source: Own Survey (2021)

From Table 5.5, we can also see that food insecured households have not only the least mean land size holding (0.54 ha) but also the smallest mean annual income earned from the sale of eucalyptus products (ETB 9,286.8) of all the three groups. This clearly suggests that resources endowments influence the food security status of rural households since land is the most critical economic resources to rural communities.

The descriptive assessments indicated that the study area is not as food secured as most people think. The reliance on *enset* which is a resilient plant in the face of drought and other

environmental problem, can surely avoid chronic food shortage and starvation, but this does not mean the area is food secured. From our analysis, we can say that there are food insecurity issues in relation to both quantity and quality as well as anxiety and uncertainty that households felt during the survey because though most households have some amount of *kocho* at their disposal; getting it ready for consumption requires labour, fire wood and other inputs which may not be easily available to all households. In addition, the consumption of *kocho* usually requires complement food items to be consumed with. Such complement items include preferably and sometimes meat or cheese but usually cooked potato, cabbage, etc.

5.3.5 Econometric results

In this section the results obtained from multinomial logistic regression are presented. Using Stata 14.2 software, we have estimated both the coefficients and marginal effects of the various socio-economic variables including annual income earned from the sale of eucalyptus products in order to assess the contribution of eucalyptus tree to food security. The estimation for coefficients is made using the food insecured group as a base category (reference group). The multinomial logistic regression showed a likelihood of –190.1636, LR chi square of 647.40 and Pseudo R-square of 0.6299 with a p-value of 0.001, which in general suggests the estimation to be sound and at least one of the explanatory variables is significantly different from zero i.e., they have joint significance of predicting households' food security status. A summary of results of estimation for coefficient and marginal effects are given in Table 5.6 and Table 5.7, respectively.

The annual income earned from sale of eucalyptus tree has positive and significant contribution to the probability of being in the intermediate group, while its contribution to the probability of falling into the food secured group compared to the base group is also positive but insignificant. From Table 5.7, we can see that when income from sale of eucalyptus increases by one unit, the probability of falling in to the categories of food insecured and food secured decreases by 8.1% and 0.4%, respectively, where as it increases falling in the intermediate group by almost 8.5%. This means income from eucalyptus tree can help pull households out of the food insecured category and bring them to the intermediate group and this as the same time prevents households from entering the food secured category.

Table 5. 6: Coefficient Estimation of Multinomial Logit Model (base outcome: food insecured)

		Intermediate Group			Food Secured		
Var.	**Description of Variables**	**Coef.**	**St. E.**	**p>|z|**	**Coef.**	**St.E**	**p>|z|**
gedr	Gender of Household Head	-0.2838	0.4953	0.567	-0.3418	0.6182	0.580
mrstt	Marital Status	0.3941	0.4815	0.413	-0.8405	0.6614	0.204
ageh	Age of Household Head	-0.0592	0.0267	0.027*	-0.1938	0.0385	0.001**
elhh	School year of Household Head	-0.0197	0.0594	0.740	-0.0159	0.0814	0.845
lnsz	Total Land of Household	11.7443	2.2814	0.001**	19.5818	2.9970	0.001**
lieet	Income from eucalyptus	1.3590	0.5196	0.009**	1.2075	0.6363	0.058
htlu	Total Livestock holding (TLU)	0.4869	0.1866	0.009**	0.9876	0.2526	0.001**
pnof	Part. in Non / Off-farm activities	-0.1590	0.4323	0.713	-0.4563	0.5488	0.406
sulne	Suitability of Land for crop	1.4950	0.4357	0.001**	4.3104	0.6314	0.001**
wedm	Dummy for *Wereda*	2.5966	0.5386	0.001**	3.1192	0.6516	0.001**
flsz	Family Size	-0.0684	0.1334	0.608	-0.0737	0.1712	0.667
actr	Proximity to main roads	0.0034	0.0088	0.700	-0.0088	0.0125	0.484
Con.	Constant	-20.569	5.2647	0.000	-22.785	6.5316	0.000

** = significant at 0.01 level; * = significant at 0.05 level

This means income from eucalyptus tree will be the right call only to bring households to the intermediate group. In other words, to improve food security status of households using eucalyptus tree, we need first to identify the group to which that particular household belongs. The general positive contribution of income on the food security of households is due to its contribution in increasing the access component of food security and some studies such as Dereje (2021), Pakravan-Charvadeh et al. (2022) and Getachew (2018) have confirmed the positive contribution of income in improving the food security status of households.

Age of household head is found to influence the probability of households to be in the category of intermediate group and food secured group as compared to the base category. As indicated in Table 5.7, as the age of the household increases by one year, the probability of the households to be in the categories of food insecured and intermediate group increases by 0.42% and 0.47%, respectively. While it decreases the probability of being in the food secured category by 0.89%. This in general suggests that older household heads are less likely to be in the food secured group compared to younger household heads. This finding is consistent with Dereje (2021).

Table 5. 7: Marginal Effect Estimation of Multinomial Logit Model

	Food Insecured			Intermediate Group			Food Secured		
Var.	**M. Ef.**	**St. E.**	**p>|z|**	**M. Ef.**	**St. E.**	**p>|z|**	**M. Ef.**	**St.E**	**p>|z|**
gedr	0.0174	0.0298	0.559	-0.0124	0.0382	0.745	-0.0050	0.0260	0.849
mrstt	-0.0183	0.0287	0.523	0.0955	0.0411	0.020	-0.0772	0.0309	0.012
ageh	0.0042	0.0015	0.007**	0.0047	0.0021	0.026*	-0.0089	0.0016	0.001**
elhh	0.0012	0.0036	0.743	-0.0013	0.0051	0.794	0.0002	0.0039	0.968
lnsz	-0.7437	0.1143	0.001**	0.1906	0.1523	0.211**	0.5531	0.1131	0.001**
lieet	-0.0814	0.0303	0.007**	0.0851	0.0380	0.025*	-0.0037	0.0256	0.886
htlu	-0.0316	0.0107	0.003**	-0.0026	0.0145	0.859	0.0342	0.0107	0.001**
pnof	0.0109	0.0260	0.675	0.0088	0.0339	0.795	-0.0197	0.0236	0.404
sulne	-0.1027	0.0234	0.001**	-0.0840	0.0307	0.006**	-0.0249	0.0169	0.142
wedm	-0.1591	0.0282	0.001**	0.1142	0.0351	0.001**	0.0449	0.0238	0.059
flsz	0.0042	0.0080	0.605	-0.0035	0.0106	0.741	-0.0006	0.0075	0.932
actr	-0.0002	0.0005	0.776	0.0009	0.0008	0.232	-0.0008	0.0006	0.203

** = significant at 0.01 level; * = significant at 0.05 level

Total land holding of households was found to be one of the most significant factors influencing food security. As can be seen in Table 5.6, one additional hectare of land increases the probability of falling in the categories of intermediate and food secured group compared to being in the food insecured category. The marginal effect shows as the total land holding increases by one Ha, the probability of falling in the food insecured category decreases almost by 74.4%. On the contrary, it increases the probability of falling into intermediate and food secured group by 19.1% and 55.3%, respectively. The contribution of land to food security is expected to be through its impact on food availability by increasing owe food production and access to food through its impact on increasing farm households' income from selling different farm products. This indicates how critical land holding is in determining households' food security status. This finding is consistence with the finding of Getachew (2018), Dereje (2021) and Kahsay and Mulugeta (2014).

We also included livestock ownership to capture its influence on food security. Livestock serve as direct source of food product, productive aids and source of income to purchase households' necessities such as food and other consumption items (Getachew, 2018). The main livestock available in the study area include cattle, sheep, horses, mule and chickens. As mentioned earlier, we used Tropical Livestock Unit (TLU) to examine the influence of livestock on the food security status of sample households. The result shows that an additional unit of TLU increases the probability of households to fall into the category of intermediate and food secured group compared to the base group- the food insecured. It is also observed that one additional unit of TLU decreases the probability of falling into the categories of food insecured and intermediate group by 3.16% and 0.26%, respectively; while

it increases falling into the category of food secured by 3.42%, if all other factors remain as they are. Since livestock holdings can be a direct source of food to rural households in addition to being a source of income, it can influence both food availability and food access components of food security of smallholder farm households. In general, our study indicated that livestock to be important resource in improving the food security status of households in the study area and this finding is consistence with the finding of Dereje (2021) and Alem (2007).

In one of the KIIs held in Ezha *wereda*, the officials claimed that eucalyptus expansion is affecting the food security of smallholder farmers in two ways in relation to livestock raring. According to the sources, the first consequence is through its direct impact on the conversion of grazing lands into eucalyptus plantation which reduces livestock ownership and the other one is its impact on the reduction of animal dung which is used as manure in *enset* cultivation which is the source of the main staple of the Gurage people, *kocho*.

Wereda dummies were included to capture the variation in economic and environmental conditions, which are not captured by our analysis. The estimates show that being in Cheha *wereda* increases the chance to be in the intermediate and food secured group compared to the base category. Finally, households who have suitable land for crop production are more likely to be food secured as compared to those whose land is less suitable for crop production. This is due to the fact that the quality of the soil affects the production of agricultural products.

5.4 Conclusions and Recommendations

The main objective of this study was to assess the contribution of eucalyptus trees and other socioeconomic factors on households' food security status in Gurage zone, Ethiopia. By using income earner from sale of eucalyptus trees as a proxy variable to the extent of eucalyptus plantation by the households and using a composite indicator of food security derived from HFIAS and FCS measurement, we found that 31.2% of the households food secure, 44.0% food insecure and almost a quarter (24.8%) to be in the intermediate group. The HFIAS analysis indicated a considerable proportion of households (45.8%) to face anxiety and uncertainty problem in relation to food access and 96.9% of households expressed the food they eat to be unsatisfactory in food quality while 46.7% of the households expressed that the food they eat is insufficient in quantity as well. In addition, the

food consumption of households in the study area was found to be poor in variety due to very low consumption frequency of animal protein, milk and milk products as well as fruits and vegetables which implies households in the study area are consuming monotonous food items such as *kocho* and other *enset* products and depending on the season cooked potatoes, roasted barley and cabbage.

The multinomial estimation indicated income earned from the sale of eucalyptus products to have positive impact on the probability of being in the intermediate group category; however, it was not found to be significant in influencing the probability of falling into the food secured category. Therefore, increasing income from the sale of eucalyptus products can help to pull households out of the food insecured category only as far as the intermediated group, but not necessarily to the food secured group which in other words means it may trap them in the intermediate group. This is maybe why Bayle (2019) described eucalyptus tree as a tree of "not good, not bad". Thus, we need to find the right balance in allocating scarce resources to satisfy the food, tree products and income needs of the rural community.

The estimation further indicated that land holding, livestock and suitability of land for crop production to be important factors that positively influence the food security status of households in the study area. This is due to the positive impact of economic resources on the food availability and access components of food security. In addition, our estimation showed significant food security differences to exist between households in the two *weredas*. Households in Ezha *wereda* were found to be in a disadvantaged position when it comes to food security, due to poorer infrastructural development and less conducive environmental conditions for agricultural production.

Furthermore, the study indicated eucalyptus expansion to influence food security not only through its direct impact of taking land meant for crop production but also on livestock holding of households through its impacts on grazing lands. This indicates the need to identify appropriate sites for eucalyptus plantation so that it may not negatively impact food production in the study area. This will require the formulation and implementation of land use policy in order to achieve a balance between food production and the demand for tree products. We propose that the planting of eucalyptus trees by households should be customized according to their unique circumstances, as it does not always have the same impact on different households. Moreover, the government and other stakeholders should take the livestock sector seriously since it contributes to rural households' food security in

many ways not only as important source of food and income but also as productive aid with tremendous positive implication on rural livelihood. Furthermore, improving rural infrastructure such as road, irrigation facilities and rural institutions should be the focus areas of development stakeholders in order to improve the livelihood and hence the food system of the study area.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

Given the rapid expansion of eucalyptus tree in the Central and Northern highlands of Ethiopia, it is very difficult to claim that there are sufficient studies on eucalyptus tree dealing with both practical and theoretical disputes on its economic and social contributions as well as its effects on the environment. In addition, the perceptions and opinion of stakeholders are not sufficiently studied to generate valuable knowledge and make sure everyone is on the same page when it comes to implementing practical measures in dealing with eucalyptus trees in rural areas.

The aim of this study was to examine the extent of eucalyptus tree farming practices and its consequences on land use and smallholder farmers' livelihoods in Gurage Zone. To fill the gaps that exist on theoretically standpoints and come up with policy recommendations, a rigorous analysis is conducted using standard and multiple tools to investigate critical issues in relation to the planting and use of eucalyptus trees and the resulting consequences on smallholders land use and livelihoods.

This chapter is organized in order to give a recap and synthesis of the major findings of the study. In addition, the major practical and policy implications of the study as well as future study areas are provided in this chapter.

6.2 Summary of Key Findings and Conclusion

The purpose of this section is to summarize the key findings and conclusions drawn to address the research questions of the study. This study used a mixed research method to study the perception, expansion, and effects of Eucalyptus tree farming on LULC dynamics and the food security status of smallholder households in Gurage Zone, Ethiopia. This method allows adequate flexibility in both data collection and analysis tools which make the results of the analysis more reliable due to triangulation of results that this method allows.

A summary of key findings and their implications are presented as follows.

I) Perceptions and opinions towards eucalyptus tree

The descriptive analysis indicated that the expansion of eucalyptus trees in the study area to be demand driven since around 85% of the sample households identified cash related motive as their prime reason to plant eucalyptus trees. As a result, the vast majority of sample

households (79.2%) believe that eucalyptus trees have positive effects on their livelihood by increasing their purchasing power and also serving them as a reliable sources of finance whenever emergency cash needs arise. In additions, eucalyptus trees help households meet own demand for tree products for the purpose of fire wood and construction.

When it comes to the perceived effects of eucalyptus tree on the environment, the majority (79%) perceived eucalyptus tree to have a negative impact on the environment. The short-term advantages of the tree, however, appear to be more important to smallholder farmers than the potential environmental issues. As a result, despite the local government's hostile stance and efforts to limit its plantation, households continue to plant eucalyptus trees. While local authorities and the majority of experts view the tree as the biggest threat facing the Gurage people because they worry that at some point in the future it may fully occupy the farming land, leaving the community completely dependent on outside sources for its food consumption; smallholder farmers appear to increasingly view the tree as an indispensable component of their farming system.

The result from the ordered logit estimation revealed that access to hydroelectric power and availability of labour force affect the perceived effects of eucalyptus tree on households' livelihood negatively while school year of household head, total land holding of households, availability of cash crops and participation on/off-farm activities affect perception positively. This goes with the general assertion that eucalyptus tree is highly preferred by households with less labour force since it requires less attention and follow up once planted. In addition, the more land the household has, the more confortable they are likely to be in allocating some land to eucalyptus while keeping enough land for food production.

While the household head's age has a negative impact on perceptions of eucalyptus trees' effects on the environment, other factors, including the head's school year, the availability of cash crops, and whether the household has a hydroelectric power connection, have positive and significant effects on householders' perception on the environmental effects of eucalyptus trees.

II) The contribution of eucalyptus tree to households' livelihood in the study area.

Eucalyptus trees provide multiple economic and social benefits to rural households in the study area. It also serves as a security tree (Adimasu et al., 2010; Gizachew, 2017) against

production and marketing related risks associated with the common crop productions. This is making eucalyptus tree increasingly important component of the farming system of the study area. To assess the contributions of eucalyptus tree to the livelihood of rural households in the study area, we used descriptive analysis tools using Stata 14.2.

Though, the most important reason for adopting eucalyptus tree is income generation, there are also other economic and social benefits households get from the tree. During the nights when household members return from their economic and social duties, they usually gather around a fire produced from leafs and branches of eucalyptus tree where they gather with neighbors for a coffee ceremony when various issues are discussed. Though, the contribution of eucalyptus tree as a principal source of lighting is declining overtime due to largely the introduction of solar panels (60.6%) and to some extent hydroelectric power connections (16.3%), it is almost the only source of energy when it comes to cooking food. In addition, more than 90% of households reported own plantation to be the source of satisfying own demand for forest products compared to purchasing from the local markets or collecting it from the forest.

The income contribution of eucalyptus tree in the study area was found to be tremendous due to the ever increasing price of eucalyptus logs and ease of selling it. Almost 60% of surveyed households identified eucalyptus tree as their prime source of income from a list of seven agricultural income sources relevant to the study area. In general, the survey result showed eucalyptus tree to constitute a third of total households' income of study area. As most rural households have limited access to financial institutions to save money and take borrowings in the face of unexpected cash demand, it was found out that eucalyptus tree serves as a 'living account' where households can readily sale it whenever an emergency cash demand arises. This is because eucalyptus products are sold on the farm at reasonably high and ever increasing prices which contributes to their high liquidity in the study area.

III) Share of Land allocated to eucalyptus trees

Numerous demographic, socioeconomic, and institutional factors are likely to have an influence on the amount of land that a specific household dedicates to eucalyptus trees. The results show that eucalyptus trees roughly occupied 31% of the total land holdings of households in the study area.

The fractional logit model indicated that elder household heads often allot a lesser portion of their land to eucalyptus trees than younger household heads. Compared to households farther away from main roads, those closer to them allotted a larger proportion of their land to eucalyptus trees. In addition, the proportion of land dedicated to eucalyptus trees seems to be positively influenced by total household income and total livestock holdings. Hence this study in general suggests richer households to allocate larger proportion of their land to eucalyptus tree. Furthermore, compared to families with less favorable perceptions of eucalyptus trees, those with positive perceptions of the livelihood impact of eucalyptus trees prefer to dedicate a greater portion of their land to eucalyptus trees. Therefore, this study has confirmed that the proportion of land allocated to eucalyptus tree is influence by many factors including the perception of households towards the tree.

IV) Expansion of eucalyptus tree

The expansion of eucalyptus is measured using different indicators such as number of eucalyptus trees planted, land allocated to it and share of land covered with eucalyptus tree from LULC of the study area.

The survey results as well as the FGDs and KIIs held at various levels unanimously confirmed that eucalyptus trees have been expanding over the past few decades in the study area. Taking the past ten years as reference period the number of eucalyptus plantation has been increasing by annual rate of 6.6% in the study area. The amount of land allocated has also been increasing and during the time of the survey the mean land allocated to eucalyptus tree was found to be 0.25 Ha which makes a third of the mean total land holding of households in the study area. What makes the expansion of eucalyptus tree in the study area more concerning is the intention of farmers to increase their plantation since more than 94% of the sample households expressed their desire to increase their plantation in the future.

The OLS estimation was used to identify factors that influence eucalyptus expansion. The results indicated that younger and more educated household heads trends to plant more eucalyptus trees than older and less educated household heads. In addition, households who had less land and those who were further away from main roads tend to plant less trees while households who had fewer members in the working age group and those who were participating in on/off-farm activities tend to plant more eucalyptus trees since it demands less labour and attention compared to regular farm work such as crop production.

V) Eucalyptus tree and LULC dynamics in the study area

One of the consequences of rapid expansion of eucalyptus tree is LULC change. From satellite images of 2000, 2010 and 2021 and field observations seven classes of LULC were identified in the study area, eucalyptus plantation being one of them. The result of analysis indicated that the study area is one of the areas of the country experiencing rapid LULC changes (33.8%) and eucalyptus plantation was identified as the major deriving force. This is because from 2000 to 2021, the land covered with eucalyptus plantation increased by almost 68% and from its fourth position in 2000 came to second position in 2021 only next to crop land, leapfrogging grass and shrub land covers which were second and third in 2000, respectively. In addition, the rate of eucalyptus expansion in the study area was found to be almost 42 Ha. per year.

From 2010 to 2021, the increase in area covered by eucalyptus plantation has come at the expense of crop lands, which suggests that eucalyptus tree is expanding at the expense of food production in the study. This goes in line with the survey finding that 42% of sample households were found to have planted eucalyptus trees on fertile agriculture land.

VI) Food security situation of the study area

In an effort to capture as many aspects of food security as possible, various indicators were used. In effect, three food security indicators were used to analyze the food security situation of households in the study area. These are HFIAS, FCS and a composite food security indicator which is derived by integrating the two measurements. The use of three indicators also enabled us to compare and contrast the outcomes of these various indicators. Although all three measures produced consistent results, the composite indicator was used to classify households into three categories: food insecured, intermediate, and food secured.

The HFIAS measurement indicated households to experience anxiety and uncertainty problem about availability of food as well as the problem of food quantity. The most serious problem was the food quality problems since almost 96% of the respondents mentioned poor food quality as a common problem.

The results of FCS indicated surveyed households' consumption to be low in variety due to the dominance of the consumption of *enset* products which means households are not getting balanced diet that is necessary to maintain good health and physical condition. This is reflected in the low consumption of animal protein, milk and milk products as well as meager

consumption frequency of fruits and vegetables. For instance, almost 92.8% and 67.2% of the sample households reported not to have consumed any animal protein and fruits in the past seven days, respectively.

According to the composite food security indicator, just 31.2% of households are food secured, while 44% are food insecured. The remaining amount, or 24.8%, belongs to the intermediate category. This shows that the study area is not as food secured as most people believe. Therefore, there is a need to take appropriate measures to improve the food security of households in the study area.

According to the multinomial logit model estimation, the probability of falling into the intermediated group as opposed to the food insecure group increases as income from eucalyptus trees increases, but its effect on increasing the probability of falling into the food secured category was not found to be statistically significant at the 5% confidence level. The econometric estimation also revealed that characteristics like land and livestock ownership are crucial for enhancing food security. Furthermore, households in Ezha *wereda* were found to be less likely to be food secured compared to households in Cheha *wereda*, but those with younger household heads and land appropriate for crop production were found to have higher probabilities of being in the food secured group.

6.3 Synthesis of Findings

This section discusses the relationship between key variables of interest, such as perceptions on eucalyptus tree, its expansion, and implications on land use and livelihoods of smallholder farmers. In addition, the findings and the methodological contributions of this paper are discussed in such a way that the unique contributions of the study are highlighted.
Methodologically this study has the following three contributions.

Firstly, unlike most studies which use a single indicator to measure perception such as Hennessay (2012) and Pervin (2017); this study used a number of indicators to calculate a perception score for each household to have a more meaningful assessment of the perception of households towards eucalyptus trees.
Secondly, to measure the expansion of eucalyptus trees the study used a number of data sources and data analysis methods. These include household survey, field observations, satellite images and interviews to get a more comprehensive investigation of eucalyptus expansion in the study area.

Thirdly, this study used a composite food security indicator. Most studies of food security use either one indicator or two or more indicators separately. However, since no single indicator can capture all dimensions of food security, using a combination of two indicators would allow us to capture more dimensions of food security and this will give us a better result compared to using only one or two indicators separately (Maxwell et al., 2013). Therefore, this study integrated HFIAS and FCS to assess the food security situation.

The findings of this study strongly support the expansion of eucalyptus tree in Gurage Zone as claimed by other research findings such as Gizachew (2017), Kebede (2017) and Belay et al. (2021) This is evident even to any visitor as there is a sharp and significant change in LULC dominated by eucalyptus tree plantation as one enters from the neighboring Oromiya Region to Gurage Zone. Nowadays, eucalyptus trees are even more common and noticeable in the Gurage land scape than *enset* plantations to which the gurage people are highly attached for both economic and cultural reasons. That is why eucalyptus tree is the second most common LULC type in the study area.

The positive smallholder farmers' perception towards eucalyptus trees and lack of strong binging laws to control land use in the study area were found to be the prime drivers of the expansion of eucalyptus tree in Gurage Zone. This means farmers have an incentive to plant more eucalyptus trees (Zerga and Berta, 2016; Getnet et al., 2022) and the authorities have no legal right to control the plantations (Gebeyehu et al., 2017) which strongly suggests the need for the formulation and implementation of land use policy that can help to regulate the expansion of eucalyptus tree and solve the eucalyptus conundrum.

Another important finding of this study in relation to eucalyptus expansion was the tendency of eucalyptus tree plantation to be higher by households with lower available labour force in the household. This confirms with the less risky and lower labour force demand of eucalyptus trees compared to regular crop production practices. This finding is in line with the findings of Getachew (2016) and Gebreegziabher et al. (2020).

This study also concluded that eucalyptus tree is so important to the livelihood of smallholders farmers in the study area that the idea of 'banning eucalyptus altogether' as suggested by Getachew (2016) and some experts and government authorities in the study area should not be encouraged given that there are no feasible alternatives that can substitute eucalyptus tree. At the same time the expansion of eucalyptus tree cannot be left unchecked

since it may gradually take all the fertile land away from food production and this clearly threaten the food system of the community.

The food insecurity problem observed in the study area can be better explained by the food entitlement decline theory- lack of entitlement to food, i.e. limited capacity to produce or purchase food (Sen, 1981). This is because the study indicated that variation in food security situation of the sample households largely depends on variables that influence the productive capacity and/or the exchange power of the households. This is due to the fact that households with larger and more suitable land are less likely to be in the food insecured groups. In addition, households in Cheha *wereda* were found to be better off compared to those in Ezha *wereda* due to better economic infrastructures. This means the political economy explanation of food security can also partly explain the food insecurity problem in the study area.

The study produced three significant findings that have practical ramifications when it comes to the distinctive practical contributions. Calculating the rate of eucalyptus expansion and identifying it as the primary determinant of the observed LULC change constitute the first contribution. This supports the stakeholders' concerns with quantitative data that can persuade policymakers to act quickly to control the spread of eucalyptus trees by striking the right balance between their advantages and the goal of food self-sufficiency. This is due to the fact that a community's food supply shouldn't be entirely reliant on outside sources. This could damage the food sovereignty of the community.

Second, by using various food security indicators, we have been able to investigate many aspects of food security. In doing so, the study has emphasized the importance of employing a variety of indicators to fully assess the state of food security in a particular community in order to come up with a workable solution. Additionally, the results of this study point to the necessity of evaluating the food security of communities that are typically thought of as being "food secure," as doing so can help to reveal "the true picture" of the community and facilitate the adoption of precautionary measures to prevent the issue from arising in the future.

Thirdly, this study demonstrated that farmers' perceptions are crucial in influencing their decisions about eucalyptus trees. Since the study has shown that eucalyptus tree is thought to have a positive impact on farmers' livelihoods and that eucalyptus farming is less labor-

intensive than other agricultural practices, it is the most preferred livelihood strategy under the existing circumstances.

6.4 Policy Implication

The study's conclusions have broad practical and policy ramifications for households and other development stakeholders extending beyond the study area. According to the study's findings, there are numerous issues that call for measures in order to permanently resolve the eucalyptus dilemma and its unfavorable effects in the study area. However, the actions that must be taken necessitate a multifaceted strategy and call for cooperation of smallholder households, experts, local authorities and their stairs.

Gurage Zone seems to be the only area where eucalyptus trees can be planted freely which is evident from its noticeable difference in terms of eucalyptus trees coverage compared to its neighboring Zones. This means local authorities cannot entirely place the blame for eucalyptus expansion on the Federal Government or the 'lack of land use policy'. This suggests that local authorities and DAs in the study area should have done more to regulate eucalyptus trees expansion instead of becoming complacent and blaming the problem on lack of 'binding land use regulations'. This study does not support any of the two extreme views concerning the stand of the government with regard to eucalyptus tree plantation- "a complete ban" or a kind of "laissez-fair" approach. It rather suggests a "controlled plantation of eucalyptus tree" in the study area.

In order to prevent farmers from continuing converting their crop land into eucalyptus plantation, DAs and local authorities should come to a common understanding with farmers. Rather the plantation of eucalyptus tree must be done on lands which are identified in consultation and full cooperation of the relevant stakeholders including the farmers themselves. This can be done by establishing stronger attachments and better communication channels as well as by acknowledging eucalyptus trees as an important integral part of the farming system. The importance of food self-sufficiency and the risk that eucalyptus expansion poses to make the community completely dependent on outside sources for their food consumption should be discussed openly through various channels including informal institutions such as *idir* and *ekub*. This could significantly alter the perception of smallholder farmers towards eucalyptus trees in the study area.

Local authorities should encourage farmers to plant improved varieties of eucalyptus trees and also give them trainings on better practices on eucalyptus cultivation so that they can grow the tree with the least amount of resources needed. Additionally, farmers should be encouraged and regulated to grow eucalyptus trees on ground that is less suitable for agricultural production or use a smaller piece of their land in the event that marginal lands are not available to a particular household.

Making rural households less reliant on eucalyptus trees as sources of income and energy is another crucial area for intervention. This can be accomplished by encouraging farmers to practice commercial farming and by increasing access to renewable energy sources that can take the place of wood-based products. Increasing access to financial services in rural areas can also help to control the expansion of eucalyptus tree as in the absence of financial services farmers tend to relay more on eucalyptus tree as a saving mechanism and also a source of cash in times of emergency.

Commercialization of smallholders' agriculture can help to produce food crops that can be consumed and sold in the market to bring adequate income as well. For this, improving farm practices and availability of farm inputs as well as tackling farm input and output market related problems will make the crop sector more attractive than eucalyptus farming. In addition, to improve income earned from crop production access to road facilities, reliable and timely information about market conditions should be made available to farmers.
The majority of eucalyptus products are sold straight to merchants who then resell them to customers outside the zone without adding any value, which does not sufficiently assist the Zone's economy. Encouraging the establishment of timber and other wood product manufacturing facilities will help to improve the price of tree products and generate more employment opportunities.

The community's food system needs to be improved in a sustainable way in order to improve the status of food security and prevent a potential food insecurity problem in the study area. Measures ranging from raising awareness about the advantages of improving food security to actions that increase food availability and access must be taken. Additionally, it's critical to persuade farmers that commercial agriculture would boost food accessibility and availability in addition to providing a reliable income. To achieve this, farming communities should receive all-around support in order to make food crops production their preferred choice over eucalyptus farming.

In order to "kill two birds with one stone," households should be encouraged to keep livestock. This will increase the consumption of animal products, which was found to be very low in the study area, as well as provide rural households with an additional source of income, which will help them become less dependent on eucalyptus trees. In order to achieve this, it might be necessary to offer animal husbandry trainings, provide improved breeds, and create market linkages with potential customers.

'What feasible alternatives do we have to eucalyptus tree within the existing conditions of the nation?' is the crucial question that government officials at all levels should ask themselves in relation to policy concerns. Our eucalyptus tree policy must be based on a sincere answer to the aforementioned query. An outright ban on eucalyptus trees might not be a sensible or workable approach given the variety of benefits smallholder farmers receive from the tree and the lack of alternative sources of revenue and tree products for their own needs. An alternative approach would be a land use plan that should guide the sustainable use of rural land. In order to achieve this, the government must evaluate the current regulations and develop and put into practice regulations for planting and use of eucalyptus trees in rural areas that do not jeopardize the community's ability to feed themselves.

In conclusion, the following measures are recommended to effectively manage and control eucalyptus trees in the study area:

- The formulation and implementation of effective land use policy, land use plan and regulatory frameworks, guidelines for planting and use of eucalyptus tree to:-
    - ✓ Enable farmers engage in eucalyptus farming without any unnecessary confrontations with local officials.
    - ✓ Enable authorities to effectively control the expansion of eucalyptus trees on fertile crop land and
    - ✓ Make waste lands and hillsides productive through planned eucalyptus and other permanent tree cultivation.
- A continuous awareness creation campaign by DAs and local experts in order to help farmers make an informed decision on their most critical resources- agricultural land.
- Since one of the most important drivers to eucalyptus expansion is income generation, it is important to improve the productivity and income of smallholder farmers through encouraging and supporting them to engage in commercial farming- both in crop production and animal husbandry.

- Providing renewable and affordable energy to households in the country in general and to the study area in particular since the study area is a major supplier of eucalyptus biomass for fire wood as far as the city of Addis Ababa and beyond.
- Promote stakeholders' awareness and collaboration (farmers, DAs, authorities, research institutions, etc.)
- Develop markets and value chain: product diversification, market expansion, supply chain integration, infrastructural development, etc
- Capacity building for farmers, DAs and other stakeholders on the technical , economic and environmental aspects of integrating eucalyptus with crop production
- Give technical support to farmers: cite selection and preparation, seedling and planting; plantation management, harvesting and marketing.
- Improve the availability and access of rural infrastructure and institutions: better roads, irrigation systems, storage facilities, and market linkages.
- Raise awareness and education: importance of food security and the nutritional value of diverse food items.

6.5 Suggestions for further Research

The very contentious eucalyptus tree cannot be fully explained by a study like this, which has its own scope and limits. Future researches in Ethiopia that cover broader topics than that of this study are required to be conducted in different regions of the nation. To this end, a few areas for further research are suggested.

To start, this study primarily used cross-sectional data to look into questions of how eucalyptus trees are perceived and grown, and how it may affect LULC changes and food security in the study area. Future research must use longitudinal data to gain a better knowledge of the scope, trends, and dynamics of these issues across time.

In addition, in order to identify and encourage improved eucalyptus tree production, from propagation of seedlings to final harvest and sale of the product, studies that examined the current eucalyptus farming practices in the study area should be conducted.

Finally, to resolve the eucalyptus dilemma and help smallholder farmers and other stakeholders reach mutual understanding, future studies may focus on the following issues.

- Study on cost-benefit analysis of eucalyptus tree plantation is necessary. This has to be done by calculating the opportunity cost of using farm resources for eucalyptus trees production instead of crop production.
- The ecological effects of eucalyptus trees are still a subject of debate. The perception that eucalyptus has harmful effects on the environment should be supported by rigorous study.
- A research on the existing eucalyptus farming practices
- A study on the ecological effects of eucalyptus trees under the local context

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Appendices

Appendix I. Household Survey Questionnaire

Introduction

I am a student of Addis Ababa University, College of Development Studies. I am undertaking a research with a title: "Perception, Expansion, and Implications of Eucalyptus Trees Farming on Land Use Land Cover Dynamics and Smallholder Households' Food Security: Evidence from Gurage Zone, Ethiopia." The Purpose of this interview is to obtain information in order to understand the extent of eucalyptus expansion and the opinion of farmers, experts and government official in the study area in addition to analyze the effects of eucalyptus tree on land use and land cover changes and also how this influences the food security situation of rural households in study area. The findings of this study will be valuable for the regional and national level policy makers by providing vital information that can be an input in formulating relevant policies at national level and also to its proper implementations. So you are kindly requested to extend your cooperation for the success of this study by genuinely answering all questions in the questionnaire. Your response to these questions would remain anonymous. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation.

General Instruction for the Interviewer

- Read out the introductory statement to the respondents.
- Put (*) inside the box or fill responses in the space provided.
- Multiple responses or ticking in more than one box is possible when it is necessary.
- After each interviewing, check over the questionnaires to ensure that all questions have been asked and that the responses are complete and legible.

1. **Identification**

Wereda Name		Enumerator Name	
Kebele Name		Interview Date	
HH Head Name		Enumerator Signature	
HH Code			

2. Demography and Occupation of Households

№	2.1 Name	2.2 Gender of member 1, male 2, female	2.3Relation with Head Code A	2.4 Age (in years)	2.5Marital Status N.A if age < 15 Code B	2.6 Education N.A if age is < 3 Code C	2.7Main Occupation N.A if age < 6 Code D
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

NB: feel free to add extra rows if the family size exceeds 10

Code A: Relation with Head

Member	Code	Member	code	Member	Code
Head	1	Father(In-law)/Mother (In-Law)	6	Grand parents	11
Spouse (Wife/Husband/Partner)	2	Sister (in-Law) / Brother (In-Law)	7	Other Relatives	12
Son (Step) / Daughter (Step)	3	Nice/Nephew	8	Servant	13
Grand child	4	Uncle/Aunt	9	Tenant	14
Father/Mother	5	Son/Daughter-In-Law	10	Other Unrelated Person	15

Code B: Marital Status

Marital status	Married	Single	Divorced	Separated	Widowed
Code	1	2	3	4	5

Code C: Education Level (Highest grade completed)

Education level	Code	Education level	Code	Education level	Code
1st Grade incomplete (Kindergarten)	**0**	7th grade	7	College complete (non-University)	14
1st grade	1	8th grade	8	University incomplete	15
2nd grade	2	9th grade	9	University complete	16
3rd grade	3	10th grade	10	Other specify ……..	17
4th grade	4	11th grade (prep 1)	11	Religious Education – can read and write	18
5th grade	5	12th grade(prep 2)	12	Adult Literacy Program	19
6th grade	6	College incomplete (non-University)	13	Illiterate (can't read and write)	20

Code D: Occupation

Occupation	Code	Occupation	Code
Agriculture	1	Foreign employment	8
wage worker	2	Elderly/disabled/	9
Business	3	household work	10
Government service	4	Unemployed	11
NGO	5	Herding	12
Private sector	6	other specify	13……
Student	7		

3. If main occupation of the household is Agriculture, then please specify ….

[1] Crop production	[2]Animal rearing	[3] Enset	[4]Eucalyptus plantation	[5] Khate	[6] Any combination Specify …….……

4. Health Condition of the Household

4.1 Did you or any other member of your family face serious illness during the past 12 months? [1] Yes ; [2] No	
4.2 If Yes to 4.1, did he/she receive medical treatment in the health center? [1] Yes [2]No	
4.3 If no to 4.2, what was/were the reason/s? **Codes** [1] Absence of nearby health centers [2] Lack of money [3] Lack of awareness about modern health treatment [4] Lack of interest to visit health center [5] Other Specify ……	
4.4 What is your main source of money for medical treatment? **Codes** [1] Use my own savings [2] Sale Domestic Animals [3] Sale Eucalyptuses tree [4] Borrow from relatives /neighbors [5] Request payment free treatment from the government [6] Use local community based health insurance [7] Other specify ……	

5. Energy use and water– related Questions

5.1 What is the source of energy for lighting? **Code** [1] Biogas [2] Solar energy [3] Electric energy [4] Kerosene , candles [5] Wood [6] Other specify ……	
5.2 If the answer to 5.1 is wood [5], then what is the main source? [1] Eucalyptus [2] other trees	
5.3 What is the main source of energy used for cooking? **Code** [1] Dung [2] wood [3] Charcoal [4]kerosene [5] Biogas [6] Electricity [7] Other specify ……..	
5.4 If the answer to 5.3 is wood, then what is the main source? [1] Eucalyptus [2] other trees	
5.5 If the answer to 5.4 is eucalyptus, how do you get it? **Code** [1] From my own plantation; [2] From the local market [3] Collected from forest [4] other specify …….	
5.6 What is the source of your household's Drinking water? **Code** [1] Pond / lake [2] Dam [3] Spring [4] River/steam [5] Piped public water [6] Bore hole in residence [7] Other specify..……	

6. Asset Ownership

6.1 Agricultural Assets

1. Do you own land? Yes [1] No [2]		
1.1 If yes, what is your total land holding in hectare?		
1.2 how much of this is suitable for farming in hectare?		
2. What is the major food you produce? **Code** [1] Enset [2] Wheat [3]Barley [4] Teff [5] Other specify ……..		
2.1 How many months do you think that your own production can feed your family?		
2.2 How much income did you get from selling food production last year?		
3. Do you have eucalyptus trees? [1] Yes [2] No		
3.1 If yes, how many eucalyptus trees do you have?		
3.2 How much income did you get from selling eucalyptus tree last year (in Birr)?		
3.3 Do you have other type of trees (other than Eucalyptus)? Yes[1] No[2]		
3.4 From the total land the household has, what amount is used for eucalyptus (in hectares)?		
3.5 On average , how many years does it take for an eucalyptus tree to be ready for market?	Small	
	Medium	
	Big	
4. Do you own enset? Yes[1] No[2]		
4.1 If yes to 4, how much income did you get last year from selling?		
4.2 If yes to 4, how many months do you think it can feed your family?		
5. Do you produce khat? [1] Yes [2] No		
5.1 If yes, how much income did you get last year from selling?		
6. Do you own livestock? [1] Yes [2] No		
6.1 If yes, how many of each do you have?		

Oxen	cow	calves	Bull	Heifer	goats	sheep	Poultry	Mules	donkeys	Horses

7. Rank your production of --- [1] Food crop (cereals. Potatoes. Pulses,...) [2] Eucalyptus trees [3] Khat [4] Livestock [5] *Enstet* [6] Coffee [7] Fruits and vegetables	according to importance of **feeding the family.**						
	according to importance of **income Generation.**						

6.2 Household Related Assets

1	What is the ownership status of the house/s you are living in? **Code** [1] Self-owned [2] Given by relative /other to use [3] Rented [4]Other specify ……..			
2	What type of roofing material is used for the main house? **Code** [1] Grass [2] Corrugated iron sheet [3] Plastic sheet [4] other specify ……..…			
3	Is the residency room /house separated from the kitchens and/ or animal residences? [1] Yes [2] No			
4	**Does your household have?**		[1]Yes ;No [2]	If yes, purchase price in Birr?
	4.1	TV-set		
	4.2	Radio		
	4.3	Tape recorder		
	4.4	Mobile phone		
	4.5	Tables		
	4.6	Chairs		
	4.7	A bed with cotton/spring mattress		
	4.8	Bicycle		
	4.9	Motor cycle		
	4.10	Energy saving stove		
	4.11	Watch		
	412	Jewelries (gold, silver, etc…)		
	4.13	Other		
		Total		

7. Household's Sources of Income during the past 12 months

	Did you earn any income from selling …	Yes[1]; [2] No	If yes, amount earned
1	Food crops (Cereals , pulses, , oil seeds, ...)		
2	*Enset* products		
3	Cash crops (khat, coffee, vegetable, fruits,..)		
4	Eucalyptus trees		
5	Livestock		
6	Livestock products (eggs, milk, cheese, butter, dung …)		
7	Off-farm / non-farm opportunities		
8	Rent of any asset		
9	Remittances (domestic and/or abroad)		
	Total		

8. Access to Basic Services

1.	Considering the means of transport frequently used how long will it take you to reach the nearest (in Minutes):	
	a. School?	
	b. All-weather road?	
	c. Local market?	
	d. Water for domestic use?	
	e. Health center?	
	f. Any formal financial institution?	
2	Are you the user of any formal financial institution? [1] Yes; [2] No	
3	If yes, how much savings do you have in the microfinance institution?	
4	Are you a member of any cooperative? [1] Yes [2]No	
5	Do you think that the water available to your household is safe? [1] Yes [2] No	
6	Does your household have access to electricity? [1] Yes 2 [No]	

9. Agricultural Technology

	Over the past 12 months	
1	Have you used chemical fertilizers? [1] Yes [2] No	
2	Have you used improved seeds? [1]Yes [2]No	
3	Have you used insecticide and /or herbicide? [1]Yes [2]No	
4	Have you practiced climate smart agriculture (CSA) such as conservation agriculture and raw planting? [1]Yes [2]No	
5	Were you getting the services of Development Agent? [1] Yes [2] No	
6	If yes, how many times did he/she visit you in the past 30 days?	
7	Were you ever given trainings at Farmers' Training Center? [1]Yes [2] No	
8	If yes, how many times did you receive the services?	

10. Eucalyptus Tree related Issues

1. Do you have Eucalyptus trees? Yes[1] No[2]			
2. If No to 1 , what is /are your reason for not having eucalyptus trees? **Code** [1] I don't have excess land for the tree [2] I prefer other agricultural products [3] I believe that it is not good for the environment [4] Other specify ……..……..			
3. If yes to 1, what is/are your prime reason? **Code** [1] Income generation [2] Immediate cash needs ; [3] household demand for wood [4] the land I use is not suitable for other agricultural Production [4] requires less labor and attention than other agricultural works [5] Other specify ……..……..			
4. If yes to 1 , how many eucalyptus trees did (do) you have ?	Before 10 years	Before 5 years	At present
5. Do you have plans to expand your eucalyptus plantation in the future? [1] yes [2] No			
6. What kind of land are you using for eucalyptus plantation? **Code** [1] Crop land [2] hillsides [3] wastelands/marginal land [4] Other specify……..			
7. Do you think that eucalyptus tree planting in your locality is good? [1] yes [2] no			
8. If No to 7, what is your reason/s ? **Code** [1] It reduces local food production [2] reduces the growth of other plants [3] Not good for the environment [4] Other specify……..			
9. Between Food production and Eucalyptus tree plantation , which one makes you more secured in terms of :			
9.1 Feeding your Family [1]Food Production; [2] eucalyptus tree			
9.2 Income generation [1]Food Production [2] eucalyptus tree			
10. In your opinion, does the government promote or discourage eucalyptus Plantation in your area? **Code** [1] Promote [2] Discourage [3] Do not know			
10.1 If there is promotion in what form? **Code** [1] Distribution of seedlings [2] Provision of advices by the DAs; [3] Market access [4] Other specify……..…			
10.2 If there is discouraging in what form? **Code**			

[1] Forceful uprooting [2] Warnings [3] Awareness creation [4] Other specify……	
11. Suppose you get 1 hectare of additional land, for what production would you use it for ……. **Code** [1] Food crop production [2] Eucalyptus plantation [3] Livestock production [4] Other specify……..	
12. How do you describe rate of eucalyptus expansion in your locality? **Code** [1] Very fast [2] Fast [3] slowly [4] very slowly	
13. If he/she replied with [1] or [2] to 12, how do you fill about its expansion? **Code** [1] I am happy [2] I am indifferent [3] I am worried	
14. If he/she respond with [3] to 13, what is your reason? **Code** [1] Bad for the environment [2] Reduce food production [3] other specify …….	
15. If he/she respond with [3] to 13, should the government take actions to stop eucalyptus expansion? [1] Yes [2] No	
16. If eucalyptus tree expansion continues at present rate in your locality, what do you think the effect of this would be on the food security of the community? **Code** [1] improve food security [2] reducer food security [3] Do not know	
17. Rank the following according to their importance in cases of emergency cash demand? [1] Food crop [2] Eucalyptus [3] coffee [4]khat [5] enset [6] livestock	

11. Perception Questions on Eucalyptus

Code: [1] Strongly Disagree [2] Disagree [3] Neutral [4] Agree [5] Strongly Agrees

Perception Statements on eucalyptus growing compered to using available resources for other completive agricultural productions	Level of Agreement				
	[1]	[2]	[3]	[4]	[5]
Livelihood related Questions					
1. It helps me to get more income.					
2. Helps me to purchase agricultural inputs such as fertilizer and improved seed.					
3. It helps me to cover social contribution such as '*ekub'* and '*idir'*					
4. It has higher market demand (marketability) than other tree species.					
5. It is a better source of money during emergency cash needs					
6. It is better for construction than other types of tree species in the area.					
7. It is better for fire wood than other tree species.					
Welfare of household					
8. It helps me to cover children's education					

9. It helps me to get better health care services.					
10. It helps in fulfilling the family's food needs.					
Women empowerment					
11. It helps to reduce household work load of women by creating easy access to fire wood.					
12. It helps to increase the decision-making role of women in the household.					
13. It creates better opportunities for girls' education.					
14. It creates income generating opportunities for women.					
Coping Mechanisms					
15. It is better in coping idiosyncratic shocks such as illness or death of household head member, crop failure and loss of transfers.					
16. It is better in coping covariate shocks such as drought, social unrest and flooding					
Environmental Effects					
17. It has negative effect on the growth of other plants (reduce forage availability).					
18. It reduces the availability of ground water.					
19. It has negative impact on soil productivity (fertility).					

12. Food Security

12.1 Household Food Insecurity Access Scale (HFIAS) Questions

1. In the past four weeks, did you worry that your household would not have enough food?	[1] No (skip to Q- 2) [2] Yes
1.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
2. In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	[1] No (skip to Q- 3) [2] Yes
2.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
3. In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	[1] No (skip to Q- 4) [2] Yes
3.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
4. In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of foods?	[1] No (skip to Q- 5) [2] Yes

4.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
5. In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	[1] No (skip to Q- 6) [2] Yes
5.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
6. In the past four weeks, did you or any household member have to eat fewer meals in a day because there was not enough food?	[1] No (skip to Q- 7) [2] Yes
6.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
7. In the past four weeks, was there no food to eat of any kind in your household because of lack of resources to get food?	[1] No (skip to Q- 8) [2] Yes
7.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
8. In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	[1] No (skip to Q- 9) [2] Yes
8.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times
9. In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food ?	[1] No (go to the next part is finished)) [2] Yes
9.1 How often did this happen?	[1] 1-2 times [2] 3-10 times [3] more than 10 times

N.B; 1 =1-2 times means **rarely**; 2= 3-10 times means **sometimes;** and 3=more than 10 times means **often**

12.2 Food Consumption Score (FCS) Questions

Could you please tell me how many days in the past 7 days (1 week) your household has eaten the following food items?

Nº	Food Groups	Food Items belonging to the group		Nº of days eaten over the past 7 days
1	Main staples	Cereals	Made of maize	
			Made of Barely	
			Made of wheat	
			Made of teff	
			Made of sorghum	
			Made of Millet	
			Rice	
		Tuber	*Kocho*	
			Bulla	
			Amicho	
			Any other *enset* product	
			Potatoes	
			Sweet potato	
			Cassava	
2	Pulse	Beans		
		Pea		
		Lentils		
		Haricot bean		
		Any other nut		
3	Vegetables	Cabbage		
		Tomato		
		Carrot		
		Onion and related leaves		
4	Fruits	Banana		
		Orange		
		Avocado		
		Any other fruit		
5	Meat and Fish	Meat of any animal		
		Organs of animal (Kidney, liver, stomach...)		
		Eggs		
		Fish including canned sea products		
6	Milk and Dairy	Fresh milk and yoghurt		
		Cheese		
		Powder milk		
7	Oil and Fats	Butter		
		Processed oils		
		Margarine		
8	Sugars	Sugar		
		Sugarcane		
		Honey		
		Any sugary drinks and foods (cakes, cookies, soft drinks,…)		
		Salt, garlic , spices		
		Meat or fish as a condiment		
		Tomato sauce		

Appendix II. Interview guide for *Wereda* level officials and experts

(Agriculture and Natural Resources Management Office)

1) Can you describe your *wereda* in terms of:

- Area in Km^2, number of KPA
- Population and density
- Rain fall (amount, distribution and variability)
- Agro-climate , land use and land cover
- Soil type. cultivated land , productivity
- Stable food
- Major constraints and challenges in the agricultural sector
- Off-farm employment opportunities

2) How do you describe your *wereda* in relation to eucalyptus plantation?

- Types of eucalyptus trees grown and which once are preferred most? Why?
- Expansion – in production and area coverage
- Which *kebeles* in your *wereda* show larger coverage of eucalyptus trees?
- Food security
- Contribution in income generation
- Sources of energy
- Construction material
- Social value

3) How do you describe the land use pattern in your *wereda* in terms of the production of

- Food crop production
- *Khat* production
- *Enset* production
- Eucalyptus production

4) What are the major food crops produced in your *wereda*?

5) What is your opinion about the expansion of eucalyptus tree plantation in your *wereda*?

6) Can you explain to me the advantages and disadvantages of eucalyptus plantation expansion in your *wereda*?

7) What is your opinion on the effect of eucalyptus trees on smallholders' livelihood compared to the conventional agricultural activities?

8) Is there any policy/ regulation regarding planting eucalyptus trees? Yes/ No

If yes:

- Please explain to me the major components of this regulation.
- What are the reactions of farmers towards this regulation?

9) Is there any support you give to farmers who are engaged in eucalyptus plantation? Yes/ No

If yes:

- Please list the type of support you give them.

10) What measures do you take to control the expansion of eucalyptus trees on fertile food producing lands in your *wereda*?

11) How do you describe your *wereda* in terms of food security?

- Food self-sufficiency– Is there surplus or shortage
- If there is deficit ,
  - What are the main factors?
  - How do you manage this deficit?
  - Is the deficit increasing or decreasing in recent years? Why?

Appendix III. Interview guide for development agents

1) How long have you been working in this area?

2) How do households in this area fulfill their food requirements?

3) What kind of support do you give to farmers in this area in relation to-

- Agricultural technology
- Markets access
- Improved seed
- Modern inputs (Fertilizer, other chemicals,. .)
- Eucalyptus farming

4) What are the major agriculture constraints in this area?

5) In your opinion, why farmers prefer to plant eucalyptus tree to indigenous tree species?

6) Can you explain to me how eucalyptus trees benefit smallholder farmers in your *kebele*?

7) How do you describe the food security of this area?

8) How do you think eucalyptus expansion affect- :

- crop production?
- *enset* cultivation?
- soil productivity?
- livelihood?
- food security
- the environment?

9) If eucalyptus expansion continues at present rate, what effect do you think will this have on food security of the area?

10) What measures are you taking to control the expansion of eucalyptus trees on fertile food producing lands in your locality?

11) Are these measures effective in controlling the expansion of eucalyptus trees? If not. Can you please explain to me the reasons?

12) What measures do you think need to be taken in order to help farmers get the benefits of eucalyptus tree without reducing the food security of the area?

13) Is there any form of support you give to farmers who are engaged in eucalyptus tree plantation eucalyptus plantation in your locality?

14) How do you describe the interest of farmers towards expanding eucalyptus plantation?

15) Is there any policy/ regulations about how farmers should plant eucalyptus trees?

If yes:

- Please explain to me the major components of this regulation?
- How do farmers react to this regulation?

Appendix IV. Interview guide for FGDs held at different *kebeles*

1) What are the major food items produced in this area?

2) When do you think eucalyptus plantation was started in this area?

3) How did eucalyptus plantation start in this area?

4) What factors do you think encourage farmers to plant eucalyptus trees in your locality?

5) In your opinion, what kind of households tend to plant eucalyptus trees in your locality?

6) What are the purposes of planting eucalyptus in your area?

6) Is eucalyptus plantation expanding in this area? If yes:

- How do you fill about future food production of the area?
- Environmental problems?

7) Do you get any support from Development Agents or the government on eucalyptus tree? if yes, in what form ?

8) In your opinion are farmers more interested in eucalyptus tree than food item production? Why?

9) In your opinion, does the government encourage or discourage the plantation of eucalyptus trees in your kebele? Please explain how?

10) What kind of support, do you think need to be given to those who are engaged in eucalyptus farming?

11) Do households in your locality purchase food items from the market?

If yes:

- What kind of food do they usually buy?
- Do they get the kind of food they want in adequate amount in local markets?
- What are the major problems you face when you want to buy food from the market?
- What is/are the major source/s of income used to buy food from the market?

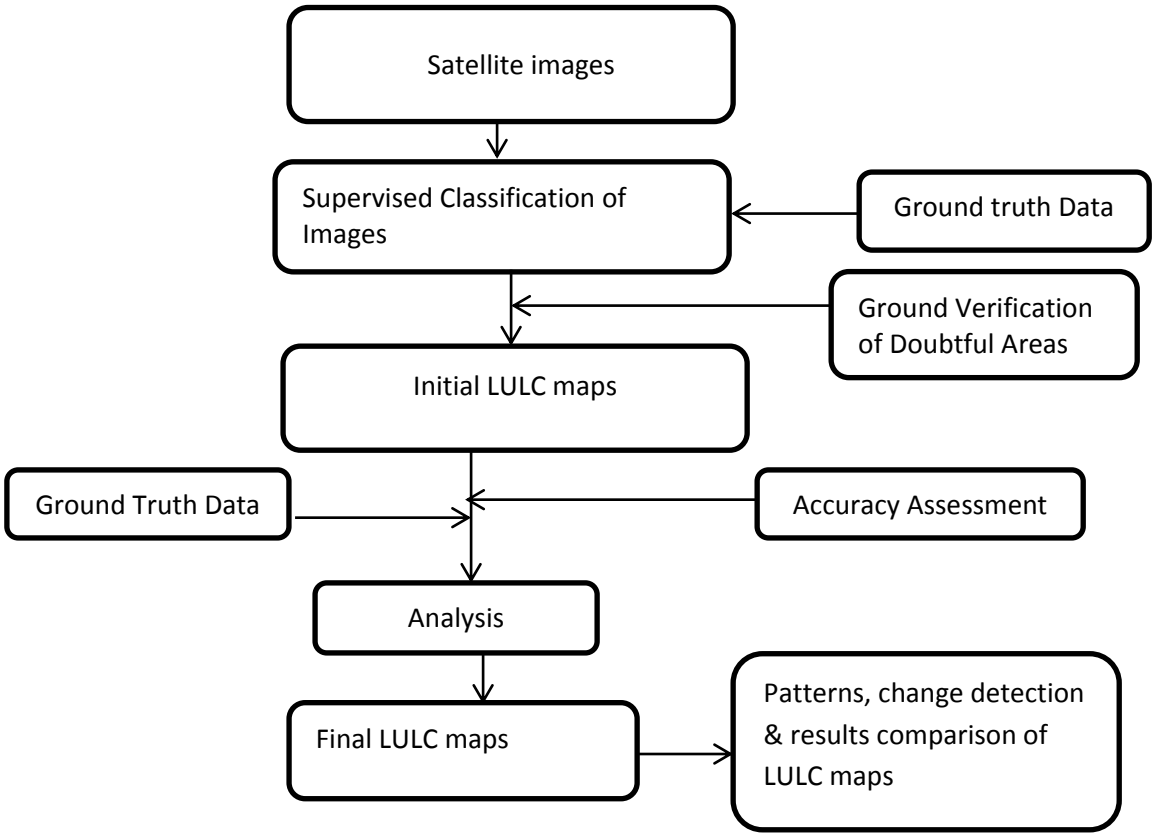
12) Comparing past and present, what is your opinion on the effect of eucalyptus expansion on-

- local food production ?
- welfare of households (income)?
- food security?

Appendix V. Collinearity Statistic for variable in the Fractional Logit Model

Description of Variables	VIF	$1/VIF$
Total Livestock holding (TLU)	3.22	0.311
Total Land of Household	2.94	0.340
Age of Household Head	1.56	0.643
Ln of Total household Income	1.42	0.706
Family members between 15 and 64 years	1.41	0.710
Wereda dummy	1.19	0.840
Part. in Non / Off-farm activities	1.19	0.841
School year of Household Head	1.14	0.874
Perceived effect of eucalyptus on Environment	1.13	0.887
Perceived effect of eucalyptus on livelihood	1.10	0.908
Suitability of land for crop	1.10	0.912
Proximity to main roads	1.07	0.933
Marital Status	1.07	0.933
Gender of Household Head	1.05	0.948
Mean VIF	**1.47**	

Appendix VI. Flow chart of activities for LULC assessment
(Adapted from Kaul and Sopan (2012)



Appendix VII Collinearity statistics for variables in the OLS estimation

Variables	**VFI**	$1/VFI$
Dgyz	1.74	0.5745
Dket	1.74	0.5757
Dzgb	1.7	0.5878
Dyes	1.45	0.6914
dwor	1.44	0.6934
Lnsz	1.32	0.7565
Ageh	1.30	0.7672
Flit	1.20	0.8308
Elhh	1.20	0.8324
Pnof	1.15	0.8668
Actr	1.10	0.9131
Gedr	1.09	0.9174
Acel	1.06	0.9403
mrstt	1.06	0.9408
Suln	1.06	0.9413
Mean VIF	1.31	

Appendix VIII. Classification Accuracy assessment for 2000

Classified	Bar land	Water bodies	Euca-lyptus	Grass land	Wet land	Forest land	Crop land	Shrub land	Settl-ements	Pros' Ac. (%)	Usrs' Ac. (%)
Bar land	0	0	0	0	0	0	0	0	0	-	-
Water bodies	0	0	0	0	0	0	0	0	0	-	-
Eucalyptus	0	0	6	1	0	0	0	0	0	54.55	85.71
Grass land	0	0	0	26	0	3	3	0	0	96.30	81.25
Wet land	0	0	0	0	1	0	1	0	0	100	50.00
Forest land	0	0	3	0	0	15	2	0	0	75.00	75.00
Crop land	0	0	2	0	0	2	93	0	0	93.94	95.88
Shrub land	0	0	0	0	0	0	0	2	0	100	100
Settlements	0	0	0	0	0	0	0	00	0	-	-

Overall Classification Accuracy = 89.38% and Overall kappa Statistics = 0.81143

Appendix IX. Classification Accuracy assessment for 2010

Clas-sified	Bar land	Water bodies	Euc-lyptus	Grass land	Wet land	Forest land	Crop land	Shrub land	Sett-lements	Prors' Ac. (%)	Usrs' Ac. (%)
Bar land	0	0	0	0	0	0	0	0	0	-	-
Water bodies	0	0	0	0	0	0	0	0	0	-	-
Eucalyptus	0	0	12	0	0	0	0	0	0	85.71	100
Grass land	0	0	0	5	0	0	0	2	0	62.5	71.43
Wet land	0	0	0	0	0	0	0	0	0	-	-
Forest land	0	0	0	1	0	13	2	0	0	68.42	81.25
Crop land	0	0	1	0	0	2	103	0	0	96.26	97.17
Shrub land	0	0	1	2	0	4	2	9	0	81.82	50.00
Settlements	0	0	0	0	0	0	0	0	1	100	100

Overall Classification Accuracy = 89.38% and Overall kappa Statistics = 0.83

Appendix X. Classification Accuracy assessment for 2021

Classified	Bar land	Water bodies	Euc-alyptus	Grass land	Wet land	Forest land	Crop land	Shrub land	Sett-Lement	Pros' Ac. (%)	Usrs' Ac. (%)
Bar land	0	0	0	0	0	0	0	0	0	-	-
Water bodies	0	0	0	0	0	0	0	0	0	-	-
Eucalyptus	0	0	9	2	0	1	0	0	0	60.00	75.00
Grass land	0	0	0	3	1	0	0	1	0	42.86	60.00
Wet land	0	0	0	0	1	0	0	0	0	50.00	100.00
Forest land	0	0	3	1	0	15	0	0	0	78.95	78.95
Crop land	0	0	2	0	0	3	103	0	0	99.04	94.5
Shrub land	0	0	1	1	0	0	1	10	0	90.91	76.92
Settlements	0	0	0	0	0	0	0	0	1	50.00	100.00

Overall Classification Accuracy = 89.75% and Overall kappa Statistics = 0.853

Appendix XI. Collinearity Statistic for variable in the Multinomial Logit Model

Description of Variables	**VIF**	$1/VIF$
Total Livestock holding (TLU)	3.08	0.324
Total Land of Household	2.96	0.337
Age of Household Head	1.46	0.687
Suitability of Land for crop	1.28	0.783
Part. in Non / Off-farm activities	1.19	0.839
Income from Eucalyptus	1.17	0.853
School year of Household Head	1.14	0.881
Wereda dummy	1.10	0.911
Family size	1.09	0.922
Proximity to main roads	1.06	0.939
Gender of Household Head	1.06	0.940
Marital Status	1.06	0.943
Mean VIF	**1.47**	

Appendix XII. Conversion factor for livestock unit (Tropical Livestock Unit)

Animal	**Livestock Unit**
Cow and Oxen	1.00
Heifer	0.75
Calf	0.25
Weaned Calf	0.34
Horse	1.00
Donkey (adult)	0.7
Donkey (young)	0.35
Camel	1.25
Sheep and Goat (adult)	0.13
Sheep and Goat (young)	0.06
Chicken	0.013

Storck and Doppler (1991)

Appendix XIII. Categories of food insecurity using HFIAS

	Frequency		
Questions	**Rarely**	**Sometimes**	**Often**
1a			
2a			
3a			
4a			
5a			
6a			
7a			
8a			
9a			

Source: Coates et al., 2007	Food Secured	Mildly insecured	Moderately insecured	Severly Insecured