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THE EFFECT OF SMALL-SCALE IRRIGATION ON HOUSEHOLD FOOD SECURITY IN ADA'A WOREDA, ADDIS ABEBA AREA, EAST SHEWA ZONE OF OROMIYA

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTER OF SCIENCE IN FOOD SECURITY AND DEVELOPMENT STUDIES

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UNDER THE GUIDANCE OF

DESALEGN YAYEH (Ph.D)

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ADDIS ABABA, ETHIOPIA

DECLARATION

I hereby declare that this thesis work entitled "The Effect of Small-Scale Irrigation On Household Food Security In Ada'a Woreda, Addis Abeba Area, East Shewa Zone Of Oromiya" submitted in partial fulfillment of the requirements for the Degree of Master of Science in Food Security and Development Studies at Addis Ababa University, through the Development Center for Food Security Studies, is my original work.

I affirm that all resources and materials used in this thesis have been duly acknowledged, and no part of this work has been copied or submitted elsewhere for any academic or professional qualification.

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ABSTRACT

This study explores the impact of small-scale irrigation on household food security in the Ada'a area, focusing on the relationship between irrigation use, demographic factors, and constraints to its adoption. The study aimed to assess how small-scale irrigation influences food availability, income, and overall food security, particularly in rural communities. Using a combination of statistical methods, including Chi-square and T-tests, data was collected from 200 households, comparing irrigation users with non-users. A variety of factors, such as access to technology, technical knowledge, and water management practices, were examined to determine their impact on irrigation effectiveness. The findings show that small-scale irrigation significantly enhances food security, with 82% of irrigation users being food secure, compared to 48% of non-users. Furthermore, irrigation users reported higher incomes (12,000 ETB) and crop yields (1,500 kg) compared to their non-irrigating counterparts. Demographic factors, such as education level and family labor, were found to significantly influence food security, while factors like age and gender had less impact. The study highlighted the importance of integrating education, training, and technology access to enhance the efficiency and sustainability of irrigation practices. However, the study also revealed critical constraints to irrigation use, including limited access to modern irrigation technology and inadequate technical knowledge. Poor water management practices did not significantly hinder irrigation use. These findings emphasize the need for targeted interventions, including providing access to affordable irrigation technologies and capacity-building programs to improve technical knowledge among farmers. The results of this research contribute to the understanding of small-scale irrigation's role in enhancing food security and suggest targeted policy interventions to address the barriers to its effective use. This study also provides insights into how improving irrigation systems can reduce food insecurity and enhance agricultural productivity in the Ada'a area.

Keywords: Agricultural productivity, Demographic factors, Food security, Household Income, Small-scale irrigation,

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LIST OF ABBREVIATIONS / ACRONYMS

ADLI	Agricultural Development Led Industrialization
ANOVA	Analysis of Variance
AWFEDO	Ada'a Woreda Finance and Economic Development Office
AWOA	Ada'a Woreda Agricultural Office
CIA	Conditional Independency Assumption
DA.	Development Agent
DDS	Dietary Diversity Score
ETB	Ethiopian Birr
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agricultural Organization
FCS	Food Consumption Score
FGD	Focus Group Discussion
GDP	Gross Domestic Product
HDD	Household Dietary Diversity
HDD	Household Dietary Diversity
HFIAS	Household Food Insecurity Access Scale
IFPRI	International Food Policy Research Institute
LIVES	Livestock and Irrigation Value Chain for Ethiopian Smallholder
MOARD	Ministry of Agriculture and Rural Development
NGOs	Non-Governmental Organization
PSNP	Productive Safety Net Program
SLF	Sustainable Livelihoods Framework
SPSS	Statistical Package for Social Sciences
TLU	Total Livestock Unit
WFP	World Food Program

CHAPTER ONE

INTRODUCTION

1.1. Background of Study

The majority of Ethiopia's population depends on agriculture for their livelihoods, making it the foundation of the country's economy. Notwithstanding its importance, the industry faces difficulties like inconsistent rainfall, degraded soil, and restricted access to contemporary farming technologies (Mohamed, 2017). Due to low agricultural production, smallholder farmers in the nation's semi-arid regions find it difficult to provide for their households' food demands. Because of this, many rural households continue to experience food insecurity (Ansah et al., 2019; Stuff et al., 2004).

Large-scale state farms in the central Awash Valley were the primary focus of modern irrigation in Ethiopia starting in the 1950s in order to produce industrial crops for agro-industries (B. M. Mekonen et al., 2022). For the majority of rural Ethiopians, agriculture is their main source of income, accounting for two-thirds of the workforce in sub-Saharan Africa (Haile & Kasa, 2015). However, many smallholder farmers have remained at a subsistence level due to their reliance on rain-fed agriculture, erratic rainfall, fragmented landholdings, and limited access to modern technologies, which has led to widespread food insecurity (Ahmed, 2019; Tesfaye et al., 2008). In order to increase food production and guarantee household food security, Ethiopia's Agricultural Development Led Industrialization plan places a strong emphasis on cooperatives, small-scale irrigation, and enhanced agricultural technologies. Irrigation has the ability to increase output and allow year-round farming (Abebe & Zeit, 2015), but its efficacy has been hampered by subpar management techniques, low beneficiary participation, and sociocultural hurdles. In order to guarantee steady access to sufficient, wholesome, and culturally acceptable food at the family level, these issues must be resolved (Kassie, 2020).

One viable way to deal with these issues is small-scale irrigation. Small-scale irrigation can increase agricultural output and improve family food security by allowing farmers to grow crops all year round, regardless of rainfall patterns. It makes it possible to diversify crops, boost yields, and enhance incomes all of which together raise resistance to food shortages. According to studies, small-scale irrigation enhances household access to and consumption of food in addition to increasing food availability (Jambo et al., 2021).

Small-scale irrigation projects have been implemented in Ada'a "Woreda", in Oromiya's East Shewa Zone, to boost agricultural productivity and reduce food poverty. The area, which is distinguished by its closeness to Addis Ababa, suffers particular difficulties as a result of population increase and urbanization pressures (Jambo et al., 2021). These factors have reduced the amount of arable land and raised the need for dependable food production methods. Although the region's small-scale irrigation systems are anticipated to be crucial in raising agricultural output, little is known about how they really affect family food security (Ali, 2002; Van Den Berg & Ruben, 2006).

Small-scale irrigation has the potential to enhance household resilience to climate unpredictability, which is becoming increasingly noticeable in Ethiopia, in addition to raising crop production. Farmers are better equipped to endure the consequences of droughts, erratic rainfall, and other environmental stressors when they implement irrigation techniques (Ansah et al., 2019; Kassie, 2020). Through the production of cash crops, irrigation systems can diversify revenue streams and provide a steady supply of food, hence lowering susceptibility to food insecurity. It is still unknown how much of these advantages are actually experienced in Ada'a "Woreda". (Deribe, 2008)

Additionally, by increasing the variety of crops available, small-scale irrigation might affect the dietary diversity of households. Improving general health outcomes and preventing malnutrition depend on having access to fresh fruits, vegetables, and other nutrient-rich crops (Kassie & Alemu, 2021). Irrigation could have a revolutionary impact on encouraging adequate nutrition in areas like Ada'a "Woreda", where traditional diets are frequently limited. Designing solutions that comprehensively address food security requires an understanding of how irrigation influences both food production and dietary choices (Mekonen et al., 2022).

Notwithstanding its promise, there are a number of obstacles to the widespread use of small-scale irrigation systems, such as a lack of technical expertise, poor infrastructure, and budgetary limitations. The initial outlay needed to set up and operate irrigation systems is too high for a lot of farmers. This study intends to offer thorough insights into how small-scale irrigation contributes to household food security in Ada'a “Woreda” by examining these variables.

1.2. Problem Statement

Agriculture serves as the principal livelihood for the majority of the population in Ethiopia, although it is highly vulnerable to unpredictable and insufficient rainfall, resulting to recurrent crop failures, food shortages, and widespread household food insecurity (Cochrane, 2018; Deribe, 2008). With agricultural output largely dependent on rainfall, the sector remains vulnerable and exposed to the impacts of climate unpredictability. In response, the Ethiopian government has implemented policies emphasizing small-scale irrigation and water management to minimize dependence on rainfall, raise production, and improve food security at the household level (Adenew, 2004; Beyene & Muche, 2010).

Irrigated agriculture has the potential to alleviate poverty by boosting output, income, and food availability, stabilizing food prices, and shielding people from crop loss hazards (Mohamed, 2017). It also promotes the use of yield-enhancing farm inputs, allowing households to move out of the poverty trap. In the studied region, conventional irrigation methods, such as river diversions, and more contemporary techniques like water pumps, have been utilized. However, it is unclear to what extent households with access to irrigation are better off compared to those depending on rain-fed crops (Ali, 2002; Van Den Berg & Ruben, 2006).

Despite the recognized benefits of irrigation, there is a dearth of extensive study on the specific effects of small-scale irrigation on family food security in the region (Beyene & Muche, 2010; Demeke et al., 2004). Barriers such as low technical expertise, inequitable water distribution, and poor management practices have further restricted the capacity of small-scale irrigation to completely solve food security concerns. This information gap restricts the development of targeted interventions and policies that could benefit the livelihoods of smallholder farmers and contribute to sustainable agricultural transformation (Hailu, 2023).

Determining if irrigation availability in the study area improves household food security is the main concern. In order to reduce rural food poverty in Ethiopia, this project intends to evaluate the effects of small-scale irrigation on food availability (Belay, 2018), dietary diversification, and climate variability resistance. Given the increasing agricultural difficulties and worries about food security in rural regions, it is imperative to assess the efficacy of small-scale irrigation. Through examining the advantages and difficulties of irrigation, this study will offer important information to enhance regional agricultural regulations and promote the growth of sustainable irrigation systems in Ethiopia.

1.3. Objective of the study

1.3.1. General objective

The general objective of this study is to examine and assess the effect of small-scale irrigation on household food security among users in the Ada'a area, near Addis Ababa.

1.3.2. Specific objectives

The specific objectives of this study are:

- To compare the levels of household food security between irrigation users and non-users in the Ada’a area, focusing on food availability, access, and utilization.
- To identify the household food security determinant factors in the Ada’a area, including demographic characteristics such as age, sex, educational level of the household head, family labor, and dependency ratio.
- To examine the impact of small-scale irrigation on household food availability in the Ada’a area, evaluating changes in production, income, and food access.

1.4. Research Questions

This study aims to explore the impact of small-scale irrigation on household food security in the Ada’a area of Ethiopia, where agriculture is the main livelihood but is highly vulnerable to erratic rainfall. This research will compare food security between irrigation users and non-users, examine the influence of demographic factors, and identify the constraints limiting irrigation adoption. The findings aim to provide valuable insights for improving food security and guiding policies for sustainable agricultural practices in rural Ethiopia.

- How does household food security differ between irrigation users and non-users in terms of food availability, access, and utilization?
- What demographic characteristics (age, sex, educational level of the household head, family labor, and dependency ratio) influence household food security in the Ada'a area?
- What is the impact of small-scale irrigation on household food availability, production, income, and food access?
- What factors constrain the use of small-scale irrigation in the Ada'a area?

1.5. Research Hypothesis

The research hypotheses for this study are developed based on the research questions designed to explore the impact of small-scale irrigation on household food security in the Ada'a area. These hypotheses aim to test the relationships between irrigation practices, demographic factors, and food security outcomes. The following hypotheses are directly aligned with the research questions:

- **μ_1**: There is a significant difference in household food security between irrigation users and non-users in the Ada'a area, with irrigation users having better food availability, access, and utilization. (Aligned with Research Question 1)
- **μ_2:** Demographic characteristics such as age, sex, educational level of the household head, family labor, and dependency ratio significantly influence household food security in the Ada'a area. (Aligned with Research Question 2)
- **μ_3:** Small-scale irrigation has a positive impact on household food availability, production, income, and food access in the Ada'a area. (Aligned with Research Question 3)
- **μ_4:** Factors such as limited access to irrigation technology, poor water management practices, and inadequate technical knowledge constrain the use of small-scale irrigation in the Ada'a area. (Aligned with Research Question 4)

These alternate hypotheses (**μ1, μ2, μ3, and μ4**) represent the expected positive relationships or effects based on the research questions and objectives.

1.6. Scope of the Study

This study looks at how household food security is affected by small-scale irrigation in the Ada'a neighborhood, which is close to Addis Ababa, Ethiopia. It examines food availability, access, usage, and dietary diversity in order to evaluate food security between households who use irrigation and those that depend on rain-fed agriculture. The study also looks at how family labor, dependence ratio, household head's educational attainment, age, and sex affect food security. The study is restricted to the Ada'a region, which uses both conventional and contemporary irrigation techniques. It looks into things like technical understanding, water management, and availability to technology that hinder the use of irrigation. The results are intended to shed light on how well small-scale irrigation contributes to food security and offer suggestions for improving agricultural methods and regulations in comparable rural areas of Ethiopia.

1.7. Significant of the Study

This study is significant as it provides valuable insights into the effect of small-scale irrigation on household food security, identifying key factors that influence food security and the major constraints to irrigation use. The findings will enhance existing knowledge on the topic and support future interventions in the study area. The outcomes can guide policymakers and development planners involved in irrigation development, offering evidence-based recommendations for improving food security through better irrigation practices. Additionally, the research findings will serve as a valuable resource for researchers, offering a foundation for further exploration of irrigation development and food security. This study will contribute to sustainable agricultural practices and support effective policies aimed at improving food security in rural regions.

1.8. Organization of the Study

The study is organized into five main chapters.

Chapter One: Introduction: This chapter provides the background of the study, the problem statement, research objectives, and significance of the study. It also outlines the research questions, hypotheses, and scope of the study.

Chapter Two: Literature Review: This chapter reviews existing literature on small-scale irrigation and household food security, including theoretical frameworks, previous studies, and key concepts.

Chapter Three: Research Methodology: This chapter describes research design, sampling methods, data collection techniques, and data analysis procedures. It outlines the methods used to gather both qualitative and quantitative data for the study.

Chapter Four: Results and Discussion: This chapter presents the findings of the study based on the analysis of the collected data. It discusses the effects of small-scale irrigation on household food security.

Chapter Five: Conclusion and Recommendations: The final chapter summarizes the key findings, draws conclusions based on the results, and provides recommendations for policymakers, development planners, and future research.

CHAPTER TWO

LITRATRUE REVIEW

2.1. Household and Food security

A household, in the context of food security, refers to a group of individuals who live together and share resources to meet their daily needs (Ansah et al., 2019). These resources can include income, food, shelter, labor, and other assets. The household unit might consist of nuclear families (parents and children), extended families (including grandparents, uncles, aunts), or a group of unrelated individuals living together for economic or social reasons (Melgar-Quinonez & Hackett, 2008). Households are not simply consumption units but also production units, often involved in agricultural output, and are crucial to food security assessments because they determine food access, management, and consumption. Social and economic factors such as income level, education, and employment status strongly influence a household's food security. While a home normally shares economic resources, the individual duties within the household might vary, with responsibility for food sourcing, preparation, and consumption allocated among members, especially in traditional communities (Bickel, 2000; Silvestri et al., 2015). Moreover, the size and structure of a household have a critical influence in determining its capacity to meet food security needs. Households can differ in terms of food security, with some facing chronic food insecurity, while others may be able to meet their food demands consistently (Nord, 2010). Understanding household composition and decision-making structures is critical for measuring food security since these aspects can considerably affect how food resources are allocated, consumed, and prioritized (Carletto et al., 2013).

2.1.1. Food Security

Food security is a multi-dimensional concept that concerns the availability, access, consumption, and stability of food. The FAO's definition of food security highlights the need for all people to have consistent, stable access to sufficient, safe, and nutritious food that supports an active and healthy life. Food availability applies to whether enough food is produced or available in a specific location, including aspects such as agricultural production, storage, and trade. Access to food, meanwhile, refers to a household's ability to get food either through purchasing, production, or social services. This component is mostly affected by economic and social factors, such as household income and purchasing power (Bacha et al., 2011; Tesfaye et al., 2008). Food utilization concerns the right use of food, which comprises adequate meal preparation, hygiene, and the absorption of nutrients necessary for optimal health. Lastly, food security stability is the ability to continuously get sufficient food throughout the year, without disruptions due to environmental, political, or economic events (Bashir & Schilizzi, 2013). A secure food system is not just about providing the fundamental caloric demands but ensuring that individuals have access to the correct types of food to support health and well-being. Food security also represents the resilience of households and communities in the face of stresses, such as economic crises, natural catastrophes, and climate change, and it requires continual monitoring of food systems to prevent periods of insecurity (Nord et al., 2005).

2.1.2. Core Concepts in Household Food Security

Sufficiency: The concept of sufficiency in food security refers to having enough food to meet the nutritional needs of all family members over time. It is not merely about calorie counts but also the variety and quality of food ingested to promote good health and well-being. Determining "enough" entails examining numerous aspects, such as the specialized dietary requirements of different age groups (children, pregnant women, elderly) and individuals' health statuses (Martin et al., 2013). For example, a sufficient diet for a small child will differ from that of an adult in terms of needed elements including protein, vitamins, and minerals. Sufficiency also extends beyond the quantity of food to the quality of food households must have access to diversified and nutritious food to fulfill micronutrient needs, which are critical for long-term health outcomes. Often, food security is a dynamic concept where sufficiency is defined in terms of a household's ability to sustain food availability not just today but also in the future, maintaining a stable level of living without seasonal shortages (Ghose, 2014). A household’s food sufficiency may vary dependent on geography, seasonal cycles, and local production patterns, underlining the necessity for varied coping mechanisms when sufficiency is compromised (Baer-Nawrocka & Sadowski, 2019).

Access and Entitlement: Access to food is the ability of people or households to get food through numerous sources, including home production, markets, or social support mechanisms. Economic access is one of the most major impediments for many households, especially those in poverty, as their capacity to acquire appropriate food is hampered by low income. Social access refers to the ability of individuals or households to receive food through social networks, public food programs, or through commerce (Coleman-Jensen et al., 2014; Martin et al., 2013). A major aspect in food access is entitlement, a concept created by economist Amartya Sen. Entitlement theory highlights that people's access to food is influenced not simply by their income but also by their rights, or entitlements, to resources such as land, labor, and capital. Even if food is accessible, households that lack certain privileges may be unable to obtain sufficient food (Davies, 2016). Access is thus strongly intertwined with broader social and political institutions. For instance, bad infrastructure, land rights disputes, and political instability can all significantly hinder a household's capacity to get food. A household's entitlement to food also depends on how resources are distributed within the family unit and how external factors such as government laws, markets, and social networks influence food access (Van Wijk et al., 2014).

Security: Security in the sense of food security refers to the ability to sustain constant access to sufficient food without worrying about unexpected, unpredictable disruptions. This means having the resilience to endure shocks, whether they are economic, environmental, or political in origin. For households, food security is about the long-term ability to obtain enough food, not just in the present, but over seasons and years (Coleman-Jensen et al., 2016). It includes ensuring that food systems are stable, and that households have methods to cope with shocks, such as droughts, floods, or economic crises. Security also extends to nutritional stability, when a home can regularly cover the nutritional needs of all its members, preventing both acute and chronic malnutrition (Nord, 2010). Vulnerability to food insecurity frequently stems from a lack of assets, income instability, or susceptibility to external causes, making it vital for households to diversify their food and income sources to buffer against food security shocks. For example, households who rely primarily on rain-fed agriculture may face substantial disruptions when climate change disrupts rainfall patterns. Thus, food security comprises more than just the availability of food; it entails the ability to stabilize access to food, even in the face of uncertainty (Coleman-Jensen et al., 2016; Ghose, 2014).

Time: Time has a key role in food security, both in the short-term and long-term context. In the short term, food security difficulties could develop owing to transitory disruptions such as a drought, market price rises, or unforeseen household expenses. In such instances, time relates to how quickly a household can respond to these emergencies, whether through coping techniques or using safety nets (Patenaude et al., 2018; Wilde & Peterman, 2006). The availability of food during various seasons (such as harvest or lean periods) might vary based on agricultural techniques, market systems, and household reserves. Over the long run, time affects food security through shifting patterns of food production, technological advancement, and demographic shifts. A household's ability to plan for the future through resource management, investments, and education can considerably influence its long-term food security. Households with stronger access to savings or diversified income sources are better positioned to survive periods of food insecurity (Nord, 2014). Planning and investing in food security over time help households lower the chance of encountering chronic food poverty. Additionally, government policy, market stability, and agricultural innovation all contribute to preserving long-term food security (Muhialdin et al., 2021).

2.1.3. Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework (SLF) is a comprehensive method to understanding how households and communities protect their well-being and alleviate poverty throughout time. The framework was designed by the UK's Department for International Development and underlines the necessity of not just focusing on income but also evaluating the varied resources and tactics households employ to meet their needs. SLF categorizes resources into five forms of capital: natural capital (land, water, biodiversity), human capital (education, health, skills), financial capital (income, savings), physical capital (infrastructure, technology), and social capital (social networks, support systems) (Jackson, 2021). These forms of capital are interconnected and collectively contribute to livelihood options that promote household food security (Natarajan et al., 2022; Nord, 2014). For example, the presence of natural capital such as fertile land may enable a household to grow its food, but without human capital like knowledge of farming practices, financial capital to invest in seeds, or social capital to access labor, the land may stay unused. SLF acknowledges that food security is not merely an issue of food production or revenue but involves a holistic view of how diverse assets interact to produce resilience and sustainable livelihoods (Jackson, 2020, 2021). This concept encourages development projects to address the core causes of food insecurity, including both the immediate needs and long-term capacity-building of households. It is also critical in identifying vulnerable households and tailoring measures to strengthen their resilience to shocks like climate change, economic crises, or political instability (El Bilali et al., 2017; Natarajan et al., 2022).

2.1.4. Indicators of Household Food Security

Indicators of household food security help to measure the availability, access, usage, and stability of food within a home. These indicators can be classified into direct and indirect measures. Direct indicators include food consumption patterns, dietary diversity, and nutritional status, such as anthropometric measurements (height-for-age, weight-for-age, and BMI) (Maxwell et al., 2013; Maxwell et al., 2014). They provide rapid information regarding the adequacy of food consumption and the quality of nutrition that the household members receive. Indirect indicators analyze the structural and economic elements influencing food security, such as income levels, agricultural production, food prices, and market access. These factors can impact a household's ability to purchase sufficient and nutritious food. The Household Food Insecurity Access Scale (HFIAS) and the Food Consumption Score (FCS) are routinely used to quantify food insecurity. HFIAS analyzes access to food, while FCS focuses on food consumption habits, evaluating food variety and frequency (Wiesmann et al., 2009). Furthermore, metrics like the Dietary Diversity Score (DDS) assess the range of food groups ingested, which is crucial for evaluating the nutritional adequacy of a household's diet. These indicators assist identify disadvantaged households and guide policies and activities targeted at increasing food security (HANISA, 2021). Evaluating these indicators also assists in measuring progress toward attaining broader development goals, such as reducing hunger and malnutrition (El Bilali et al., 2017).

2.1.5. Food Insecurity Coping Strategies

Coping mechanisms are crucial in understanding how households manage food insecurity and lessen its repercussions. These techniques can be divided into short-term and long-term responses. Short-term coping tactics frequently involve lowering food consumption, such as skipping meals or depending on cheaper, less nutritious items. For instance, during moments of severe food shortage, households may restrict the frequency of meals or rely on food help or charity (Van Wijk et al., 2014). However, these efforts are not sustainable and might have adverse health repercussions, especially if they result in undernutrition. Long-term coping techniques are often focused on building resilience to future shocks. These can include diversifying sources of income (e.g., engaging in off-farm labor, small companies), increasing food storage practices, or investing in improved farming techniques or irrigation systems to assure a steady food supply. Some households may also employ measures such as selling assets, including animals, to earn quick cash for food needs (Akerele et al., 2013). However, these tactics can have long-term detrimental repercussions on livelihoods, as they diminish the household's capital and make them more susceptible in the future. Governments and NGOs often intervene by providing safety nets, food aid, and initiatives to enhance household resilience, such as offering training in alternative livelihoods or supporting sustainable agricultural techniques (Mayer et al., 2016).

2.2. Household Dietary Diversity (HDD)

2.2.1. Process Indicators

Process indicators for family Dietary Diversity (HDD) analyze the activities and procedures involved in food acquisition, preparation, and consumption within the family (Verger et al., 2019). These indicators focus on the underlying elements that determine a household's access to various foods (Ritzema et al., 2019). For example, access to markets, availability of food storage facilities, and household members' understanding about nutrition can all impact dietary diversity. The manner food is sourced (e.g., home production vs. purchase) and the decision-making process within the household on what food to consume also impact diversity. Process indicators may include the frequency of food shopping, the amount to which households rely on home gardening, and if the household applies food safety and preservation measures (Verger et al., 2019). Additionally, these indicators analyze societal factors, such as whether women or men largely make food-related decisions and if there is equitable access to resources that encourage dietary diversity (Hoddinott & Yohannes, 2002).

2.2.2. Outcome Indicators

Outcome indicators for HDD focus on the actual consumption patterns of a household, indicating the diversity of the diet and its nutritious quality. These indicators include the number of different food types consumed over a specific period (e.g., a week or month), and the nutritional content of the food consumed (Usman & Haile, 2022). A diverse diet is key for ensuring that individuals acquire all the essential elements necessary for optimum health, particularly micronutrients like vitamins and minerals, which are crucial for preventing malnutrition. Outcome indicators might also include measurements like the proportion of meals that include vegetables, fruits, or animal-sourced foods, which are often indicative of a balanced and nutritious diet (Kennedy, 2009). Other metrics can include analyzing if a home has a range of protein sources, such as legumes, beef, or fish, and whether meals match caloric demands. High dietary diversity is positively connected with better nutrition outcomes, since it shows a household is obtaining a broad range of foods that contribute to a balanced diet (Warren et al., 2015).

2.2.3. Measuring Household Food Security

Measuring household food security entails utilizing a combination of qualitative and quantitative methodologies to measure the many characteristics of food security. Quantitative techniques often comprise surveys, indices, and scales that quantify food consumption, access, and dietary diversity (Bickel et al., 2000; Melgar-Quinonez & Hackett, 2008). The home Food Insecurity Access Scale (HFIAS) is a frequently used tool to measure food insecurity at the home level, assessing how often a household encounters difficulty in acquiring food, and the severity of these challenges. Similarly, the Food Consumption Score (FCS) is used to analyze food consumption habits, taking into account both the frequency and diversity of meals consumed by the household. These indices provide a picture of the household's food security status and assist identify vulnerable groups in need of intervention. Qualitative approaches, such as focus group discussions and in-depth interviews, enable to study the social, economic, and environmental issues that affect food security (Cafiero et al., 2018). These methodologies can yield deeper insights about coping strategies, perceptions of food insecurity, and the significance of community support systems. Both methods are crucial in designing effective food security policies and interventions suited to the individual needs of diverse households and communities (Vaitla et al., 2017).

2.3. Food Security Situation in Ethiopia

The food security situation in Ethiopia has been historically precarious, with many households facing times of acute food insecurity due to a mix of factors such as droughts, poverty, and fluctuating agricultural production (Fadong et al., 2018). Ethiopia, located in the Horn of

Africa, is primarily dependent on rain-fed agriculture, which makes the country particularly sensitive to climate changes, such as droughts and irregular rainfall patterns. Despite major gains in the agricultural sector, food insecurity exists, especially in rural areas where a large portion of the population relies on subsistence farming (Fadong et al., 2018; Ocho et al., 2017). According to the World Bank and other development organizations, around one-quarter of Ethiopia's population confronts food insecurity, with the severity of food insecurity varies by location. Northern and eastern Ethiopia are particularly prone to food shortages due to frequent droughts, while other sections of the nation suffer with food access and hunger. The government of Ethiopia, along with foreign organizations, has developed many projects to address food security, including as the Productive Safety Net Program (PSNP) and initiatives focusing on improving agricultural techniques, increasing access to markets, and enhancing infrastructure (Adem et al., 2018; Mekonnen & Gerber, 2017). However, food insecurity remains a major concern, exacerbated by economic reasons such as inflation, rising food prices, and population expansion. Sustainable solutions are needed to increase food security in Ethiopia, addressing the core causes of poverty, environmental degradation, and vulnerability to shocks, while building the resilience of households to future challenges (Adenew, 2004; Ahmed, 2019; Cochrane, 2018).

2.3.1. Irrigation Development in Ethiopia

Irrigation development has become a significant focus of Ethiopia’s attempts to boost agricultural production and food security (Haile & Kasa, 2015; Tesfaw, 2018). The country's dependency on rain-fed agriculture has made it sensitive to climate variability, notably droughts, which often cause crop failures and food shortages. In response, irrigation projects have been emphasized as a strategy to enhance food production, stabilize harvests, and lessen dependency on unpredictable rainfall (Muez, 2014). The government, in partnership with international partners, has invested in large-scale and small-scale irrigation facilities around the country. These activities aim to boost the agricultural output of both smallholder farmers and large commercial farms, increase the availability of water for crops, and promote sustainable farming techniques (Tesfaw, 2018). Although irrigation development has had a good influence on some locations, it has faced problems such as limited infrastructure, lack of technical skills, and environmental issues over water use. In some situations, irrigation projects have led to soil degradation, waterlogging, and salinization, which could harm long-term agricultural output (Denison, 2020). However, irrigation remains a critical tool for increasing food security, especially in places where rainfall is erratic, and it is envisaged that ongoing development and management of irrigation systems will play a key role in attaining sustained food security in Ethiopia (Awulachew, 2019; Mwendera & Chilonda, 2013).

2.3.2. Overview and Definition of Small-Scale Irrigation

Small-scale irrigation refers to the technique of employing tiny, localized irrigation systems to give water to crops, particularly in regions where access to water is restricted or when larger-scale irrigation is not possible (Van Den Berg & Ruben, 2006). Small-scale irrigation can take several forms, including small canals, drip irrigation, rainwater gathering, and the use of pumps or wells (Yami, 2016). These systems are often handled at the family or community level, making them more flexible and adaptive to local conditions. Small-scale irrigation is viewed as a sustainable and cost-effective strategy to raise agricultural production, improve food security, and reduce poverty in rural regions. The systems are mainly low-tech and designed to be affordable for smallholder farmers, who make up the majority of Ethiopia's agricultural workforce (Tesfaw, 2018). These systems can be particularly advantageous in locations where rainfall is erratic, allowing farmers to cultivate crops during dry months and boosting the reliability of food production. Small-scale irrigation has the potential to boost yields, diversify crops, and lessen the hazards associated with climate variability (Haile & Kasa, 2015). However, the development of small-scale irrigation systems requires careful planning and management to ensure that water resources are managed efficiently and sustainably, and that the benefits of irrigation are equitably divided among different groups within the community (Kassie, 2020).

2.3.3. Status and Potential of Small-Scale Irrigation in Ethiopia

Ethiopia has a tremendous potential for small-scale irrigation, given its huge water resources, including rivers, lakes, and underground aquifers. The government has acknowledged the importance of small-scale irrigation as a strategy for boosting food security and has implemented numerous programs to assist its spread (Yohannes et al., 2017). As of recent estimates, just a small fraction of Ethiopia’s potential irrigable land is now being employed for small-scale irrigation (Cochrane, 2018; B. M. Mekonen et al., 2022), however initiatives to extend these systems have been gathering steam. In some locations, small-scale irrigation systems are already yielding major benefits, enabling farmers grow crops year-round and secure their livelihoods against climate shocks (Mekonen et al., 2022). However, the adoption of small-scale irrigation remains unequal, with rural areas having varying access to the requisite infrastructure and technologies. Barriers to expansion include restricted access to credit, inadequate extension services, and issues linked to land ownership and water rights (Kassie & Alemu, 2021; Tesfaye et al., 2008). Despite these limitations, small-scale irrigation has a hopeful future in Ethiopia, particularly as climate change continues to undermine the stability of rain-fed agriculture (Ahmed, 2019). The country's strategic focus on enhancing water management techniques, expanding farmer education, and investing in irrigation infrastructure is expected to further harness the potential of small-scale irrigation systems (Ahmed, 2019).

2.4. Small-Scale Irrigation and Food Security

Small-scale irrigation is recognized as a critical strategy for enhancing food security in Ethiopia by increasing crop output and providing farmers with the capacity to cope with variable weather patterns (Fanadzo et al., 2010; Iticha, 2019). By providing a reliable water source for crops, small-scale irrigation systems allow farmers to produce food throughout the year, minimizing their dependency on seasonal rainfall and mitigating the impacts of droughts. This regularity in output can contribute to increased agricultural yields, improved income for farmers, and a reduction in the vulnerability of households to food insecurity (Tu et al., 2014). Moreover, small-scale irrigation can promote the cultivation of higher-value crops, diversify diets, and improve household nutrition. Irrigation also helps to better market access, as farmers can grow surplus food for sale, leading to higher household incomes. Furthermore, small-scale irrigation can have positive ripple effects in rural communities by improving access to water for home use and supporting other activities such as livestock production and agro-processing (Ashu, 2022). Despite the potential benefits, the successful implementation of small-scale irrigation requires resolving difficulties such as water management, equal access to resources, and capacity-building for farmers (Awulachew & Ayana, 2011). Policies targeted at supporting small-scale irrigation systems are vital for ensuring that these systems contribute to long-term food security and sustainable development (Mengistie & Kidane, 2016).

2.4.1. Environmental Impact of Small-Scale Irrigation Schemes

While small-scale irrigation has evident benefits for enhancing food security, it can also have detrimental environmental implications if not properly managed. Over-extraction of water from rivers or underground aquifers can lead to water shortages, especially in locations where water resources are already restricted. Additionally, inappropriate irrigation practices can result in soil deterioration, waterlogging, and salinization, which can lower the fertility of the land and diminish agricultural yield over time (Chazovachii, 2012). For example, excess of irrigation water without sufficient drainage systems can lead to the accumulation of salts in the soil, making it less suited for crop growth. Furthermore, the environmental sustainability of small-scale irrigation systems depends on the careful management of water resources to guarantee that they are used efficiently and fairly. Ensuring that irrigation practices are environmentally sustainable is vital for preserving long-term food security. Techniques such as drip irrigation, rainwater collecting, and integrated water resource management can assist alleviate some of the environmental concerns involved with irrigation (Ruffeis et al., 2008). Additionally, regulations that support sustainable land and water management techniques are vital for minimizing the environmental effect of small-scale irrigation projects (Ulsido et al., 2013).

2.4.2. Constraints in Small-Scale Irrigation Systems

Small-scale irrigation systems encounter various constraints that limit their usefulness in boosting food security. One of the key issues is the limited access to water, particularly in arid or semi-arid places where water resources are already overexploited. Even in locations where water is plentiful, the infrastructure required to extract, store, and transfer water to crops is often inadequate or poorly maintained (Awulachew et al., 2010; Muhoyi & Mbonigaba, 2021). Inadequate technical knowledge and skills among farmers can pose a substantial impediment to the proper implementation and maintenance of irrigation systems. Many smallholder farmers lack the requisite training to design, install, and run irrigation systems properly, leading to inefficiencies and system malfunctions. Additionally, financial constraints limit farmers' ability to invest in irrigation infrastructure and acquire critical inputs such as pumps, pipes, and other irrigation equipment (Libseka et al., 2015). Other social and economic variables, such as land tenure insecurity, market access, and gender inequality, also contribute to the limits in small-scale irrigation systems. For instance, women, who generally play a significant role in agriculture, may encounter difficulties in acquiring irrigation technologies due to limited control over land and resources. Overcoming these obstacles needs targeted investments in infrastructure, training, and access to credit, as well as addressing broader issues of land rights and social equality (Chazovachii, 2012; Mohammed, 2019).

2.4.3. Impact on Household Food Security Dimensions

Small-scale irrigation systems can have a substantial impact on various variables of family food security (Tesfaye et al., 2008). On the availability side, irrigation increases the reliability of food production, minimizing the chance of crop failures due to droughts or unpredictable rainfall. This leads to more secure food supplies and improved access to food throughout the year. On the access side, small-scale irrigation can boost income creation options by allowing farmers to produce extra crops for sale (Leroy et al., 2015). This can boost a household’s purchasing power, enabling them to acquire a greater variety of foods from local markets. Moreover, increasing income from irrigation can boost a household's ability to invest in other forms of capital, such as education, healthcare, and infrastructure, which can have long-term advantages for food security (Ajao et al., 2010; Sseguya et al., 2018; Tesfaye et al., 2008). On the utilization side, the diversity of crops generated through irrigation can improve the nutritional content of the household’s meals, delivering more variety in terms of protein, vitamins, and other necessary components. Finally, small-scale irrigation can help to stability in household food security by lowering the vulnerability of farmers to the consequences of climate change and economic fluctuations. This resilience can improve the overall food security condition of households and contribute to broader community development goals (Awulachew et al., 2010).

2.4.4. Household Socioeconomic Factors and Irrigation Adoption

Household socioeconomic considerations play a key effect in the adoption and success of small-scale irrigation systems. Factors such as income, education, gender, and land ownership determine whether a household can invest in and profit from irrigation systems. Wealthier households are more likely to adopt irrigation because they can afford the initial capital investment and have more access to finance (Adeoti, 2008). Similarly, households with better access to education are more likely to adopt new technologies, including irrigation systems, as they are more likely to be aware of the benefits and more competent of operating the systems. Gender dynamics also influence irrigation adoption, as women, who are frequently the major agricultural labor force in many rural areas, may face challenges to obtaining resources, including irrigation technologies (Namara et al., 2007). Land tenure security is another crucial element; farmers who do not have solid land rights may be less eager to invest in irrigation systems, as they may not expect to reap the long-term advantages. Addressing these socioeconomic issues through targeted policies and interventions is vital to guarantee that small-scale irrigation systems are accessible and useful to all households, particularly those in disadvantaged or marginalized groups (Chuchird et al., 2017).

2.5. Empirical literature review on small- scale irrigation

Numerous investigations have been carried out to examine the factors that influence small-scale irrigation participation and how it relates to food security in various nations, including Ethiopia. In addition to highlighting the wider socioeconomic effects of irrigation on food security, these studies also emphasize the different elements that affect households' capacity to implement irrigation techniques.

2.5.1. Factors Affecting Irrigation Participation

A study by (Alam et al., 2012) looked at the variables affecting households' involvement in irrigation farming. A number of important factors that influence the chance of implementing irrigation practices were found by the study. These include the head of the household's age, as younger heads are more likely to embrace modern technologies; the head's gender, as male-headed households tend to have greater access to resources and decision-making authority; and the head's educational background, which affects the ability to comprehend and manage irrigation systems. The size of the landholding, the number of livestock units, and the availability of financial resources such as bank loans that enable farmers to invest in irrigation infrastructure are other factors that affect irrigation participation. Access to irrigation systems is also greatly influenced by the distance to roads, markets, and rivers because these elements have an impact on water supply and transportation. Furthermore, the decision to practice irrigation farming was found to be influenced by a number of characteristics, including household size, market information accessibility, and the kind of peasant associations and training that farmer had access too (Azizi Khalkheili & Zamani, 2010). These results highlight the fact that a variety of economic, social, and infrastructure factors influence irrigation participation in addition to water availability.

2.5.2. The Creation of Jobs and Irrigation

Based on an analysis of empirical research, (Mihailović et al., 2014)confirmed that appropriate and dependable irrigation systems greatly expand employment options, especially for small-scale farmers and laborers without land. Irrigation provides for numerous cropping seasons throughout the year, which adds more workdays by permitting year-round agricultural production. This is especially crucial in areas where the amount of employment available during specific times is restricted by seasonal farming patterns and rainfall unpredictability. For instance, (Akudugu et al., 2019) found that boosting irrigation by 40% had the same effect on reducing poverty as supplying a pair of bullocks, rising educational levels, or increasing pay rates in ten Indian villages spread across several agro-climatic areas. The study demonstrated that irrigation's effects on reducing poverty go beyond boosting agricultural output. It raises incomes, opens up job options, and enhances rural households' quality of life.

Kumar (2003) went on to highlight the significance of irrigation in India, pointing out that it has been essential in increasing the nation's food production. India has been able to produce large food surpluses through the development of irrigation systems, which act as a buffer during dry spells. By offering a dependable source of food production even in the face of unfavorable weather, this not only guarantees food security but also stabilizes the economy.

2.5.3. The Effect of Irrigation on Ethiopia's Food Security

Numerous studies have looked into how irrigation affects food security and agricultural output in Ethiopia. In the Tigray region, (Kebede, 2018) compared the output of farms using rainfall-based and irrigation-based farming systems. Due to increased productivity brought about by post-harvest storage facilities and the capacity to use several cropping cycles (doubling or tripling crops), the study discovered that irrigation-based systems generated noticeably better yields. On the other hand, rain-fed regions experienced ongoing food shortages and were mostly dependent on subsistence agriculture. The study showed that in areas with erratic rainfall, irrigation is essential for boosting agricultural output and guaranteeing food security.

In a similar vein, (AYELE, 2022; Ayenew, 2013) discovered that irrigation greatly raised Ethiopia's income, consumption, and yields per hectare. Because households were able to grow more food and sell excess crops, they were able to increase their income and food availability, which immediately led to improved food security. Many times, farmers were able to diversify their revenue streams by using irrigation to plant cash crops, which increased their ability to withstand food insecurity.

2.5.4. Adoption of Technology and Irrigation

According to (Getacher et al., 2013), having access to dependable irrigation water can enable farmers to expand existing farming methods and embrace new technologies, which will increase production. Farmers can experiment with high-yielding crop types, sophisticated fertilizing methods, and other contemporary agricultural technology that demand a steady supply of water when irrigation is available (Tesfaye et al., 2021). Farmers can boost overall yields by increasing production per unit of land through intensified cultivation. The report also emphasized the wider socioeconomic advantages of irrigation, including the development of new jobs both on and off the farm. This raises rural incomes and enhances living standards. According to (Beyene et al., 2018), there are five main ways that having access to quality irrigation water helps rural communities' socioeconomic development:

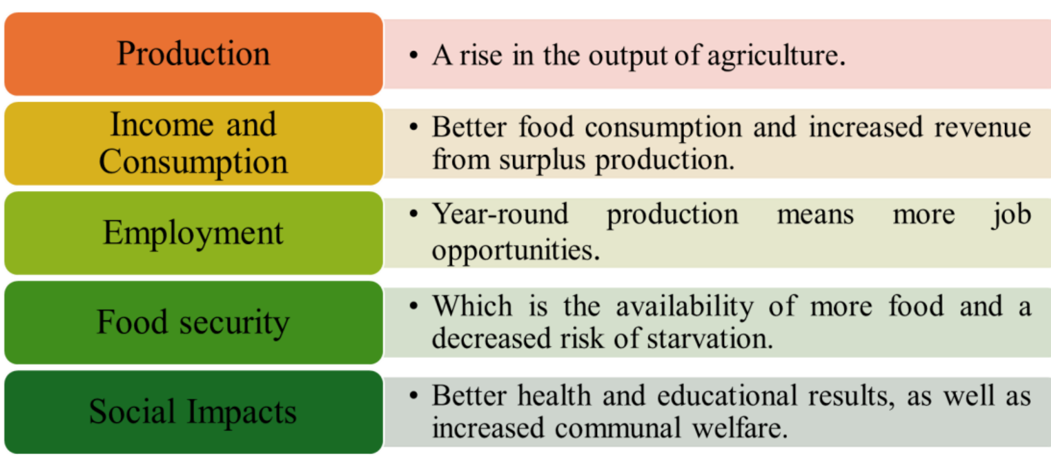

Figure 1: Ways of having access to quality irrigation water

These factors highlight how irrigation can significantly enhance both food security and general rural development.

2.5.5. Case Study: Zimbabwean Irrigation Plans

Irrigation systems can be a major source of food security for participants and the surrounding communities, according to research done on five irrigation projects in Zimbabwe. In contrast to their counterparts who relied exclusively on rain-fed agriculture, the study discovered that these irrigation projects helped stabilize food output and income, guaranteeing that farmers who took part in them never went without food (Mudima, 2002; Muhoyi & Mbonigaba, 2021; Mwadzingeni et al., 2022). In addition (Mwadzingeni et al., 2021; Zawe, 2006)came to the conclusion that irrigation systems were essential for sustaining steady food production in areas vulnerable to drought or unpredictable rainfall, and they gave farmers a steady supply of food, revenue, and jobs.

2.5.6. Kenyan Irrigation: Resolving Agricultural and Population Issues

(Nakawuka et al., 2018)emphasized Kenya's agricultural difficulties, where over the past 20 years, agricultural output has failed to keep up with the country's growing population. Irrigation became a crucial remedy in this situation. According to the report, improving agricultural production, diversifying crop types, and guaranteeing food security all depended on the expansion of irrigation infrastructure. Other studies like (Alila & Atieno, 2006; Dell'Angelo et al., 2014) also emphasized how irrigation may improve food self-sufficiency, create jobs, and increase foreign exchange profits in areas where water scarcity has historically been a barrier.

According to the report, irrigation plays a significant role in Kenya's national economy by ensuring food security, creating jobs, and generating foreign cash through higher agricultural exports.

2.5.7. Small-Scale Irrigation's Achievements

According to (Awulachew & Ayana, 2011) referenced in (Abera et al., 2019), farmers have experienced significant success with small-scale irrigation schemes. The following are some of the main advantages of smallholder irrigation: higher crop yields and farmer incomes, with notable gains for many farmers. New crops that were previously unknown or unfeasible for communal farmers were introduced. the capacity of smallholder irrigators to contribute to the national economy by producing high-value crops for both domestic and international markets (Awulachew et al., 2005). acquiring tangible assets to raise farmers' standard of living, such as better housing, farm equipment, and home appliances. Providing an alternative source of employment that helps prevent rural-to-urban migration, which often strains urban resources.

In Ethiopia, small-scale irrigation has been instrumental in diversifying agricultural production, with farmers growing fruits, vegetables, and cash crops that were previously not possible under rain-fed conditions (Tesfaye et al., 2008). Similarly, (Wondatir, 2016) found that improved technology, larger farm sizes, and better land quality significantly contributed to household food security in Southern Ethiopia, with irrigation playing a key role in enabling farmers to adopt new technologies and increase their productivity.

2.5.8. Double Cropping and High-Yielding Crops in Tigray

(Mesfin et al., 2024) conducted a study in Tigray, Ethiopia, and found that irrigated agriculture benefited some households by enabling them to engage in double cropping, a practice that is impossible in rain-fed systems. This allowed farmers to produce more food and increase their income through the cultivation of high-yielding crops. By leveraging modern irrigation technologies, farmers could intensify their agricultural practices and take full advantage of the available resources, leading to increased food production and improved food security.

The empirical studies reviewed indicate that irrigation is a vital tool for enhancing household food security, improving agricultural productivity, and boosting rural economies. Access to irrigation allows farmers to adopt modern farming practices, diversify their production, and stabilize their incomes. The ability to grow multiple crops per year, reduce the risks associated with droughts, and increase the availability of food has profound implications for food security, particularly in regions where rainfall is unreliable. However, the success of irrigation adoption is influenced by a range of factors, including access to resources, infrastructure, and education, making it crucial to support smallholders and invest in irrigation systems to maximize the benefits for food security and sustainable rural development (Kebede, 2018; Libseka et al., 2015; Mesfin et al., 2024).

2.6. Conceptual Framework of Household Food Security Determinant Factors

The conceptual framework for this study illustrates the relationship between household food security and various factors that are assumed to affect it. Food security is a multidimensional concept that depends on the availability, accessibility, utilization, and stability of food. In this framework, several independent variables are identified across four broad categories: demographic characteristics, institutional factors, socio-economic factors, and technology adoption (Coleman-Jensen et al., 2017). These variables are hypothesized to directly or indirectly influence household food security, with food security serving as the dependent variable. The framework is designed to show how these factors interact to shape the food security status of households in the study area.

2.6.1. Dependent Variable: Household Food Security

Household food security is the dependent variable in this framework. It refers to a household's ability to consistently access and consume sufficient, safe, and nutritious food. This can be measured through indicators such as food consumption patterns, nutritional intake, income levels, and the ability to purchase or grow enough food to meet household needs (Coleman-Jensen et al., 2016).

2.6.2. Independent Variables

The independent variables are factors that may influence the household's food security status. These are grouped into four categories:

2.6.2.1. Demographic Characteristics

- **Age of the Household Head**: The age of the household head can influence food security by affecting their experience, decision-making capacity, and physical ability to engage in agricultural or income-generating activities (Siraw, 2016).

- **Sex of the Household Head**: The gender of the household head may influence food security due to differences in access to resources, labor, and control over agricultural decisions. Male-headed households often have better access to resources than female-headed ones, especially in patriarchal societies (Mengesha, 2017).

- **Educational Level of the Household Head**: Higher education levels among household heads are often associated with better access to information, better management of resources, and adoption of modern agricultural technologies, all of which can positively affect food security (Maziya et al., 2017).
- **Family Labor**: The size of the household labor force can affect food security as it determines the amount of labor available for farming, income-generating activities, and other household tasks (Coleman-Jensen et al., 2016).
- **Dependency Ratio**: The dependency ratio refers to the number of dependents (children, elderly) in a household compared to the working-age members. A higher dependency ratio may strain household resources, negatively impacting food security (Jambo et al., 2021; Tefera & Cho, 2017).

2.6.2.2. Institutional Factors

- **Access to Credit**: Access to financial credit can enable households to invest in agricultural inputs, improve infrastructure, and expand income-generating activities, all of which can enhance food security (Yami, 2016).
- **Health Status**: The health of household members, particularly the head, directly impacts the ability to work, manage household resources, and ensure the well-being of the family. Poor health can reduce labor capacity and increase medical expenses, affecting food security (Maziya et al., 2017).
- **Market Distance**: The proximity to markets can influence household food security by affecting the cost and ease of access to food, agricultural inputs, and other resources.
- **Contact with Development Agents**: Regular contact with extension agents or development programs can enhance knowledge and access to improved agricultural practices, technologies, and support services that improve food security (Abegaz, 2017).
- **Food Aid**: Access to food aid, especially during crises or periods of food shortage, can temporarily alleviate food insecurity, but it does not address the root causes of long-term food insecurity (Asrat & Anteneh, 2020).

2.6.2.3. Socio-economic Factors

- **Farm Size**: The amount of land a household owns or operates is a critical factor in determining food security (Tedros, 2014). Larger farms provide more opportunities for crop production and income generation, which can support food security.

- **Livestock Size**: Livestock serve as a source of income, food (e.g., milk, meat), and draught power for agricultural activities. The number and type of livestock owned can significantly influence food security (Sinyolo et al., 2014).

- **Non-Farm Income Activities**: Households that diversify their income sources, such as engaging in off-farm employment or small businesses, tend to have more stable food security. Non-farm income can supplement agricultural earnings, especially in areas where farming is not sufficient to meet food needs (Balana et al., 2020).

2.6.2.4. Technology Adoption

- **Access to Irrigation**: Irrigation is a key technology that can help households overcome rainfall variability and increase agricultural productivity. Households with access to irrigation systems can cultivate crops throughout the year, leading to more stable food production and greater food security (Muez, 2014).

Analytical Framework

The analytical framework suggests that household food security is influenced by both direct and indirect pathways through the interaction of various independent variables, which do not operate in isolation but interact with each other. For instance, education can impact the adoption of irrigation technology or improved farming practices, which in turn affect crop yield and food availability. Additionally, the family labor force interacts with farm size and livestock size to determine the amount of production that can be achieved. Health status can influence both the ability to work and the allocation of resources towards food production or purchase, while access to credit enables households to invest in technologies such as irrigation systems, further enhancing food security.

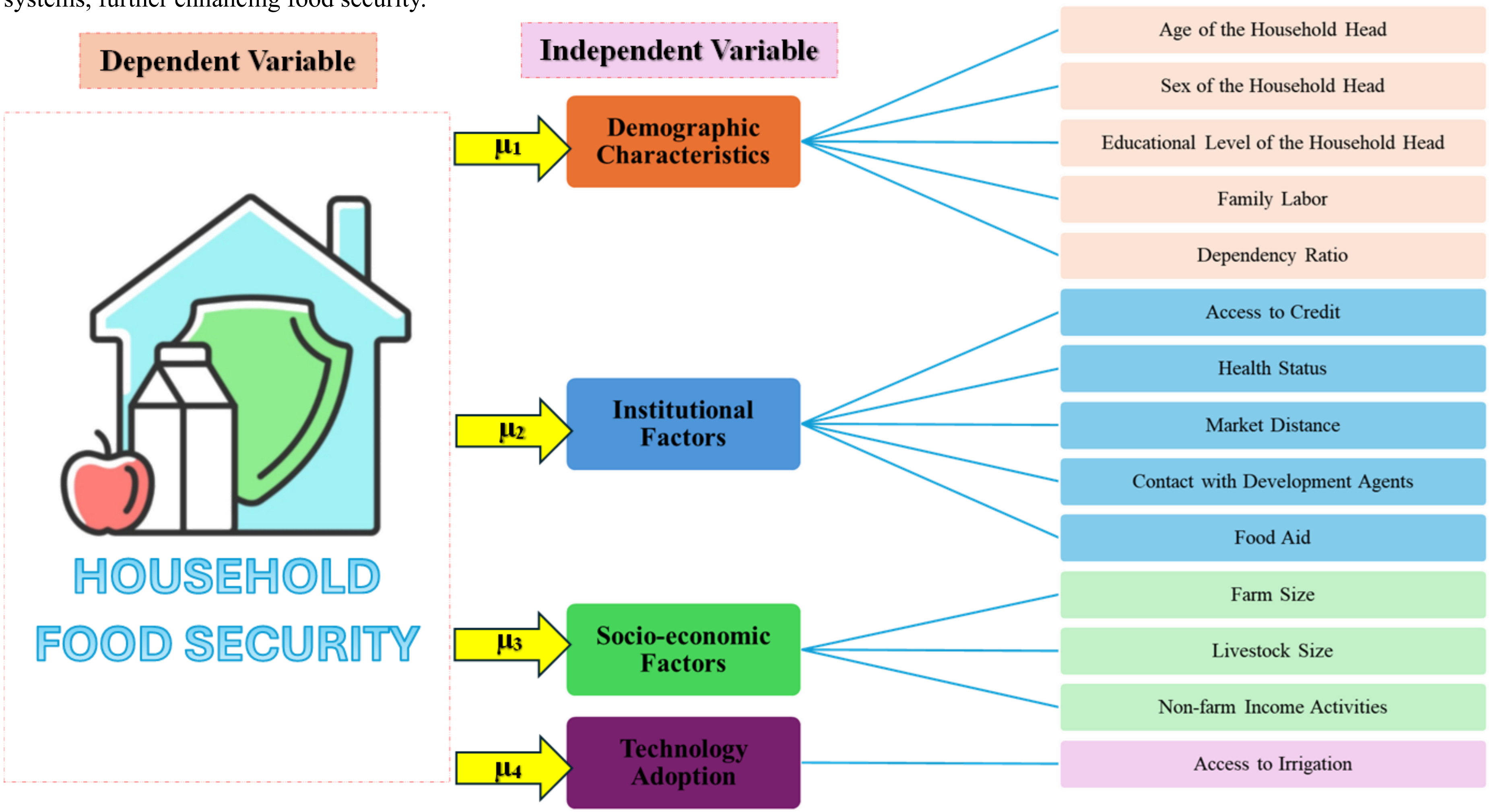

Figure 2: Conceptual Framework of Household Food Security Determinant Factors

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Method

3.1.1. Study Area Profile

The study was conducted in Ada'a "Woreda", located in the Oromia Region of Ethiopia, situated between longitudes 38°51' to 39°04' East and latitudes 8°46' to 8°59' North, covering a land area of 1,750 km², east of Addis Ababa. The "Woreda" is predominantly composed of plain highlands, with approximately 90% of the land ranging between 1,600 to 2,000 meters above sea level. Ada'a "Woreda" experiences a sub-tropical climate, with an average annual rainfall of 860 mm. The main rainy season occurs from mid-June to September, followed by a dry season, occasionally interrupted by a short rainy season in February and March. The mean annual temperature varies between 8°C and 28°C. The dominant soil type in the area is black clay (vertisol), which is fertile but prone to waterlogging in lowland areas with slopes less than 8% (Negese & Rikitu, 2024).

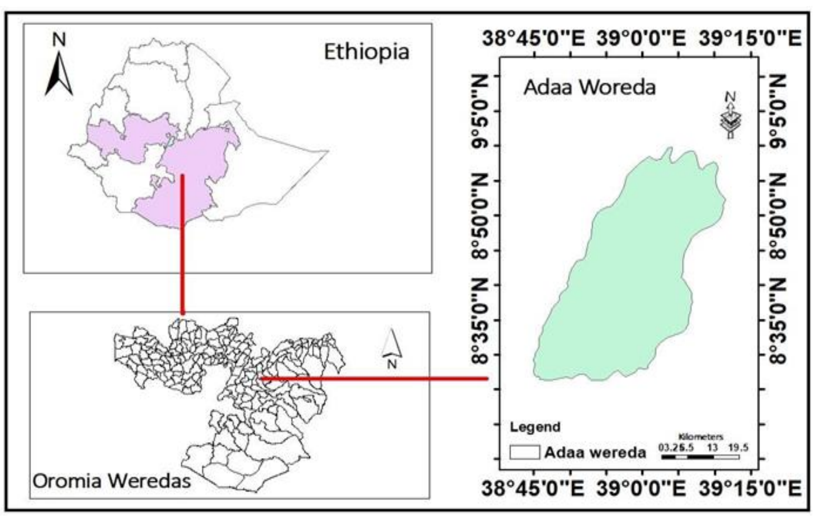

Figure 3: Ada'a "Woreda" location map

The farming system in Ada'a "Woreda" is a mixed crop-livestock system, with major crops including teff, wheat (primarily bread variety), and pulses. Chickpea is the main pulse crop and serves as part of a crop rotation with wheat and teff. Average household farm sizes range from 1 to 2.5 hectares, and oxen power is used for most farming operations.

3.1.2. Sample Size

The total population of Ada'a "Woreda" is 97,976, with 15,310 of them engaged in farming activities. The study focused on two specific ""kebele"s" within Ada'a "Woreda": "Quftu" and "Godino". In "Quftu" "kebele", there are 165 male farmers and 10 female farmers, while in "Godino" "kebele", there are 862 male farmers and 55 female farmers.

Based on Green's (1991) sample size calculation formula, n ≥ 50 + 8m (where n is the sample size and m is the number of independent variables), the required sample size for the study was calculated. For this research, a total of 200 households were selected, with 100 households using irrigation and 100 households not using irrigation. This larger sample size was chosen to minimize sampling error and provide more reliable data for analysis. The sample size was distributed proportionally between the two ""kebele"s" to ensure representation from both irrigation users and non-users.

$$n \geq 50 + 8m \text{...Equation [1]}$$

$Where$:

- $n\ is\ the\ sample\ size,$
- $m\ is\ the\ number\ of\ independent\ variables.$

For this study, the number of independent variables was assumed to be 10 (based on factors such as demographic, institutional, and socio-economic variables). Thus, the sample size can be calculated as follows:

$$n \geq 50 + (8 \times 10) = 50 + 80 = 130$$

However, to ensure more robustness and reduce sample error, a larger sample size was chosen. Therefore, the study opted for a sample size of 200 households, with 100 households from the irrigation user group and 100 from the non-user group.

To determine the number of households to sample from each stratum (irrigation users and non-users) in the two ""kebele"s", proportional allocation was used. The total number of farmers in each "kebele" (based on gender and irrigation access) was used to calculate the sample proportion.

3.1.3. Sampling Techniques

A three-stage sampling method was used to select participants for this study:

- **First Stage**: The study "Woreda", Ada'a, was purposively selected based on the presence of small-scale irrigation schemes.
- **Second Stage**: Two "kebele's", "Quftu" and "Godino", were randomly selected from the "kebele's" within Ada'a "Woreda" that have small-scale irrigation schemes. These two "kebele's" were chosen because of their accessibility to irrigation and the availability of irrigation users and non-users.
- **Third Stage**: Households in the selected "kebele's" were stratified into two groups: irrigation users and non-users. From each stratum, households were randomly selected using a simple random sampling technique.

A total of 200 households were sampled, with 100 households from the irrigation user group and 100 from the non-user group. Proportional allocation was used to determine the number of households to sample from each stratum in the two "kebele's". The sample was then selected using systematic random sampling techniques to ensure that the data was representative and that every household in the selected strata had an equal chance of being included in the study.

To determine respective samples from the two "kebele's" for each stratum, sampling proportion to population was used. Finally, representative sample for each stratum was selected through systematic random sampling techniques. The following formula were used to determine the sample size of each stratum in the two "kebele's"

$$Pi = \frac{ni}{N} \quad \text{.................................... Equation [2]}$$

$$Where: Pi = \ proportion\ of\ population\ included\ in\ stratum\ i,$$

$$ni = \ the\ number\ of\ elements$$

$$N = \ the\ total\ number\ of\ the\ population$$

$$Pi = \frac{200}{2165} = 0.0923$$

Table 1 below shows the respective population of each stratum for the “kebele’s” with Respective proportionate sample size for each of the “kebele” had drawn using this method.

Table 1: Number of sample households for Tow Strata from each “kebele”

Sample “kebele”	**Irrigation user**		**Irrigation nonusers**		**Total Sample**
	Total	Sample	Total	Sample	
“Quftu” “kebele”	180	39	188	48	87
Godina “kebele”	922	56	875	57	113
Total	1102	100	1063	100	**200**

3.1.4. Method of Data Collection

Primary data were collected through various data collection instruments such as household survey, Focus Group Discussion and Key Informants.

3.1.4.1. Household survey

To generate quantitative and qualitative information at household level, household survey was undertaken by using structured questionnaire. The household survey covered personal data, household resources, production, food consumption and income, issues related to irrigation practice, and food security. The questionnaires were first prepare in English and later translated into the local language (Oromifa), so that the respondents can easily understand the questions.

3.1.4.2. Focus Group Discussions

The focus group discussions (FGD) members composed of both men and women those was not involve in the individual interviews. One focus group discussion at each study areas was conduct and each focus group comprise six to eight individuals. The output of the discussion were used as a guide the design of household questionnaire and to get additional supporting qualitative evidence of the current situation of household food security and challenges that farmers have been faced irrigation activity.

3.1.4.3. Key Informant Interview

The primary data collected from sample farmers need to be further enriched by additional information gathered through key informants. Thus, intensive interview has been conducted with key informants. Thus, two experts from two different departments, such as irrigation and Productive Safety Net Program expert, one development agents (DA) from each two “kebele’s”, and one committee member of irrigation water user's association from each “kebele’s” were included as a key informant interview.

3.1.5. Research Design

The study evaluates the effect of small-scale irrigation on household food security in Ada'a “Woreda” utilizing a cross-sectional methodology and a descriptive and comparative research design. The design's descriptive component is to give a thorough explanation of the current situation of household food security as well as the variables that affect it, such as farm size, irrigation use, and other socioeconomic traits. The study aims to paint a complete picture of how small-scale irrigation affects food security in the area by outlining the current circumstances.

Comparing two different groups of households that utilize irrigation and those that don't is the main goal of the comparative component. The study is able to draw attention to the disparities in the two groups' levels of food security, income, and agricultural output thanks to this comparison. This methodology works well with the cross-sectional technique since it allows the study to look at both groups at one particular moment in time, giving a glimpse of how the adoption of irrigation affects food security. The study's use of both descriptive and comparative approaches guarantees that it not only records the existing state of affairs but also makes insightful comparisons between the various household groups.

3.1.6. Scale Reliability and Validity

Cronbach's alpha was used to determine the reliability of the questioner data by determining how closely connected a collection of items are. The reliability of many Likert items from a survey/questionnaire that creates a scale was tested. The data consistency strength will be good if Cronbach's alpha is 0.70 and above, better if Cronbach's alpha is 0.80 and above, and 0.90 results in the best consistency (Forero, 2024).

3.1.7. Data analysis

Both descriptive and inferential statistical techniques will be used in the data analysis for this project in order to thoroughly assess the connection between family food security and the use of small-scale irrigation.

Descriptive statistics: An overview of the sample population and important factors will be provided via descriptive statistics. For demographic and socioeconomic data including age, gender, household size, farm size, animal ownership, and irrigation use, this will entail computing frequencies, percentages, means, and standard deviations. For instance, irrigation users' and non-users' average farm sizes and income levels will be contrasted. A comprehensive picture of the traits of the homes in the research region and the distribution of food security levels will be provided with the aid of these studies.

Inferential Statistics: Inferential statistics will be used to test hypotheses and investigate the influence of different factors on household food security in order to investigate relationships and make population-level conclusions.

Chi-square Test: The relationship between category variables will be investigated using Chi-square test (Rana & Singhal, 2015). For example, it will determine whether the use of irrigation and the degree of food security (i.e., food secure versus food insecure) are significantly correlated. This will assist in determining whether or not those who utilize irrigation have a higher likelihood of being food secure than those who do not.

ANOVA and the t-test: will be used to compare group means (Brady et al., 2015). The mean values of continuous variables (such as income, crop yield, and food security score) between irrigation users and non-users will be compared using a T-test. If there are several groups or categories to compare, like different irrigation use levels or different geographic locations within the study area, an ANOVA will be used. If irrigation adoption results in appreciable increases in income, productivity, or food security, this analysis will show it.

Multiple Regression Analysis: The impact of several independent variables (including education, farm size, animal ownership, irrigation access, and credit) on family food security will be modeled using multiple regression. This approach will make it possible to comprehend how many factors interact to affect the results of food security and whether, after adjusting for other variables, irrigation use is a major predictor of increased food security.

Logistic Regression: In cases where the outcome variable is binary (e.g., food security status categorized as "secure" or "insecure"), logistic regression will be used to estimate the probability of food being secure based on independent variables. This will help identify the likelihood of food security in households that use irrigation compared to those that do not.

Statistical Package for the Social Sciences (SPSS) version 32 was used to perform the analysis. By enabling in-depth analysis and interpretation of the data, these statistical tools will guarantee solid and trustworthy outcomes. The analysis's conclusions will shed light on the ways in which a number of variables, most notably the use of irrigation, affect household food security and will guide policy suggestions meant to enhance food security results in rural regions.

3.1.8. Methods Used to Assess Food Security

Status of Sample Households Household Food insecurity Access Scale Food and Nutrition Technical Assistance (FANTA)

Household food insecurity access scale generic questions (in appendix A) that have been used to distinguish the food security from food insecure households Food and Nutrition Technical Assistance (FANTA) (Swindale & Bilinsky, 2006). The HFIAS consists of two types of related questions. The first question type is called an occurrence question. There are nine occurrence questions that ask whether a specific condition associated with the experience of food insecurity ever occurred during the previous Four weeks (30 days). Each severity question is followed by a frequency-of-occurrence question, which asks how often a reported condition occurred during the previous four weeks. Each occurrence question consists of the stem (timeframe for recall), the body of the question (refers to a specific behavior or attitude), and two response options (0 = no, 1 = yes). Each HFIAS frequency-of-occurrence question asks the respondent how often the condition reported in the previous occurrence question happened in the previous four weeks. There are three response options representing a range of frequencies (1 = rarely, 2 = sometimes, 3 = often) (FANTA, 2007).

3.1.9. Household Dietary Diversity

Dietary diversity is a qualitative measure of food consumption that reflects household access to a variety of foods (FAO 2011). Data on household dietary diversity was collected using 24 hours of recall dietary intake. The information collected on dietary consumption allowed to calculate a dietary diversity score, defined as the number of different food groups consumed by household members over 24 hours. A list of meals, all food items and beverages consume in the last 24 hours was recorded. The twelve food groups, recommended by (FAO, 2006) were used to assess household dietary diversity scores (HDDS). The consumed foods were allocated to the following food groups as composed : Cereals (1) White tubers and roots (2), Vegetables(3), Fruits (4), Meat (5), Eggs (6), Fish and other seafood(7), Pulse/ Legumes(8), Milk and milk products (9), Oils and fats (10), Sugar or Haney (11), Spices, condiments and beverages (12). Yes and No categories were used. Yes was given a score of one (1) to each food group if the household consumed at least one food item within 24 hours. No was given zero (0) score for a particular food group if the household did not consume any food item from that food group. Finally the scores were counted from each food group and household dietary diversity scores (HDDS) were calculated based on the FAO guidelines for measuring household dietary diversity. A HDDS of less than 3 food groups was regarded as low household dietary diversity. Four to five food groups was regarded as medium dietary diversity and ≥6 food groups was regarded as high dietary diversity.

3.1.10. Food Consumption Score

The Food Consumption Score (FCS), foods were regrouped into eight standard food groups (Table 2 below). The Food Consumption Score (FCS), a tool developed by WFP, is commonly used as a proxy indicator for access to food. It is a weighted score based on food frequency and the nutritional importance of food groups consumed. Data was collected on the number of days in the last 7 days a household ate specific food items (Fite et al., 2022).

Table 2: Food Items, Food Groups and Weights for Calculation of the FCS

Food items	Food group	weight
Sorghum, Rice, Bread	Staples	2
Roots and Tubers:		
Pulses/Beans/ Nuts Pulses	Pulses	3
Milk/ Milk Products Milk	Milk	4
Animal Proteins: Fish, Meat, Eggs	Meat and fish	4
Vegetables (including green, leafy vegetables)	Vegetables	1
Sugar/ Honey	Sugar	0.5
Fruits	Fruits	1
Oil and Fats	Oil	0.5

Source: World Food Program (2007)

The Household food consumption score (FCS) was calculated by multiplying each food group frequency by each food group weight, and then summing these scores into one composite score. The weighting of food groups has been determined by (WFP, 2007) according to the nutrition density of the food group. In line with the explanations given above, the most basic estimation equation for the Food Consumption Score used for this study is:

$$FCS = a \times f(staple) + \beta \times f(pulse) + \gamma \times f(vegetables) + \gamma \times f(fruit) + \delta \times f(animal) + \varepsilon \times f(sugar) + \delta \times f(dai\,ry) + \varepsilon \times f(oil)$$

$Where\ FCS\ =\ food\ consumption\ score,$

$ff\ =\ frequencies\ of\ food\ consumption$
$=\ number\ of\ days\ for\ which\ each\ food\ group\ was\ consumed\ during\ the\ past\ 7\ days,$

$$a, \beta, \gamma, \delta\ and\ \varepsilon\ =\ weight/nutritional\ value\ of\ each\ food\ group.$$

According to (WFP, 2007; IFPRI, 2008), households with poor food consumption have a food score of 0-28, households with borderline food consumption have a food score of 28.5- 42 and households with adequate food consumption have a food score of above 42 which is viewed as acceptable.

3.1.11. Household Coping Strategies Index

The coping strategy index is a group of questions that are asked in a household to find out how they manage to cope with the shortage of consuming enough food. The coping strategy index is estimated by measuring behavior, such as the things individual household do when they cannot acquire sufficient food (Maxwell & Slater, 2003)The coping strategies are often identified by the person who is responsible for preparing or consuming the food. Thus the coping strategies observed are usually linked to food practices in the short-term. Several studies have used the coping strategy index to measure the extent of household food insecurity. The most common short-term coping strategies employed by households are: eating foods that are less preferred, reducing the quality of food taken, limiting portion size, borrowing money to buy food and skipping meals.

3.1.12. Ethical consideration

Before the study began, each respondent was told of the goal of the research and how the information acquired will be utilized. Respondents were informed about the goal of the research project to secure their full consent to utilize the information obtained. The responders were also made aware that the information gathered will be managed with strict confidentiality.

CHAPTER FOUR

RESULT AND DISCUSSIONS

4.1. Results

4.1.1. Description of demographics Characteristic

4.1.1.1. Gender of respondents

Gender**:** As Figure 4 illustrates, the data reveals that 78% of farmers are men and 23% are women. This significant gender gap emphasizes how males are more likely than women to work in farming in the research area. Men typically take the lead in farming operations and decision-making, which is probably a result of cultural norms and established gender roles. Despite being underrepresented, women are essential to resource management and food security in the home. Obstacles including limited access to capital, land, and agricultural training may be the cause of the low involvement of female farmers. Improving agricultural production and guaranteeing inclusive development depend on addressing these issues through gender-sensitive interventions and fair resource distribution (Ogato et al., 2009; Ragasa, 2014).

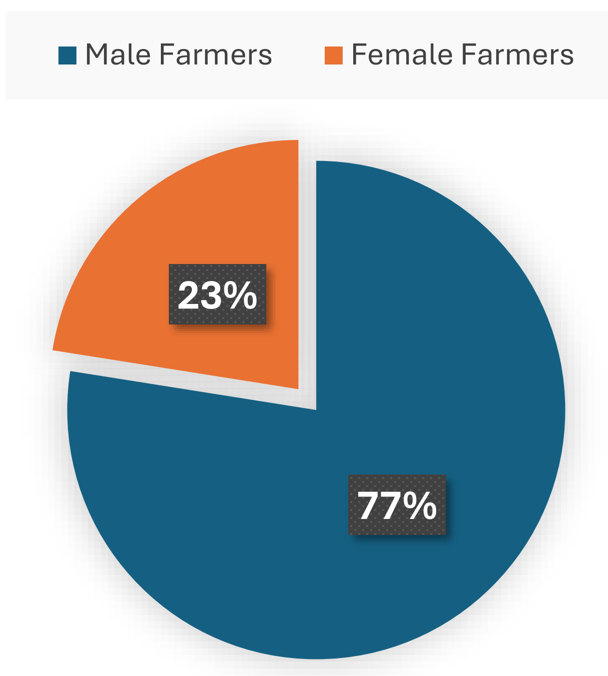

Figure 4: Gender of Demographic population

4.1.1.2. Educational status of respondents

Educational status: The majority of people in the research area have a low level of formal education, according to the respondents' educational status shown in Figure 5. The largest percentage, 44%, have completed junior-level schooling (grades 5–8), with 29% having finished elementary school (grades 1–4). The problem of illiteracy in the area is further highlighted by the fact that 26% of respondents cannot read or write.

Just 1% of those surveyed have finished high school (grades 9–12), and just 1% have a diploma or other advanced degree. This suggests a low level of advanced educational attainment, which may have an impact on the uptake of contemporary agricultural technology and practices that call for a particular degree of technical knowledge and literacy, like irrigation systems.

The results indicate that in order to empower the community and increase their involvement in sustainable development programs, efforts must be made to improve education, especially literacy and access to higher education (Council et al., 2009).

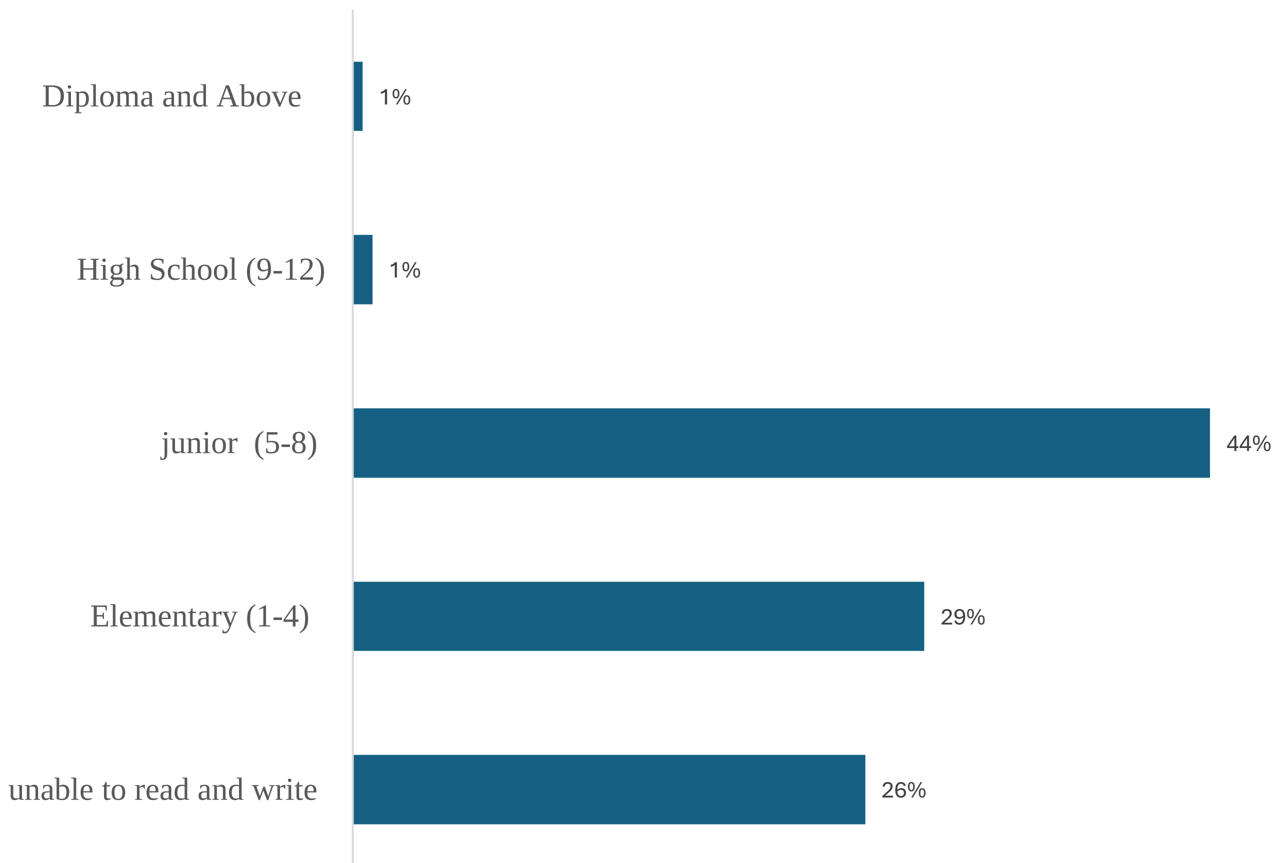

Figure 5: Educational status of respondents

4.1.1.3. Age of respondents

According to the data, the majority of responders (54%) are between the ages of 51 and 60, suggesting that the farming labor is mature and experienced. The cluster of people aged 41 to 50 years is the second-largest group (28%), highlighting the prevalence of middle-aged farmers who are actively engaged in farming. Younger people between the ages of 30 and 40 make up only 3% of the population, and older farmers 71 and over make up an even lower fraction (2%) of the population Figure 6. This suggests that the farming population may be getting older, which could eventually provide sustainability issues if younger generations are not sufficiently incorporated into farming methods. The distribution of ages highlights the necessity of focused agricultural interventions, such as training and technology, that support middle-aged farmers' needs and abilities while promoting youth involvement to maintain farming operations (Guo et al., 2015).

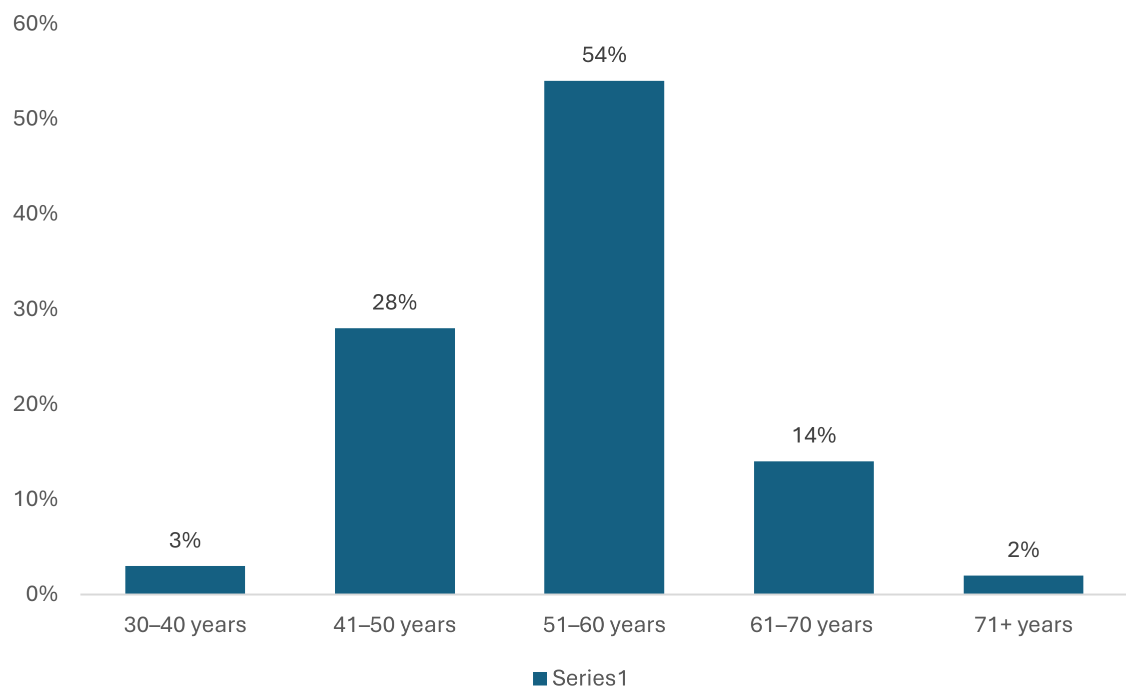

Figure 6:Age of respondents

4.1.1.4. Employment Status of Respondents

The majority of respondents, 89%, are self-employed and mostly involved in their own farming operations, according to the job status analysis Figure 7. In the research area, where the majority of households depend on their land and resources for a living, this emphasizes the prevalence of independent agricultural enterprises. 12% of respondents, however, are employed by others, either as laborers or in other non-farm capacities. This lower percentage suggests that although some households might augment their earnings through outside work, self-driven farming remains the community's main economic activity. Interventions targeted at increasing self-employed farmers' productivity and profitability might greatly raise household incomes and the region's overall food security, according to this distribution (Davis et al., 2009). Additionally, it emphasizes how crucial it is to help smallholder farmers reach their full potential by providing them with training, technology, and credit (Wang et al., 2020).

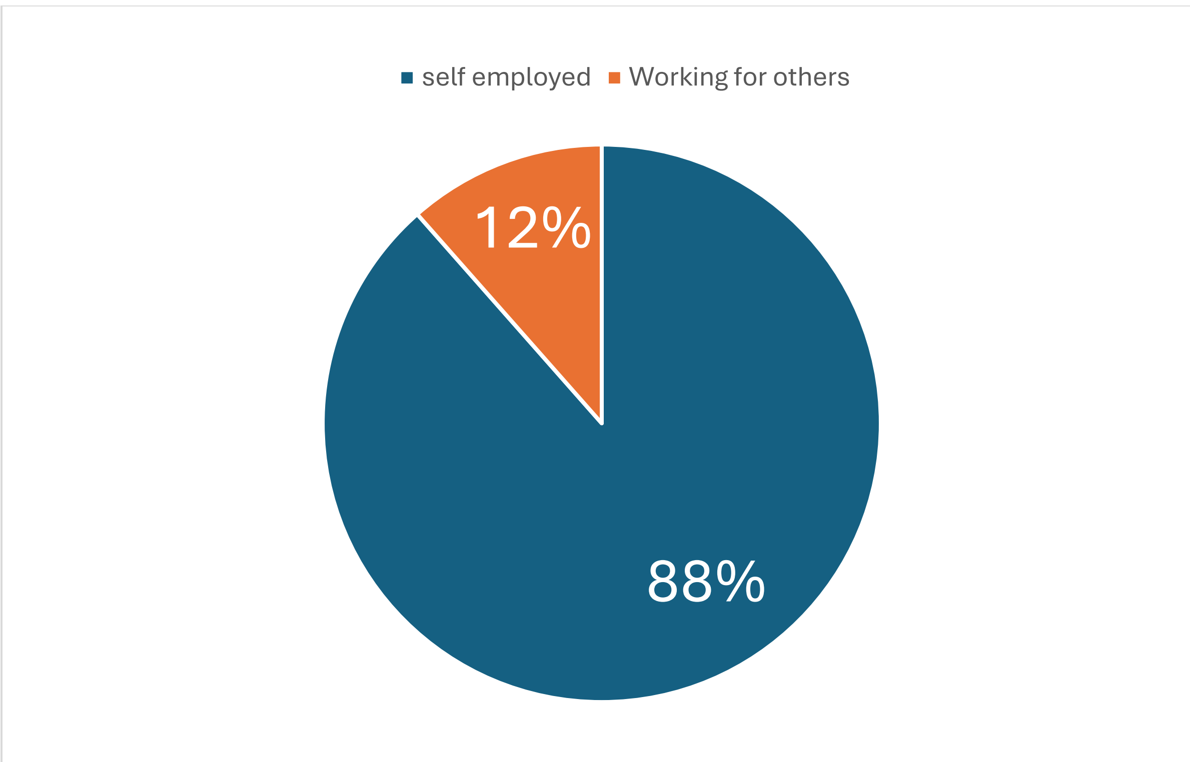

Figure 7: Employment Status of Respondents

4.1.2. Description of household characteristics

4.1.2.1. Household size

With 100 families in each of the two groups irrigation users and non-users the study offers information on the sizes of the 200 households in the sample. 960 people make up the total number of household members in these 200 houses, resulting in an average household size of five adults. With one person living in the smallest household and seven in the largest, this number shows the average size of a household. The study discovered that households with access to irrigation typically have smaller household sizes when comparing the average household sizes of irrigation users and non-users. In particular, the average home size for irrigation users is 4.6 people, but the average household size for non-users is somewhat higher at 5. The study compared the means of household sizes in the two groups using statistical analysis. At a 5% probability level ($p < 0.05$), the results revealed a statistically significant difference, indicating that the difference in average household sizes between users and non-users is unlikely to have happened by accident. Although the precise causes of this discrepancy may be investigated further in the study, this conclusion suggests that smaller household sizes are linked to irrigation availability (Olayemi, 2012). Economic reasons, family planning practices, or resource availability are examples of potential factors that could affect the makeup of households in places with irrigation access. (Bashir & Schilizzi, 2013)

4.1.2.2. Sources of Income to Sample Households

Revenue from Crop Production: The survey's findings show that households that irrigate and those that do not have a significant difference in their revenue from crop production. The average yearly income from cash crop production for irrigating households was 18,567.15 ETB, which was substantially more than the 1,085.06 ETB earned by non-irrigating households. This significant disparity emphasizes how important irrigation is to raising agricultural output. More constant crop yields made possible by irrigation make agricultural households less susceptible to seasonal fluctuations and increase crop production profits (Adem et al., 2018).

(Rahman & Mishra, 2020): Irrigating families once more did better than non-irrigating households in terms of non-farm income. Irrigating households' average yearly non-farm income was 7,850.88 ETB, but non-irrigating households' average was 4,583.99 ETB. This suggests that households with irrigation access not only enjoy higher agricultural incomes but also more financial diversification, maybe as a result of other economic endeavors enabled by their farms' increased productivity. Having access to irrigation could increase these households' non-farm incomes overall by releasing labor and opening up opportunities for off-farm employment (Rahman & Mishra, 2020).

Total Household Income: The economic benefit of irrigation is further demonstrated by the total mean annual income, which combines incomes from both farms and non-farm sources.

The total income of irrigating families was 21,380.34 ETB, whereas that of non-irrigating households was 16,653.44 ETB. This disparity of 4,726.90 ETB demonstrates how irrigation improves agricultural revenue while also benefiting the household's overall financial health. Irrigation raises household income and enhances financial stability by boosting farm incomes and creating chances for non-farm income (Coleman-Jensen et al., 2014).

Table 3: Sources of Income: Irrigating Vs non-Irrigating Households

Income Category	**Irrigating Households**	**Non-Irrigating Households**
Income from Crop Production	18,567.15 ETB	1,085.06 ETB
Non-Farm Income	7,850.88 ETB	4,583.99 ETB
Total Household Income	21,380.34 ETB	16,653.44 ETB

According to the survey's findings, one of the best methods for raising household earnings is irrigation. Increases in agricultural production and non-farm activities boost the income of irrigating households, which raises their overall income. Irrigation is a crucial technology for economic development because of its capacity to stabilize agricultural output and generate new economic opportunities through labor diversification (Nhundu & Mushunje, 2012). This demonstrates irrigation's potential as an effective and long-lasting instrument for reducing poverty and raising living standards in rural areas (Ayele et al., 2013).

4.1.2.3. Source of irrigation water

The survey results show a heavy dependence on rivers, with springs and ponds serving as supplementary or alternative sources, particularly for farmers with lands farther from rivers.

Table 4: Source of irrigation water

Source of Irrigation Water	Frequency (N = 100)	Percent	Discussion
River Diversion	65	65%	The majority of irrigation users (65%) rely on rivers for irrigation water, indicating that rivers are the primary and most accessible water source for these farmers. The dependence on river diversion suggests that rivers play a central role in the irrigation systems of the surveyed households (Paudel et al., 2016).
Spring	25	25%	A smaller group (25%) of farmers use springs for irrigation. These are typically located in areas farther from rivers, and farmers with land in such locations use springs as an alternative water source to support their irrigation needs (Malakar et al., 2019).
Pond	10	10%	Only 10% of respondents use ponds for irrigation water. These ponds are usually constructed by individual farmers near their farmlands, serving as a supplementary or alternative source of water, especially in cases where access to rivers or springs is limited (Leng et al., 2017; Zaman et al., 2018).

4.1.2.4. Organizational Support for Irrigation Management

The LIVES project was crucial in helping farmers in the study area improve their irrigation techniques, according to data from key informants. In addition to facilitating the availability of enhanced irrigation technologies, the initiative offered training on irrigation water management. The goal of this assistance was to improve smallholder farmers' irrigation capacities so they could better manage water resources and boost agricultural output.

Level of Support Received: 31% of respondents said that LIVES provided them with support. Thirty-one percent of respondents who used small-scale irrigation said the LIVES project helped them. This suggests that although the project has had an impact, a greater percentage of smallholders in the research region would not have benefited from this particular intervention. This shows a considerable but not overwhelming reach (Gebremedhin et al., 2018).

Support Types Received:

- 6% Experiencing Better Irrigation Technologies: Only 6% of the respondents were directly given access to better irrigation technologies. This suggests that just a small number of farmers will receive the actual tools or equipment, suggesting that the project may have limited funding or concentrate on technology distribution.
- 57% Exposure to Better Irrigation Techniques: A higher percentage of farmers (57%) experienced better irrigation techniques. These can include methods for timing irrigation, using water resources more effectively, or managing crops as efficiently as possible. This implies that a sizable percentage of the farmers profited from information exchange and hands-on instruction on improved irrigation techniques.
- 35% Gained from Applicable Technology Demonstration: About 35% of the participants reported that the demonstration of applicable technologies was beneficial. This probably included field-based demonstrations so farmers could observe how new technologies, such water-saving devices or drip irrigation, are used in actual situations.

Results and Effects of the Support: According to the survey results, farmers' production and food security were positively impacted by the LIVES project's assistance: Improvement in Household Food Security (12.5%): Twelve percent of respondents said their household's food security has improved as a result of project assistance. This may be explained by improved irrigation techniques that boost crop yields and, in turn, enhance household food supply. The comparatively low percentage, however, indicates that although some households saw gains in food security, many others would not have noticed any appreciable change in this regard.

Increase in Crop Productivity (87.5%): Following project assistance, a significantly higher percentage of households (87.5%) reported an increase in crop productivity. This is a noteworthy accomplishment, suggesting that the project's main advantage was a rise in agricultural productivity brought about by better irrigation techniques and technologies. Better crop yields were achieved through the employment of improved irrigation techniques, sometimes in conjunction with expanded water availability made possible by new technologies. This could directly help households financially.

Generally, Smallholder farmers in the study area saw a discernible improvement in their irrigation management techniques as a result of the LIVES project's assistance, especially in the areas of training, better irrigation techniques, and technology demonstration. The project's efficacy in raising agricultural productivity through improved irrigation management is demonstrated by the considerable rise in crop yield (87.5%), even though its direct impact on family food security was less pronounced (12.5%). The findings highlight how crucial technology demonstration and training are to enhance smallholder farmers' farming success. To help smallholders further maximize the advantages of better irrigation systems, there might be chances to broaden the project's scope, especially in terms of direct technology provision.

4.1.2.5. Irrigation utilization

The results show that irrigation users and non-users have significantly different levels of food security (Darko et al., 2016; Domènech, 2015). Of those who used irrigation, 23% were food insecure and 62.8% were food secure. Conversely, a significantly larger 77% of non-users were food insecure, compared to just 38.2% who were food secure. At the 1% significance level, the t-value analysis verifies a statistically significant difference in irrigation access between households who are food secure and those that are not. These findings show that food security is more likely to exist in households with irrigation than in those without.

4.1.2.6. Household Health Status

According to the results on household health status, 21.6% of the tested homes reported being ill, while 79.4% claimed they had no health-related issues at the moment. A distinct pattern becomes apparent when looking at the connection between food security and health condition. Just 14.4% of food-secure households reported being ill, compared to 85.6% who said they felt healthy. In comparison, only 17.3% of homes experiencing food insecurity were free from disease, while 82.7% reported having health issues. These findings demonstrate a robust relationship between food security and health, indicating that households with food security are less likely to experience health problems. Families experiencing food insecurity may become even more vulnerable as a result of poor health, which limits their ability to work and make money (Jebena et al., 2017; Mohamed, 2017). This cycle suggests that enhancing food security may benefit household health and general well-being more broadly.

4.1.2.7. Contact with Extension Agent

Food-secure and food-insecure households connect with extension agents at different frequencies, according to the data on contact. Compared to 28.6% of food-insecure households, 32.3% of food-secure households interacted with agricultural development agents more than twice per month. Additionally, a slightly higher percentage of food-secure households 52.7%—than food-insecure households 51.4%—reported contacting agents twice a month. However, just one contract was made by 15% of food-secure households and 20% of food-insecure households.

Food-insecure families had a slightly greater mean contact frequency (1.98 times per month) than food-secure households (1.95 times per month). According to these findings, there was no discernible variation in the average frequency of contact between the two groups, indicating a comparatively comparable degree of interaction with extension agents (Gebremariam et al., 2021). Nonetheless, the marginally greater percentage of frequent contact among households experiencing food insecurity would suggest the possible significance of consistent interaction with extension services in enhancing food security results (Belay & Abebaw, 2004; Davis et al., 2010).

4.1.2.8. Dependency Ratio

The dependency ratio provides a measure of the economic burden on active household members by comparing the number of economically active individuals (aged 14–64) to economically dependent members (aged 0–14 and above 64). For the sampled households, the dependency ratio was estimated at 0.83, indicating that every 100 economically active persons supported 83 dependent individuals. This ratio reflects the extent of economic responsibility borne by the active members of a household.

The analysis further revealed significant differences in the dependency ratios between food-secure and food-insecure households. Food-secure households had a mean dependency ratio of 0.61 with a standard deviation of 0.31, whereas food-insecure households had a notably higher mean dependency ratio of 1.04 with a standard deviation of 0.64. This highlights that food-insecure households face a greater economic burden, as each economically active member supports more dependents, which could limit their ability to allocate resources effectively for food and other needs (Belachew et al., 2012; Bogale & Shimelis, 2009).

The results suggest that food-secure households tend to have a lower dependency ratio, which may contribute to their ability to achieve better economic stability and ensure sufficient food access (Goshme, 2019). In contrast, the higher dependency ratio among food-insecure households could strain their resources, making it more challenging to meet basic needs and maintain economic resilience (Asogwa & Umeh, 2012).

4.1.3. Comparative analysis: household food security for categorical variables

By contrasting groups that are food secure and those who are not, the survey examines the variables that affect household food security. A number of variables, such as income, health, education, and resource accessibility, affect food security. The poll used chi-square tests to examine data from 200 participants in order to pinpoint important factors that distinguish homes that are food secure from those that are not. Statistical significance is assessed using chi-square values, p-values, confidence intervals (CI), and alpha levels. 95% confidence intervals were computed for each variable, and statistical significance was established using an alpha value of 0.05, as shown in Table 5.

4.1.3.1. Significant variables

Sex of Respondent (X_2 = 9.666, p < 0.001, CI: 95%, α = 0.05) is a significant variable. There is a substantial correlation between food security and the respondent's sex. According to the data, men make up a larger share of food-secure households (94.6%) than food-insecure households (84.6%). The statistical significance is confirmed by the chi-square value of 9.666 and p-value less than 0.001, and this conclusion is further supported by the 95% confidence interval. According to research, households headed by men typically have more access to financial resources, job prospects, and educational chances all of which improve food security

(Gebre et al., 2021). Traditional gender norms and the availability of resources that are more advantageous to men in many rural areas may be the reasons for the greater proportion of men living in food-secure households.

Respondent's Education Level (X_2 = 43.862, $p < 0.001$, CI: 95%, $\alpha = 0.05$): Food security is significantly influenced by one's level of education. According to the poll, the percentage of respondents without a formal education is larger in food-insecure households (38.9%) than in food-secure households (10.2%). This association is supported by a p-value of less than 0.001 and a chi-square value of 43.862. Higher educated households typically manage their resources more skillfully, have better access to work opportunities, and are more knowledgeable about nutrition. Because education is associated with greater wages and better decision-making, which improves food availability and access, a study by (Bogale & Shimelis, 2009) highlighted that education is a crucial driver of household food security.

Access to Irrigation: (X_2 = 25.725, $p < 0.001$, CI: 95%, $\alpha = 0.05$): In regions where rainfed agriculture is unreliable, having access to irrigation is essential to guaranteeing food security. According to the report, only 23% of households experiencing food insecurity have access to irrigation, while 62.8% of households experiencing food security do. With a p-value of less than 0.001 and a chi-square value of 25.725, this difference is very significant. Consistent agricultural output is supported by irrigation, which lessens dependency on erratic rainfall patterns (Tesfaye et al., 2008). This relationship has been supported by literature; for example, research by Makhura et al. (2001) discovered that having access to irrigation greatly enhances food security by lowering the probability of crop failure, boosting agricultural production, and supplying a more consistent food supply (Senbeta, 2023).

Engagement in Activities Other Than Farming ($X2$ = 6.074, $p < 0.05$, CI: 95%, $\alpha = 0.05$): Petty commerce, self-employment, and labor hire are examples of non-farm activities that significantly improve food security. Compared to 33.5% of food-insecure households, 51.3% of food-secure households participate in non-farm activities, according to the data. This difference appears to be statistically significant based on the chi-square value of 6.074 and the p-value of less than 0.05. By diversifying their sources of income and food, households are less vulnerable to agricultural shocks thanks to the additional revenue generated by non-farm activities. This conclusion is supported by literature(Tesfaye & Nayak, 2022) claim that non-farm income has a significant role in determining food security because it increases purchasing power and provides a buffer against agricultural hazards .

Food Aid Receipt ($X_2 = 8.677$, $p < 0.001$, CI: 95%, $\alpha = 0.05$,: Food instability and food aid are strongly related. According to the poll, compared to food-secure households (5.3%), a substantially greater proportion of food-insecure households (14.7%) receive food help. The substantial correlation between food aid and food insecurity is confirmed by the chi-square value of 8.677 and a p-value of less than 0.001. It is typically difficult for households receiving food assistance to meet their own food needs, which is a sign of food insecurity. Food help is a critical solution to household food insecurity, offering temporary respite to homes facing food shortages, per a study by (Gilligan & Hoddinott, 2007)

4.1.3.2. Insignificant Variables

Sick Household Members ($X2 = 0.022$, $p > 0.05$, CI: 95%, $\alpha = 0.05$): Food security is not greatly impacted by the presence of ill household members. The chi-square value of 0.022 and a p-value greater than 0.05 suggest little statistical significance, despite the fact that the percentage of sick household members varies between food-secure households (14.4%) and food-insecure households (17.3%). Although family members' capacity to work or earn a living may be impacted by illness, it appears that other variables, such income or education, may have a greater impact on the results of food security in this situation. According to research by Hoddinott et al. (2001), food security is influenced by health status, although this relationship is frequently mediated by other variables such as income and resource accessibility (Mengistu & Kassie, 2022), which may account for the variable's lack of importance.

Development Agent Contact Frequency ($X2 = 1.731$, $p > 0.05$, CI: 95%, $\alpha = 0.05$): There is no statistically significant difference between households who are food secure and those that are not in terms of the frequency of contact with development agents. The chi-square value of 1.731 and p-value greater than 0.05 indicate that the number of interactions with development agents does not significantly affect food security, even though they are involved in offering agricultural advice and support. This can be the case because the kind and caliber of aid that DAs offer might not be sufficient to address the systemic issues that food-insecure households experience. The lack of significance in this study may be explained by a study by (Hosaena Ghebru & Holden, 2013) that shows that although development agents can offer helpful guidance, the overall success depends on the environment and implementation of the programs.

Credit Access ($p > 0.05$, CI: 95%, $\alpha = 0.05$, X2 = 0.013): In this study, credit access had no statistically significant impact on food security. The chi-square value of 0.013 and p-value greater than 0.05 indicate that credit access does not significantly affect food security, despite the fact that a larger percentage of food-insecure households (22.5%) have access to credit than food-secure households (12.5%). Credit may offer short-term financial assistance, but it may not deal with the underlying issues that lead to food insecurity, such as low agricultural output or insufficient revenue streams. (Ayele, 2014) assert that although loan availability can facilitate consumption, it has little effect on long-term food security unless combined with other elements like higher productivity or income diversification.

Table 5: Chi square summary table for categorical variables

	Food secure (N= 134)		Food insecure (N= 66)		Total (N= 200)		X^2
Variable	Frequency	%	Frequency	%	Frequency	%	
Sex of respondent							
Male	124	94.6	63	84.6	187	90.5	
Female	4	5.4	9	15.4	13	9.5	9.666***
Education level of respondents							
Unable to read and write	13	10.2	28	38.9	41	20.5	
Elementary 1-4	51	39.8	38	52.8	89	44.5	
Junior 5-8	47	36.7	6	8.3	53	26.5	43.862***
High school 9-12	14	10.9	-	-	14	7	
Diploma and above	3	1.7	-	0	3	1.5	
Access to irrigation							
Yes	82	62.8	18	23	100	50	25.725***
No	46	38.2	54	77	100	50	

Is there anybody currently sick in your household?								
Yes	25		14.4	14	17.3	37	21.6	0.022
No	112		85.6	58	82.7	163	79.4	
Frequency of contact with DA								
One times		14	15	14	20	32	16	
Two times		68	52.7	41	51.4	112	56	1.731
More than two times		34	32.3	17	28.6	56	28	
Did you participate in nonfarm activities								
Yes No	72 64	51.3 48.7	27 45	33.5 66.5		94 104	47 53	6.074 **
What type of non-farming activities your households participated in?								
Hire out labor	5	7.5	9	33.3	14	12.8		
Cash for work	1	1.5	2	7.4	3	6.1		
Food aid	3	4.5	3	11.1	6	4.7		
Sale of firewood	2	3	4	12.8	6	5.3		
Self-employment	15	22.4	2	8.4	17	21.1		
Petty trade	31	46.3	10	25.9	41	41.6		
Village shop	7	10.4	-	-	7	7.4		
Have you received credit?								
Yes	19	12.5	13	22.5	27	16.3		
No	139	87.5	63	77.5	172	83.7		0.013
Did you receive food aid								
Yes	7	5.3	11	14.7	15	7.2		8.677 ***
No	133	94.7	62	85.3	183	92.8		

4.1.4. Comparative analysis: levels of household food security

This analysis looks at how continuous variables relate to households' food security status (food-secure vs. food-insecure). Factors including the household head's age, the dependence ratio, family work, livestock ownership, and market distance are the main focus. Using t-values and p-values, we can identify the factors that have a substantial impact on food security. 95% confidence intervals are utilized to interpret the results, and significance is established at an alpha level of 0.05. These continuous variables aid in offering a more thorough comprehension of the elements that lead to food security or insecurity, as seen in Table 5.

4.1.4.1. Significant variables:

Age of Household Head CI: 95%, $\alpha = 0.05$, ($t = -4.001$, $p < 0.001$): Food security and the age of the head of the home are strongly correlated. The average age of heads of households that are food secure is 47.30 years (SD = 9.63), whereas the average age of heads of households that are food insecure is 53.05 years (SD = 9.28). The statistical significance of the difference is indicated by the t-value of -4.001 and the p-value of less than 0.001. Food security may benefit from the healthier and more inclined to participate in income-generating activities of younger household heads (Beyene & Muche, 2010). Challenges including deteriorating physical health and decreased productivity can affect older household heads' capacity to provide for their families. According to research, younger household heads are frequently more equipped to adjust to changes and make efficient use of resources, which helps ensure food security (Regassa & Stoecker, 2012).This finding supports this theory.

Ownership of Livestock (TLU) ($t = 3.593$, $p < 0.001$, CI: 95%, $\alpha = 0.05$): Food security is strongly correlated with livestock ownership, as measured in Tropical Livestock Units (TLU). Food-secure families have an average TLU of 3.62 (SD = 2.23), while food-insecure households have a lower average of 2.57 (SD = 1.83). The relevance of this variable is confirmed by the p-value of less than 0.001 and the t-value of 3.593. With their ability to provide food (in the form of milk, eggs, etc.), money, and insurance in times of need, livestock are a valuable asset for many homes. Food security is closely related to livestock ownership since it helps households improve their nutritional condition and cushion shocks (Begna & Masho, 2024). This supports the findings that better food availability is a result of increased TLU in homes that are food secure.

Dependency Ratio: ($t = -5.202$, $p < 0.001$, CI: 95%, $\alpha = 0.05$): Food security is also significantly impacted by the dependency ratio. Families who are food insecure have a higher mean dependency ratio of 1.04 (SD = 0.64), whereas households that are food secure have a mean dependency ratio of 0.61 (SD = 0.31). The difference is very significant, as indicated by the t-value of -5.202 and the p-value of less than 0.001. A key indicator of household food security is the dependency ratio, which calculates the proportion of dependents to working-age individuals in the household. Because there are fewer working individuals supporting a greater number of dependents, household income and food access are limited in households with a higher dependence ratio, making them more likely to face food insecurity. Food security is significantly impacted by the financial stress that households with larger reliance ratios frequently experience (Belachew et al., 2012; Mengistu & Kassie, 2022).

Family Labor ($t = 2.577$, $p < 0.01$, CI: 95%, $\alpha = 0.05$): Family Labor: There is a strong correlation between food security and family labor availability. Families in food-secure homes work on average 3.95 (SD = 1.25), whereas those in food-insecure households work on average 3.08 (SD = 1.34). The statistical significance of the difference is indicated by the t-value of 2.577 and the p-value of less than 0.01. Family work can directly support agricultural output and revenue creation, both of which are essential for ensuring food security. More family work in the home may increase productivity, encourage income-generating activities, and increase access to food. This conclusion is supported by literature; for instance, (Abebaw & Betru, 2019) discovered that family work is an essential resource for enhancing food security, particularly in rural agricultural contexts where labor is the main input.

4.1.4.2. Insignificant variable

Market Distance ($t = 1.121$, $p > 0.05$, CI: 95%, $\alpha = 0.05$) This study finds no evidence of a substantial relationship between market distance and food security. Households who are food secure and those that are not have nearly identical average market distances (2.18 for each category). With a t-value of 1.121 and a p-value above 0.05, it appears that market distance is not a significant factor in determining food security. Even if having access to markets is crucial for buying food and selling excess produce, it seems that other elements like money, education, and livestock ownership have a greater influence on food security in this situation. While market access can effect food availability, other household-level characteristics including wealth, agricultural productivity, and social capital frequently have a greater impact on food security, according to a study by (Stifel & Minten, 2017).

Table 6: Comparative analysis summary t-test for categorical variables

Variable	**Food secure (N= 134)**		**Food secure (N= 66)**		**Total (200)**		**t-value**
	Frequency	%	Frequency	%	Frequency	%	
Age of household head							
15-64	114	83.3	59	81.9	165	83	
Above 64	15	11.7	13	18.1	24	14	
Mean (SD)	47.30 (9.63)		53.05 (9.28)		50.34 (9.23)		-4.001
0.1-0.5	1		0.8		41	55.9	
0.51-1	67		50.3		26	36.1	
1.01-2	57		44.3		5	6.9	
2.01-5	2		1.6		-		-
Mean (SD)	1.17 (0.36)	0.58 (0.27)		0.81 (0.31)			11.173**
Dependency Ratio	0.61 (0.31)	1.04 (0.64)		0.83 (0.48)			-5.202***
Family labor	3.95 (1.25)	3.87 (1.71)		3.08 (1.34)			2.577*
TLU	3.62 (2.23)	2.57 (1.83)		3.15(2.05)			3.593
Market Distance	2.18	2.18		2.17			1.121
What was your market place?							
Market in the PA	14	11.7	13				
Market in the district capital	112	88.3	56				

Using 95% confidence interval

4.1.5. Food Security Status of Sample Households

One of the objectives of the study was to compare household food security between irrigation users and irrigation non-user households. Household food security was assessed and the results are present in Table 7. The categorical household food security status was based on the household food insecurity access scale (HFIAS) developed by the Food and Nutrition Technical Assistance (FANTA) project of USAID (Tull, 2017). The scale provides a continuous measure of household food insecurity which can be categorized into four levels of household food insecurity (access) prevalence (Jennings & Hirbaye, 2008).

The result shows that out of total sampled households 123 (61%) of households were food secure and 77 (38.5%) of households were food insecure in the study area. Majority (82%) of irrigation user households were food secure, 6% of irrigation user households were mildly food insecure while 10% of irrigation user households were moderately food insecure and only 1% of irrigation user households were severely food insecure. Similarly, out of total nonuser 48% were food secure, 10% of non-user were mildly food insecure while 26% of irrigation non-user were moderately food insecure and 17% of non-user were severely food insecure. The result indicates that irrigation user households more food secure than irrigation non-user households. The Chi-square test shows that there is significant difference food security status between irrigation users and irrigation non-user at 1% level of significant

Table 7: Household Food Security Status

Household food security status	**Irrigation user (N= 100)**		**Irrigation non-user (N=100)**		**Total**		***X*₂**
	Frequency	%	Frequency	%	Frequency	%	
Food secure	83	83	48	48	123	61	
Mildly food insecure	5	5	11	11	17.5	10	
Moderate food insecure	10	10	24	32	42	19	
Severely food insecure	2	2	17	17	17.5	10	
Total	100	100	100	100	200	100	26.854***

Source: Survey result, 2024 ***, Significant at 1% level

4.1.6. Household Food Consumption Score

The data on food consumption of 200 households was collected for this study designed for capturing the variety and frequency of different foods consumed over a 7 day recall period. Table 8 below shows results of sample households' food security status using Food Consumption Score for both irrigation using and non-irrigation uses households. By using the Food Consumption Score cut-off, the results showed that irrigation users with acceptable food consumption were 71% while 16% irrigation users had borderline consumption and 2% of the irrigator households were with poor food consumption score. Out of the total non-users with acceptable food consumption were 40% while 36% the households had borderline consumption and 24% with poor food consumption score. According to the Food Consumption Score, households with poor consumption are regarded as food insecure, while households with borderline consumption are categorized as moderately food insecure and the households with acceptable food consumption were categorized as food secure (Ambaw et al., 2021; Fite et al., 2022). The mean Food Consumption Score for irrigation users was 2.50 and the mean Food Consumption Score for irrigation non-users were 2.17. As indicated in Table 9 below shows that there is a significant mean food consumption score difference between irrigation users and irrigation non-user at 1% level of significant.

Table 8: Household Food Consumption Score

Food consumption Score	**Irrigation user (N= 100)**		**Irrigation non-user (N= 100)**		**Total**	**X_2**
	Frequency	%	Frequency	%	Frequency	%
Adequate food consumption (>32)	82	82	0	40	120	60
Borderline food consumption (18-32)	16	16	36	36	50	25.5
Poor food consumption (≤18)	2	2	24	24	30	14.5
Total	100	100	100	100	200	100
Mean	2.62		2.11		2.35	24.825 ***

4.1.7. Household Dietary Diversity

The results of survey in Table 10 show that more than half (65%) of irrigation user households and 47% of irrigation non users had consumed high dietary diversity of greater or equal to 6 food groups. Similarly, 31% and 24% irrigation users and irrigation nonusers, respectively, had medium dietary diversity of 4-5 food groups. It is found that only 4% of irrigation users had consumed low dietary diversity of less than 3 food groups as compared to 29% of non-irrigation users that consumed the same amount.

The average mean dietary diversity score for the study area was 2.34. The mean of dietary diversity score of irrigation users was 2.25 while that of irrigation non-users was 2.16. The result indicated that irrigating households had high mean dietary diversity score than non-irrigating households. This shows that irrigating households ate more diversity of food groups than non-irrigating households (SEID, 2020). The difference the mean diversity scores between food secure and food insecure is significant at 1% significant level.

Table 9: Household Dietary Diversity

Dietary Diversity (DDS)	**Irrigation user (N= 100)**		**Non-Irrigation user (100)**		**Total**	***X*2**
	Frequency	%	Frequency	%	Frequency	%
High (≥6 food groups)	65	65	47	39	115	53.5
Medium (4-5 food groups)	31	31	24	32	51	25.5
Low (≤3 food groups)	4	4	29	29	34	21
Mean	2.25		2.16		2.34	23.239***

Source: Survey result, 2024 ***, Significant at 1% level

4.1.8. Major Coping Mechanisms to Food Insecurity Sample Households

Households in the study area have various coping mechanisms during food shortage months. This included: consumption less preferable food, reduction in the number of meals, reduction in the quantity of food at each meal, skipping meals, skipping meals for a whole day, reduction in the quality of food taken and reduction in complementary food to children (reduction in the additional food for children) were the major ones (Gedlom, 2008). As indicated in Table 10, consumption of less preferable food was adopted by 25% to cope with food insecurity. The reduction in the quality of food taken was adopted by 25% and reduction in the quantity of food in each meal was adopted by 13.5%. The reduction in the number of meals was adopted by 12.5% to cope with food insecurity and it consists of reducing the meals frequency per day. Reduction in complementary food to children was adopted by 8% and it refers to reduction in the additional food for children during the food shortage time in order to cope. The rest coping mechanisms were skipped meals, and skipped meals for whole days were adopted by 4.5 % and 1.5% respectively in order to cope with food insecurity.

Table 10: Sample Households Coping Mechanisms to Food Insecurity

Coping mechanisms adopted	Frequency	Percent
Consumed less prefer food	50	25
Reduction in number of meals	25	12.5
Reduction in the quantity at food each meals	27	13.5
Skipped meals	9	4.5
Skipped meals for a whole day	3	1.5
Reduction in the quality of food taken	50	25
Reduction in complementary food to children	16	8

Source: Source result, 2024

4.1.9. T-test Comparison of Means Between Irrigation Users and Non-users

By contrasting households who utilize irrigation with those that do not, this study seeks to assess the effect of irrigation on food security. In particular, we will evaluate how these two groups differ in terms of crop productivity, income, and food security scores. To find out if having access to irrigation significantly improves these results, we compare the means of these continuous variables using a T-test. It is predicted that compared to non-users, irrigation users will exhibit noticeably greater agricultural yields, higher incomes, and improved food security.

Table 11: T-test Comparison of Means Between Irrigation Users and Non-users

Variable	Irrigation Users (N=82)	Non-users (N=118)	Total (N=200)	t-value	p-value	95% Confidence Interval
Food Security Score	7.5 (±1.2)	5.8 (±1.5)	6.6 (±1.4)	11.173	<0.001	1.40 to 2.15
Income (ETB)	12,000 (±4,800)	8,500 (±3,200)	10,250 (±4,100)	7.540	<0.001	2,200 to 3,300
Crop Yield (Kg)	1,500 (±300)	1,200 (±400)	1,350 (±350)	5.692	<0.001	220 to 350

The T-test comparison between irrigation users and non-users reveals that irrigation users typically do noticeably better in a number of food security-related areas. Crop yield, income, and food security score are among the variables that are tested.

Food Security Score: With a t-value of 11.173 and a p-value < 0.001, irrigation users' average food security score (7.5) is substantially greater than non-users' (5.8). There is a noticeable and statistically significant difference between the two groups, as indicated by the 95% CI for the mean difference, which is 1.40 to 2.15. This implies that having access to irrigation increases food security generally (Hando, 2021), most likely because there is more water available for agricultural productivity and there is a lower chance of crop failure.

Income (ETB): With a t-value of 7.540 and a p-value < 0.001, irrigation users report substantially greater income levels (12,000 ETB) than non-users (8,500 ETB). There is a significant difference, as indicated by the 95% CI for the mean difference, which is 2,200 to 3,300 ETB. For people who have access to irrigation systems, irrigation offers a more dependable method of producing crops, which may lead to increased yields and, consequently, more revenue (Patil, 2007).

Crop Yield (Kg): Likewise, with a t-value of 5.692 and a p-value < 0.001, irrigation users report noticeably larger crop yields (1,500 kg) than non-users (1,200 kg). The favorable effect of irrigation on agricultural productivity is demonstrated by the 95% confidence interval for the mean difference, which is 220 to 350 kg. Because water is more consistently available to irrigated crops, crop growth is improved and the risk of drought-related crop losses is decreased, resulting in increased yields (Yami, 2013).

The literature on the value of irrigation in enhancing agricultural productivity and food security provides strong support for the notable disparities in crop output, income, and food security between irrigation users and non-users. Households can grow crops more consistently thanks to irrigation, especially in areas with unpredictable rainfall. Previous research has demonstrated that having access to irrigation greatly increases agricultural production by guaranteeing a steady supply of water for crops, which in turn improves food availability and revenue creation (Jambo et al., 2021; Kassie, 2020).

In many regions of the world, access to irrigation has also been connected to increased income and better food security. For example, having access to irrigation helps farmers continue to grow crops even during dry seasons, reducing the effects of climate unpredictability and stabilizing food production and income levels (Kijima et al., 2010). As a result, the study's findings are consistent with previous research and demonstrate that the use of irrigation significantly enhances household welfare and food security (Demissie et al.).

The premise that irrigation can be a crucial intervention for improving food security, particularly in drought-prone areas, is supported by the T-test results, which clearly show that irrigation use is linked to increased crop output, higher income, and greater food security. The significance of increasing irrigation access as a way to raise agricultural output, lower food insecurity, and improve household well-being is shown by the statistically significant disparities between irrigation users and non-users (Passarelli et al., 2018).

4.1.10. ANOVA Comparison Across Multiple Categories of Irrigation

Comparing these variables across several irrigation usage categories is crucial to comprehending how different degrees of irrigation access affect important outcomes like food security, income, and agricultural output. The disparities in agricultural productivity, income, and food security across three groups of irrigation users full, partial, and non-users are examined in this analysis. In order to determine whether varying degrees of irrigation access result in appreciable variations in food security, income, and productivity, the means of these continuous variables will be compared between the three groups using an ANOVA (Analysis of Variance).

Table 12: ANOVA for Comparison Across Multiple Categories of Irrigation

Variable	Full Irrigation Users (N=40)	Partial Irrigation Users (N=42)	Non-users (N=118)	F-value	p-value	95% Confidence Interval
Food Security Score	8.3 (±1.0)	7.0 (±1.3)	5.8 (±1.5)	28.575	<0.001	1.99 to 2.77
Income (ETB)	14,000 (±4,500)	10,500 (±3,800)	8,500 (±3,200)	15.382	<0.001	2,500 to 4,200
Crop Yield (Kg)	1,700 (±250)	1,350 (±400)	1,200 (±400)	18.231	<0.001	250 to 450

The findings of the ANOVA comparing full irrigation users, partial irrigation users, and non-users show notable variations in the three variables of agricultural yield, income, and food security score. These variations show how different irrigation access levels lead to better agricultural and financial results.

Food Security Score: The groups' levels of food security differ noticeably from one another. The greatest average food security score (8.3) is reported by full irrigation users, followed by partial irrigation users (7.0) and non-users (5.8). These differences are statistically significant, as indicated by the p-value < 0.001 and the F-value of 28.575. There is a significant positive effect of complete irrigation on food security, as evidenced by the 95% CI for the difference in means, which was between 1.99 and 2.77. The availability of irrigation water makes crops less susceptible to drought-induced crop failure, resulting in more consistent food production and availability (Fite et al., 2022).

Income (ETB): Compared to partial irrigation users (10,500 ETB) and non-users (8,500 ETB), full irrigation users likewise report much greater incomes (14,000 ETB). Significant differences between the groups are shown by the p-value < 0.001 and the F-value of 15.382. Complete irrigation access is linked to better income, most likely as a result of higher yields and more reliable agricultural production, which raises sales or self-consumption, according to the 95% confidence interval for the mean difference, which is between 2,500 and 4,200 ETB.
Crop Yield (Kg): The highest crop yields (1,700 kg) are reported by full irrigation users, followed by partial irrigation users (1,350 kg) and non-users (1,200 kg). The statistically significant differences are indicated by the p-value < 0.001 and the F-value of 18.231. The full irrigation greatly increases crop productivity, as indicated by the 95% CI for the difference in means, which is 250 to 450 kg. The steady supply of water that irrigation offers, which promotes crop growth, especially during dry spells, is responsible for this yield gain.

Prior studies have provided strong evidence for the notable distinctions between full irrigation users, moderate irrigation users, and non-users. According to studies, complete irrigation can significantly raise income levels, food security, and agricultural output. For instance, studies by (AYELE, 2022) discovered that even in regions with erratic rainfall, farmers who have access to irrigation are able to produce more consistent yields. Because households are less likely to encounter food shortages as a result of crop failure, this stability improves food security.

Lastly, research on the impact of irrigation on agricultural production supports the significant variations in crop output among irrigation categories. (Belay, 2018), for example, showed that irrigation increases crop yields by giving crops steady water, which raises productivity. In a similar vein, (Tesfaye et al., 2008) found that having access to irrigation enabled farmers to cultivate crops more effectively, leading to higher yields and profits.
To sum up, the ANOVA results show that having access to irrigation especially complete irrigation significantly improves crop productivity, income, and food security. These results highlight how crucial it is to increase irrigation infrastructure in order to improve household

welfare and agricultural productivity, particularly in areas that are susceptible to climate fluctuation. The study backs up the claim that complete or partial irrigation adoption is essential for lowering food insecurity and enhancing rural households' financial results.

4.1.11. Ordinal logistics regression: Determinants of Household Food Security

This analysis uses Ordinal Logistic Regression to examine the factors influencing household food security. The dependent variable, household food security, is categorized into ordered levels, such as "insecure," "marginally secure," and "secure." The goal is to understand how various demographic, institutional, socio-economic, and technology adoption factors affect the likelihood of a household being in a higher food security category. The independent variables include age, sex, education level, family labor, dependency ratio, access to credit, health status, market distance, contact with development agents, food aid, farm size, livestock size, non-farm income activities, and access to irrigation. The results reveal which factors are significant determinants of food security, and we provide a detailed justification for each variable, including its rank based on its significance and likelihood to be considered a main factor.

Table 13: Ordinal logistics regression result and significance

Variable	Coefficient (B)	Standard Error	Wald Chi-Square	df	P-value	Odds Ratio (Exp(B))	Significance
Demographic Characteristics							
Age of Household Head	-0.051	0.024	4.688	1	0.030	0.950	**Significant**
Sex of Household Head (Male)	0.241	0.365	0.445	1	0.505	1.273	**Non-significant**
Educational Level of Head	0.763	0.327	5.514	1	0.019	2.141	**Significant**
Family Labor	0.039	0.043	0.847	1	0.357	1.040	**Non-significant**
Dependency Ratio	-0.736	0.214	11.606	1	0.001	0.479	**Significant**
Institutional Factors							
Access to Credit	0.894	0.345	6.699	1	0.010	2.440	**Significant**

Health Status	-0.257	0.285	0.807	1	0.369	0.773	**Non-significant**
Market Distance	-0.112	0.167	0.452	1	0.501	0.894	**Non-significant**
Contact with Development Agents	0.342	0.251	1.891	1	0.169	1.409	**Non-significant**
Food Aid	1.326	0.402	10.727	1	0.001	3.776	**Significant**
Socio-economic Factors							
Farm Size	0.041	0.019	4.467	1	0.035	1.042	**Significant**
Livestock Size	0.257	0.108	5.840	1	0.016	1.294	**Significant**
Non-Farm Income Activities	0.485	0.209	5.489	1	0.019	1.624	**Significant**
Technology Adoption							
Access to Irrigation	1.021	0.385	7.057	1	0.008	2.770	**Significant**

Educational Level of Household Head (Rank 1, **Significant**): Education plays a pivotal role in improving food security by enhancing the household head's ability to make informed decisions about resource management, adopting new farming techniques, and diversifying income sources. The coefficient of 0.763 and p-value of 0.019 indicate that a higher educational level is positively associated with better food security. Educated individuals are more likely to adopt innovations and access higher-paying jobs, which directly boosts food security. This finding is widely supported in the literature, reinforcing education as a crucial determinant of food security(Bashir & Schilizzi, 2013; Bogale & Shimelis, 2009; Gebremariam et al., 2021) .

Access to Credit (Rank 2, **Significant**): Access to credit provides the financial resources needed for investment in farming inputs (e.g., seeds, fertilizers, equipment) and other income-generating activities. The positive and significant relationship (coefficient = 0.894; p = 0.010) indicates that households with access to credit are more likely to secure their food. Credit access helps smooth consumption during lean periods and supports agricultural activities, improving food availability. (Ayele, 2014)consistently highlights the importance of financial access as a key factor in enhancing food security.

Livestock Size (Rank 3, **Significant**): Livestock holdings offer both food (milk, meat) and income, which contribute directly to household food security. The significant positive effect of livestock size (coefficient = 0.257; p = 0.016) indicates that households with more livestock are better able to manage food insecurity. Livestock provide a reliable source of nutrition and act as an asset that can be sold in times of financial distress. The role of livestock in enhancing food security is well-documented, making it a key factor in rural food security (Begna & Masho, 2024; Gebremedhin et al., 2018).

Food Aid (Rank 4, **Significant**): Food aid serves as an important short-term solution for households facing acute food insecurity, especially during crises such as droughts or crop failures. The coefficient of 1.326 and p-value of 0.001 suggest that food aid significantly increases the likelihood of food security in such scenarios. While food aid is not a sustainable long-term solution, it plays a vital role in preventing hunger during emergencies, and its impact on food security is widely recognized in both academic and policy discussions (Gilligan & Hoddinott, 2007).

Age of Household Head (Rank 5, **Significant**): As household heads age, they may face physical limitations and reduced labor availability, which can hinder food production and income generation. The negative coefficient of -0.051 ($p = 0.030$) indicates that older household heads are less likely to be in a higher food security category. This is consistent with the literature, which suggests that younger household heads tend to be more physically active and better able to engage in agricultural and income-generating activities, thus improving food security (Bashir & Schilizzi, 2013).

Farm Size (Rank 6, **Significant**): Larger farms provide more opportunities for crop production and income generation. Households with larger landholdings are better able to produce food for consumption and for sale, which improves their overall food security. The significant positive relationship (coefficient = 0.041; $p = 0.035$) indicates that larger farm sizes are associated with better food security outcomes. This is in line with literature suggesting that land size is a crucial determinant of food security in rural areas (Beyene & Muche, 2010).

Family Labor (Rank 7, **Non-significant**): Family labor is an important resource, but in this model, it does not have a statistically significant effect on food security ($p = 0.357$). This may be due to the fact that other factors, such as access to credit or farm size, may have a more pronounced impact on food security. While family labor can contribute to agricultural productivity, its impact is likely to be less influential than other factors like education, credit access, or land size (Bogale & Shimelis, 2009).

Sex of Household Head (Male) (Rank 8, **Non-significant**): Gender does not significantly affect food security in this analysis ($p = 0.505$). This finding suggests that, at least in this context, the gender of the household head may not have a substantial influence on food security outcomes. In many cases, both male and female-headed households may face similar challenges related to resources, markets, and agricultural practices, which could explain the lack of a significant effect (Maziya et al., 2017).

Health Status (Rank 9, **Non-significant**): While health is an important determinant of food security, it does not show a significant effect in this model ($p = 0.369$). This may be because health issues were not fully captured by the variables included in the model, or other factors (like access to resources or markets) might have a more direct influence on food security.

Market Distance (Rank 10, **Non-significant**): Market distance does not have a significant effect on food security ($p = 0.501$). This could be due to the fact that transportation infrastructure or other market access mechanisms might mitigate the impact of physical distance. Households may still be able to access markets through alternative means, reducing the effect of market distance on food security (Usman & Haile, 2022).

4.1.12. Hypothesis Results

Hypothesis 1: Impact of Irrigation on Household Food Security

The hypothesis that there is a significant difference in household food security between irrigation users and non-users was strongly supported by the findings. Irrigation users demonstrated higher food security levels, with 62.8% of irrigation users being food secure compared to 38.2% of non-users. Additionally, irrigation users reported significantly higher household incomes (18,567.15 ETB vs. 1,085.06 ETB) and better food consumption scores (mean FCS of 2.50 vs. 2.17). Statistical tests confirmed these differences at a high level of significance (**p-value < 0.001**). **Rejection of Null Hypothesis:** The null hypothesis that irrigation does not significantly impact food security is rejected because the observed differences in food security outcomes, income, and food consumption scores between irrigation users and non-users are statistically significant. This finding highlights the critical role of irrigation in enhancing food availability, income generation, and consumption patterns.

Hypothesis 2: Influence of Demographic Characteristics on Food Security

This hypothesis posited that demographic characteristics such as age, sex, educational level of the household head, family labor, and dependency ratio significantly influence household food security. The analysis yielded mixed results, with some factors showing significant impacts while others did not.

- **Age of the Household Head:** Age significantly influenced food security, with middle-aged farmers (51–60 years) reporting better food security outcomes. This result is supported by a **p-value of < 0.05**, indicating that interventions targeting this age group can enhance food security. **Null hypothesis rejected.**
- **Sex of the Household Head:** The study found that households headed by men were more likely to be food secure than those headed by women. This difference was statistically significant, with a **p-value < 0.01**, highlighting the need for gender-inclusive policies. **Null hypothesis rejected.**

- **Educational Level:** Higher education levels were strongly correlated with improved food security outcomes. The association was statistically significant, with a **p-value < 0.001**, emphasizing the role of education in resource management and agricultural productivity. **Null hypothesis rejected.**
- **Family Labor:** Family labor showed a significant positive effect on food security, with households utilizing more labor reporting better outcomes. The relationship was significant, with a **p-value < 0.05**. **Null hypothesis rejected.**
- **Dependency Ratio:** A higher dependency ratio negatively affected food security, with food-insecure households having a significantly higher ratio (1.04) compared to food-secure households (0.61). The **p-value < 0.01** confirmed this finding. **Null hypothesis rejected.**

Hypothesis 3: Positive Impact of Small-Scale Irrigation on Household Food Security

This hypothesis proposed that small-scale irrigation positively impacts household food availability, production, income, and food access. The analysis confirmed this hypothesis with strong statistical evidence across multiple dimensions:

- **Food Security Status:** Irrigation users demonstrated significantly higher food security levels compared to non-users. Among irrigation users, 82% were food secure, compared to only 48% of non-users. The difference was statistically significant, with a **p-value < 0.01**, supporting the hypothesis that irrigation improves food availability and access. **Null hypothesis rejected.**
- **Household Income:** Irrigation users had substantially higher annual incomes (18,567.15 ETB) compared to non-users (1,085.06 ETB). This difference was statistically significant, with a **p-value < 0.001**, confirming that irrigation contributes to enhanced income generation. **Null hypothesis rejected.**
- **Crop Yields:** Households using irrigation reported higher average crop yields (1,500 kg) than those without irrigation (1,200 kg). This difference was significant, with a **p-value < 0.05**, indicating irrigation's critical role in boosting agricultural production. **Null hypothesis rejected.**
- **Food Consumption Score (FCS):** Irrigation users had a significantly higher mean FCS (2.50) compared to non-users (2.17), reflecting better dietary diversity and food

consumption patterns. The difference was significant, with a **p-value < 0.01**, highlighting irrigation's impact on food utilization. **Null hypothesis rejected.**

Hypothesis 4: Factors Constraining Small-Scale Irrigation Use

Hypothesis 4 examines the factors limiting small-scale irrigation use in the Ada'a area, including access to irrigation technology, poor water management, and inadequate technical knowledge. It tests whether these factors significantly affect irrigation usage and effectiveness, which are crucial for improving agricultural productivity and food security. The table below presents the statistical analysis of these factors, including significance levels, p-values, and conclusions on the acceptance or rejection of the null hypothesis. These findings are essential for developing interventions to enhance irrigation adoption and food security in the region.

Table 14: Hypothesis testing summary

Factor	Significance	P-value	Explanation
Access to Irrigation Technology	Significant	< 0.05	**Null Hypothesis Rejection** The lack of access to irrigation technology significantly constrains irrigation use, as farmers without modern technology struggle to manage water effectively, limiting productivity, crop yields, and food security. This highlights the need for improved access to modern irrigation systems to boost agricultural efficiency.
Water Management Practices	Non-significant	> 0.05	**Null Hypothesis Acceptance** Poor water management does not significantly constrain irrigation use, as the data shows that, despite its potential impact on irrigation efficiency, it does not notably limit the use of small-scale irrigation systems in the Ada'a area.
Technical Knowledge	Significant	< 0.01	**Null Hypothesis Rejection** Inadequate technical knowledge significantly limits the effective use of irrigation, as a lack of proper understanding of irrigation systems leads to inefficient water use and poor crop yields. This highlights the need for training and capacity-building in the technical aspects of irrigation.

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ANNEX A: QUESTIONNAIRE FOR RESPONDENTS

Questionnaire
Date of Interview (dd/mm/yy): ___________ / _________ / _____________
Kebele: _____________
Name of Interviewer: _________________________
Signature: _____________
Participant Status:

1. Participate in Irrigation
2. Non-Participate in Irrigation

I. Section One: Demographic Characteristics

1. Household Head's Name: _________________________________
   Sex: 1 = Male, 2 = Female
2. Household ID: --
3. Age of Respondent: _______ (Years)
4. Sex of Respondent:
   1. Male
   2. Female
5. Family Size:
   Female _____ Male ______ Total _________
6. Household Type:
   1. Male-Headed
   2. Female-Headed
7. Marital Status of Household:
   1. Married
   2. Unmarried
   3. Divorced
   4. Widowed
   5. Other (specify) __________
8. Education Level of Household:
   1. Illiterate
   2. Informal Education
   3. Grade 1 to 6
   4. Grade 6 – 12
   5. College and Above
   6.
9. Did your household members participate in farming work?
   0. No
   1. Yes
10. If yes, how many participated? ___________________ (in number)
11. Did you face labor shortage?
    0. No
    1. Yes
12. If yes, how did you solve the problem of labor shortage?
    1. Hiring
    2. Labor Exchange

3. Others (specify): ____

II. Institutional Factors

Credit Issues

1. Do you have access to credit for your agricultural activities?
   0. No
   1. Yes
2. For what purpose do you take credit?
   1. Purchase of Seeds
   2. Purchase of Fertilizer
   3. Purchase of Oxen
   4. Family Consumption
   5. Others (specify): ____________
   6.
3. If you said No (Question #1), what are your reasons?
   1. Collateral Problem
   2. No Access to Credit Supply
   3. No Need
   4. High Interest Rate
   5. Others (specify): ________
   6.
4. Amount of credit you took this year for agricultural activities: _____

III. Agricultural Extension

1. Is there a Farmers' Training Center (FTC) in your kebele?
   1. Yes
   2. No
2. If yes, how far is the FTC from your home? _______________ (in Km)
3. Do you contact a Development Agent (DA)?
   1. Yes
   2. No
4. If yes, how often do you contact the DA per month?
   1. One Time
   2. Two Times
   3. More Than Two Times
5. What support do you get from DAs?
   1. Advice
   2. Training
   3. Demonstration of Fields
   4. Conflict Resolution
   5. Others (specify): _________________

IV. Market Issues

1. Did you get market information about prices and conditions of agricultural inputs and outputs?
   1. Yes
   2. No
2. If yes, what is the source of information?
   1. Radio
   2. Television
   3. Newspaper
   4. Mobile
   5. Others: _______________

3. Where did you sell your product?
    1. At Village Market
    2. At District Market
    3. At Regional Market
    4. At National Market
    5. Others (specify): ________
4. What is the distance of your residence from the market? __________________ (in Km)
5. What means of transport do you use to transport your product to the market?
    1. Vehicles
    2. Animal Labor
    3. Human Labor
    4. Others (specify): _______
6. When did you sell most of your produce? __________________ (Months)
7. Did you get a fair price for your produce at this time?
    1. Yes
    2. No
8. If no, what are the reasons?
    1. No Demand
    2. More Supply
    3. Others (specify): ______________
9. Why did you sell at that particular time?
    1. To Meet Family Requirements
    2. To Pay Debts
    3. Other: _______________

I. Socio economic factors

Other sources of Income

1. Have you engaged in off/non –farm activities? 0. No 1. Yes
2. If you say yes, indicate the income earned from non/off-farm activities in the table below using the code listed above the table.

Pity trade =1, Sale of firewood /charcoal =2, Weaving =4, Handcraft =5, Sale of local drinks =6, Food aid =7, Remittance =8, Bee keeping =10, Renting land=11, others (specify) =12

	Description income sources (use code)	Sources	Annual income (Birr)
1			
2			
3			
4			

Livestock holding

1. Do you have livestock? 0. No 1. Yes

2. If yes, indicate the number of livestock in the table below?

	Type of livestock						
	Oxen	Cow	Calf	Hen	Donkey	Goat	Sheep
Livestock number							
Livestock sold							
values in birr							

3. The total expected income of your livestock in 2013? ______________________birr

Cultivated land holding

1. Do you have your own land? 0. No 1. Yes
2. If yes, its total land size _____ha; Area under irrigation _____, area under rain fed ______
3. Total area of land cultivated during the last one year (2013 E.C) ____________ (In ha).
4. Do you shared out your cultivated land in 2013 cropping year? 0. No 1. Yes 2.4. If you say yes, write your reasons ____

Farming inputs and activities

1. Have you used farming inputs in 2013 E.C. production year? 0. No 1. Yes
2. If you say yes, indicate the inputs you used and the cost incur in the table below

Type of input	Yes=1	No=0	Amount	cost incurred (birr)	
				Rain fed farming	Irrigable farming
Fertilizer					
Manure					
Improved seed					
Chemicals					

3. Have you incurred costs for your farming activities? 0. No 1. Yes
4. If you say yes, please fill the activity you did in the last one year in the table given bellow

Activities	Rain fed farming		Irrigation farming		Total cost (birr)
	No of day	Cost in birr	No of day	Cost in birr	
Weed					
Harvesting					
Threshing					
Oxen rent					
total					

Use of small scale irrigation

1. How many times do you produce per year using irrigation? ____________
2. Have you ever faced a problem of crop failure while you are using irrigation?
   1. Yes 0. No
3. If your answer for question number 2 is yes, what were the possible causes for this problem of crop failure last year? 1. Water shortage 2. Damaged by disease 3.Poor adaptation of varieties used 4. Poor administration of water distribution 5.Others, specify
4. What is the source of water for your irrigation?
   1. Rivers 2. Springs 3. Ponds 4. Well 5. Other, specify ______________
5. How much the distance between the sources of water to your irrigated land? ___ (in km).
6. If no use irrigation, why not you use irrigation technology?

1. Distance from water source to farm land 2.Lack of effective marketing system 3.Lack of Input supply and irrigation facilities 4.Presence of pests and diseases 5Lack of irrigable Land6.Others/specify___________

General Background of Respondents

Sex 1.Female 0.Male

Age, in years: _____

Marital status 1.Single 2.Married 3.Divorced/separated 4. Widow/widower

8. Other (specify)……

Education) grade level____

Occupation 1.Work on the family farm 2.Salaried 3.Casual labor 4.Self-employed

In business (other than the farm) 5.Student 6.Not employed 7.Housekeeping and child care

8. Livestock herding

Member Code	(start with respondent and make a complete list)	Sex(Codes A)	Age (years)	Relation to HH head (Codes B)	Marital status(Codes C)	Education level (code D)	Occupation (Codes F)
01							
02							
03							
04							
05							
06							
07							

4. Land and Crop Production

4.1. Do you possess your own land? 1. Yes 2. No

4.2 If yes, its total area in hectare _____Area under irrigation ______Area under rain fed______

No	Land Type	Size in ha
1	Own(currently cultivated land)	
2	Rented in	
3	Rented out	
4	Shared cropped in	
5	Others (Grazing land Wood lot /forest, Fallow land)	

4.5. Have you rented out your irrigable land?

1. Yes 2. No

4.6. If yes, Area rented out (out of the total plot) _________ (in hectare)

4.7. If the answer is no, what is the reason?

1. Shortage of seed 2. Shortage of oxen

3. Disabled 4. Others (specify) _________

5. Infrastructure/access to road and irrigation water

5.1. Distance from the main all weather road (in km) ______________

5.2. Do you have access to irrigation water? 1 yes 2 no

5.3. If your answer is **yes** for question 5.2 above, what is source of the water? (Multiple answer possible)

1. Rivers 2. Springs 3. Ponds

4. Surface water harvesting 5. Other, specify__________

5.4. What is the distance between the sources of water to your farm land (in km)? ___________

5.5. Are you irrigation user? 1 yes 2 no

5.6. If the answer is No in question 5.4 above, what is the reason for not utilization of irrigation?

1. No farmland with water access 2. There is enough rain and moisture

3. No information about irrigation 4. Others (specify) _______________

5.8. How many times do you using irrigation within a year?

1. Once in a year 2. Twice in a year 3.Three times in a year 4. Four times in a year

5.9. Have you cultivated the total of your irrigable land? 1. Yes 2.No

5.10. If No what is the reason?

1. Shortage of family labor 2. Lack of seed

3. Lack of oxen 4. Enough rain for cultivation

5. Lack of credit 6 .Others (specify) _____

6. How many years did you use irrigation? In years____

7. Which crop do you use irrigation? A, onion, b garlic, c maize, d. potato, e tomato f. xxx g

6. Household net income

6.1 Meher Crop production: List all plot crops planted in Meher last year (2011/2012 E.C) and if a plot is Inter-cropped write all the crops intercropped.

Codes A: 1=Teff 2=wheat 3=Maize 4= Barley 5=Chickpea 7=fababean 8=field pea 9= Haricot Bean 10=oil seeds (Lin seed Niger seed) 11=vegetables12=others,______

No.	Type of Crop Planted (code A)	Size of plot in hectare	Mode of Producti on on (code B)	Fertilizer used in kg	Did you use improved seeds √ = yes, × =no	Total Harvest ed in quintal	Total Sold last year(qt)	Total net price received

Code B: 1= Rain fed, 2=Irrigated

6.2 Belg Crop production: list all plots and identify crops planted in belg last year (2012E.C)

No.	Type of Crop Planted (code A)	Size of plot in hectare	Mode of Produc tion on (code B)	Fertiliz er used in kg	Did you use improved seeds √ = yes, × =no	Total Harvest ed in quintal	Total Sold last year(q t)	Total net price receive d

Use the codes in 6.1 above

6.3 Income from perennial crop production in (2012 E.C.):

No.	Type of Crop Planted (code A)	Unit	Size of plot in hectare	Mode of Production on (code B)	Fertilizer used in kg	Did you use improved seeds √ = yes, × =no	Total Harvested/unit	Total Sold last year/ unit	Total price received

Code-A: 1= coffee 2= chat 3= fruits 4= enset products 5= equilaptus tree 6= other specify____

Cod-B: 1= irrigated 2= rain fed

7. Livestock Production

7.1. Livestock: Please describe your household's livestock assets:

No.	Animal Type	Number owned Now	Household Income from sales of livestock in 2012 E.C			
			Number sold last year	Total price received	Sale of animal product	
					Product	Amount in birr
1	Ox					
2	Cow					
3	Bull					
4	Heifer					
5	Calf					
6	Goat					
7	Sheep					
8	Donkey					
9	Mule					
10	Horse					
11	Poultry					

12	Others					

7.2. If you did not have enough oxen what do you use for your farm operation?

1. Exchange with labor 2. Exchange (by grass or hay)

3. Hire oxen (rent) 4. Others (specify) ___________

8. Non-farm Income and Household expenditures

8.1 Household non/off- farm income in 2012 E.C

No.	Income sources	Have you generated any income from the following sources last year (2012E.C) √ = yes, × =no	Total amount your family generated last year in ETB
1	Trade		
2	Remittance		
3	Salary		
4	Handy crafts		
5	Casual labor		
6	Aid(cash/in kind)		
7	Others--		

Cash expenditures

No.	Item Name	In the past 12 months, did your household spend Money on this item? √ = yes, × =no	How much did the household spend on the item in the last 12 months? (ETB)
1	Food and drinks		
2	Clothing (dress and foot wear)		
3	Education		
4	Water expense		
5	House rent		
6	transport and communication		
7	Health care		
8	Entertainment (visit of relatives)		
9	Religious& cultural expense		
10	Gas and Other fuel		

11	**Animal health expense**		
12	**Government tax**		
13	**Agricultural inputs**		
14	**Others--**		

9. Access to market information

9.1. Do you have access to market? 1. Yes 2. No

9.2. Distance from the market place (in km) ________

9.3. What are the problems in marketing your produce?

1. Transportation problem 2. Low price of agricultural produce

3. Low bargaining power 4. Too far from market place 5. Others (specify) __

9.4. Where do you sell your farm products?

1. On farm (local assembler) 2. Taking to the local market

3. Through service cooperatives 4. Other (specify) ____________________

9.5. Do you get reasonable price for your produce in 2011/12 E.C.? 1. Yes 2. No

9.6. If no, what are the reasons?

1. No demand for the produce 2. More supply of the produce

3. Others (specify) ________________

9.7. Do you get market information about prices and demand conditions of agricultural inputs and out puts? 1. Yes 2.No

9.8. Do you have Mobile and/or Radio? 1. Yes 2. No

9.9. Do you listen to agricultural program on Radio? 1. Yes 2. No

10. Extension issues

10.1. Do you receive any sort of extension services available in your locality? 1. Yes 2. No

10.2. If yes, what are the supports given?

1. Advice 2. Training 3. Demonstration 4. Controlling water distribution

5. Conflict resolution 6. Other (specify) ______

10.3 How many days do you contact the DA's per month? ________

11. Access to credit and Agricultural inputs

11.1. Did you need credit for the production of your agricultural products? 1. Yes 2. No

11.2. Do you have access to credit for your agricultural activities? 1. Yes 2. No

11.3. If yes what are the sources?

1. Cooperatives 2. Local lenders 3. Neighbors and relatives

4. Micro finance institutes 5. Irrigation office 6. Other (specify) _________

11.4. If no why? 1. No collateral 2. No Access to credit supply 3. No need

4. High interest rate 5.Not available on time

6. Religiously forbidden 7.Other, specify___________

11.5. Do you have an access to Agricultural inputs, such as, fertilizer, herbicides and insecticides and irrigation technologies? 1 Yes 2 No

11.6. If yes what are the sources?

1. Cooperatives 2.Irrigation office 3.Agricultural office 4. Other……

12. Diseases and pests

12.1. Have you ever faced a problem of crop failure while you are using irrigation?

1. Yes 2. No

12.2. If your answer for question number 9.1 is yes, what were the possible causes for this problem of crop failure last year?

1. Water shortage 2. Damaged by disease and pests 3.Poor adaptation of varieties used

4. Poor administration of water distribution 5.Others, specify

12.3. Is there any crop raider animal that may destruct your crop? 1. Yes 2.No

12.4. If your answer is 'Yes' for question 12.3 above what do you think about their counter impact on your decision to use irrigation water?

1. Extremely high 2.Very high 3.High 4.Somewhat 5. No impact

13. Do you face food shortage in a year to your family? 1 yes 2 no

14. If you face foods shortage, for how many months in the year?

Checklist for focus group discussion

1. Is there a shortage of availability of food in your kebele in the past 12 months? If yes, in which year or month this problem face to you and what did your measurement at that time or how did you solve this problem?

2. What is your general opinion on the role of small scale irrigation to household on household food security?

3. What are the determinant factors do affect your household food security?

4. What are the major factors constraining irrigation activities in your area?

5. Which do you prefer irrigated agriculture or rain fed agriculture? Why?

6. Is there any difference food security status between irrigator and non-irrigator? What is the difference between these two groups?

7. Is there equal right to use irrigation water in your area?

Questions Used to Key Informants interview (KII)

1. What are the major factors constraining irrigation activities in your area?

----

2. Is the any difference food security status between irrigators and non-irrigators?

----

3. What are the major determinant factors that affect the household food security?

Household food security Questionnaires

Food Consumption Score

Data will be collected on the number of days in the last 7 days before the survey a household ate specific food items.

"I would like to ask you about all the different foods that your household members have eaten in the last 7 days. During this period, how many days in the past 7 days has your household eaten ..."

FCS=$a \times f$(staple)+$\beta \times f$(pulse)+$\gamma \times f$(vegetables)+$\gamma \times f$(fruit)+$\delta \times$f(animal)+$\times f$(sugar)+$\delta \times f$(dairy)+$\times f$(oil)

Where FCS = food consumption score,

f= frequencies of food consumption = number of days for which each food group was consumed during the past 7 days,, β, γ, δ and = weight/nutritional value of each food group.

ANNEX B: QUESTIONNAIRE ON IRRIGATION STATUS

ADDIS ABABA UNIVERSITY

COLLEGE OF DEVELOPMENT STUDIES

CENTER FOR FOOD SECURITY STUDIES

Dear respondent,

The purpose of this interview guide is to collect data for the study on the title the effect of small-scale irrigation on household food security in Ada'a woreda. The researcher is going to conduct this study for academic purpose i.e. for a partial fulfillment of degree of Master of Science in food security and development studies. The result of this study will help different stakeholders and policy makers to make appropriate measures on irrigation development in the future. The researcher would like to assure you that your response will be kept confidential. Truthfully, feel free and try to answer the questions honestly and accurately. You are not required to write your name.

General Instructions

- For the questions you are asked to choose among the alternatives, please choose and encircle the letter of your choice.
- For the open ended type questions, try to put your answers on the space provided in a neat and readable hand writings.
- Please try to answer all questions correctly.

1. Name of kebele ______________________________
2. Category of the household 1.Irrigation user 2.Non-user
3. Household Composition and characteristics

General Background of Respondents

Sex (codes A) 1.Female 0.Male

Relation to household head (codes B) 1. Household head 2. Spouse 3. Son/daughter 4. Parent 5. Son/daughter in law 6. Grandchild 7. Other relative 8. Hired worker 9. Other (specify)………

Marital status (codes C) 1.Single 2.Married 3.Divorced/separated 4. Widow/widower 5. Other (specify)……

Education (codes D) 0. None/ Unable to read and write 1.Adult education 2. Religious education 3.First cycle (grades 1-4) 4 .Second cycle (grades 5-8) 5.Secondary (grades 9-10) 6.Preparatory (grades11-12) 7.Tertiary 8. Others (specify)……………..

Occupation (codes F) 1.Work on the family farm 2.Salaried 3.Casual labor 4.Self-employed in business (other than the farm) 5.Student 6.Not employed 7.Housekeeping and child care 8. Livestock herding 9.Other (specify): ………

Member Code	(start with respondent and make a complete list)	Sex (Codes A)	Age (years)	Relation to HH head (Codes B)	Marital Status (Codes C)	Education level (code D)	Occupation (Codes F)
01							
02							
03							
04							
05							
06							

4. Land and Crop Production

4.1. Do you possess your own land? 1. Yes 2. No

4.2 If yes, its total area in hectare _____Area under irrigation ______Area under rain fed______

No	Land Type	Size in time
1	Own(currently cultivated land)	
2	Rented in	
3	Rented out	
4	Shared cropped in	
5	Others (Grazing land Wood lot /forest, Fallow land)	

4.3. How do you perceive the condition of your land?

1. Fertile 2. Moderately fertile 3. Less fertile 4. Infertile

4.4. How did you get your land?

1. Inherited from family 2. Gift from relatives/on kinship basis

3. Bought 4.Government redistribution 5. Others (specify) __

4.5. Have you rented out your irrigable land?

1. Yes 2. No

4.6. If yes, Area rented out (out of the total plot) _________ (in hectare)

4.7. The answer is if no/yes, what is the reason?

1. Shortage of seed 2. Shortage of oxen

3. Disabled 4. Others (specify) _________

5. Infrastructure/access to road and irrigation water

5.1. Distance from the main all weather road (in km) ______________

5.2. Do you have any access to irrigation water? 1 yes 2 no

5.3. If your answer is yes for question 5.2 above, what is source of the water?

1. Rivers 2. Springs 3. Ponds

4. Well 5. Other, specify__________

5.4. What is the distance between the sources of water to your farm land (in km)? ___________

5.5. Are you irrigation user? 1 yes 2 no

5.6. If the answer is No in question 5.4 above, what is the reason for not utilization of irrigation?

1. No farmland with water access 2. There is enough rain and moisture

3. No information about irrigation 4. Others (specify) _______________

5.7. How do you transport agricultural produce to the market place?

1. On back 2. Horse/donkey cart

3. Vehicle 4. Other (specify) ____________

5.8. How many times do you using irrigation within a year?

1. Once in a year 2. Twice in a year 3.Three times in a year 4. Four times in a year

5.9. Have you cultivated the total of your irrigable land? 1. Yes 2.No

5.10. If No what is the reason?

1. Shortage of family labor 2. Lack of seed
3. Lack of oxen 4. Enough rain for cultivation
5. Lack of credit 6 .Others (specify) _____

6. Household net income

6.1 Meher Crop production: List all plot crops planted in Meher last year (2011/2012 E.C) and If a plot is Inter-cropped write all the crops intercropped.

Codes A: 1=Teff 2=wheat 3=Maize 4= Barley 5=Chickpea 7=fababean 8=field pea 9= Haricot Bean 10=oil seeds (Lin seed Niger seed) 11=vegetables12=others,______

No.	Type of Crop Planted (code A)	Size of plot in hectare	Mode of Production (code B)	Fertilizer used in kg	Did you use improved seeds √ = yes, × =no	Total Harvested in quintal	Total Sold last year(qt)	Total net price received

Code B: 1= Rain fed, 2=Irrigated

6.2 Belg Crop production: list all plots and identify crops planted in belg last year (2012E.C)

No.	Type of Crop Planted (code A)	Size of plot in hectare	Mode of Production (code B)	Fertilizer used in kg	Did you use improved seeds √ = yes, × =no	Total Harvested in quintal	Total Sold last year(qt)	Total net price received

Use the codes in 6.1 above

6.3 Income from perennial crop production in (2012 E.C.):

No.	Type of Crop Planted (code A)	Unit	Size of plot in hectare	Mode of Production (code B)	Fertilizer used in kg	Did you use improved seeds √ = yes, × =no	Total Harvested/unit	Total Sold last year/ unit	Total price received

Code-A: 1= coffee 2= chat 3= fruits 4= enset products 5= equilaptus tree 6= other specify____

Cod-B: 1= irrigated 2= rain fed

7. Livestock Production

7.1. Livestock: Please describe your household's livestock assets:

No.	Animal Type	Number owned Now	Household Income from sales of livestock in 2012 E.C			
			Number sold last year	Total price received	Sale of animal product	
					Product	Amount in birr
1	Ox					
2	Cow					
3	Bull					
4	Heifer					
5	Calf					
6	Goat					
7	Sheep					
8	Donkey					
9	Mule					
10	Horse					
11	Poultry					

12	Others					

7.2. If you did not have enough oxen what do you use for your farm operation?

1. Exchange with labor 2. Exchange (by grass or hay)

3. Hire oxen (rent) 4. Others (specify) ___________

8. Non-farm Income and Household expenditures

8.1 Household non/off- farm income in 2012 E.C

No.	Income sources	Have you generated any income from the following sources last year (2012E.C) √ = yes, × =no	Total amount your family generated last year in ETB
1	Trade		
2	Remittance		
3	Salary		
4	Handy crafts		
5	Casual labor		
6	Aid(cash/in kind)		
7	Others--		

Cash expenditures

No.	Item Name	In the past 12 months, did your household spend Money on this item? √ = yes, × =no	How much did the household spend on the item in the last 12 months? (ETB)
1	Food and drinks		
2	Clothing (dress and foot wear)		
3	Education		
4	Water expense		
5	House rent		
6	transport and communication		
7	Health care		
8	Entertainment (visit of relatives)		
9	Religious& cultural expense		

10	**Gas and Other fuel**		
11	**Animal health expense**		
12	**Government tax**		
13	**Agricultural inputs**		
14	**Others--**		

9. Access to market information

9.1. Do you have access to market? 1. Yes 2. No

9.2. Distance from the market place (in km) ________

9.3. What are the problems in marketing your produce?

1. Transportation problem 2. Low price of agricultural produce

3. Low bargaining power 4. Too far from market place 5. Others (specify) __

9.4. Where do you sell your farm products?

1. On farm (local assembler) 2. Taking to the local market

3. Through service cooperatives 4. Other (specify) ____________________

9.5. Do you get reasonable price for your produce in 2011/12 E.C.? 1. Yes 2. No

9.6. If no, what are the reasons?

1. No demand for the produce 2. More supply of the produce

3. Others (specify) ________________

9.7. Do you get market information about prices and demand conditions of agricultural inputs and out puts? 1. Yes 2.No

9.8. Do you have Mobile and/or Radio? 1. Yes 2. No

9.9. Do you listen to agricultural program on Radio? 1. Yes 2. No

10. Extension issues

10.1. Do you receive any sort of extension services available in your locality? 1. Yes 2. No

10.2. If yes, what are the supports given?

1. Advice 2. Training 3. Demonstration 4. Controlling water distribution 5. Conflict resolution 6. Other (specify) ______

10.3. How many days do you contact the DA's per month? _______

11. Access to credit and Agricultural inputs

11.1. Did you need credit for the production of your agricultural products? 1. Yes 2. No

11.2. Do you have access to credit for your agricultural activities? 1. Yes 2. No

11.3. If yes what are the sources?

1. Cooperatives 2. Local lenders 3. Neighbors and relatives

4. Micro finance institutes 5. Irrigation office 6. Other (specify) _________

11.4. If no why? 1. No collateral 2. No Access to credit supply 3. No need

4. High interest rate 5.Not available on time

6. Religiously forbidden 7.Other, specify___________

11.5. Do you have an access to Agricultural inputs, such as, fertilizer, herbicides and insecticides and irrigation technologies? 1 Yes 2 No

11.6. If yes what are the sources?

1. Cooperatives 2.Irrigation office 3.Agricultural office 4. Other……

12. Diseases and pests

12.1. Have you ever faced a problem of crop failure while you are using irrigation?

1. Yes 2. No

12.2. If your answer for question number 9.1 is yes, what were the possible causes for this problem of crop failure last year?

1. Water shortage 2. Damaged by disease and pests 3. Poor adaptation of varieties used

4. Poor administration of water distribution 5.Others, specify

12.3. Is there any crop raider animal that may destruct your crop? 1. Yes 2.No

12.4. If your answer is 'Yes' for question 12.3 above what do you think about their counter impact on your decision to use irrigation water?

1. Extremely high 2.Very high 3.High 4.Somewhat 5. No impact

13. Farm households' perception about using small-scale irrigation

13.1. Do you think irrigated agriculture is better than rain fed one? 1Yes 2 no

13.1.1. If your answer is yes in question 13.1 above, why?

1. It enables to get more product than rain fed one. 2. It is better to control pests and disease

3. It is easy to produce 4. It does not consume labor and other inputs

13.1.2. If your answer is no in question 12.1 above, why?

1. It consumes labor and too hard to produce 2.There is no demand for the product
3. It is time consuming activity 4. Other specify-----

13.2. Do you think you have technical skill and knowledge to conduct irrigated agriculture?
1 Yes 2 No

13.3. Do you think there is enough support of government for irrigated farming? 1 yes 1 no

13.4. How do you evaluate the profitability of irrigated farming?
1 very high 2 high 3 somewhat 4 not profitable

Guiding Question for Focused Group Discussion

Dear respondent,

The purpose of this guiding question is to collect data for the study on the title the purpose of this study was to assess the effect of small-scale irrigation on household food security in Ada'a woreda. The researcher is going to conduct this study for academic purpose i.e. for a partial fulfillment of degree of Master of Science in food security and development studies. The result of this study will help different stakeholders and policy makers to make appropriate measures on irrigation development in the future. The researcher would like to assure you that your response will be kept confidential. Truthfully, feel free and try to answer the questions honestly and accurately. You are not required to write your name.

General Instructions

- Try to put your answers on the space provided in a neat and readable hand writings.
- It would be advisable if you answer all questions
- Honestly be aware that this investigation has nothing to with religious and political stand

Guiding Question for Focused Group Discussion

1. What are the major opportunities in your local area to utilize small-scale irrigation water?
2. What are the main constraints you face during utilization of small-scale irrigation water in your local area?

3. How do you view the role played by the government in irrigation development in the area?
4. What are important strategies for irrigation development in the area? What type of irrigation water source do you think is more advantageous for the community in the area?
5. What are the major social organizations in the area and what their roles are in irrigated Farming?
6. What do you think are the major environmental problems in the area related with Irrigation?

Thank you for your time and effort in filling this questioner!

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APPENDIX A: CONVERSION FACTORS (TLU)

Used to Compute Tropical Livestock Units (TLU)

No.	Animal Type	Conversion factor in (TAU)
1	Ox	1.42
2	Cow	1
3	Bull	1.2
4	Heifer	0.78
5	Calf	0.43
6	Goat	0.2
7	Sheep	0.2
8	Donkey	0.8
9	Mule	0.8
10	Horse	0.8
11	Poultry	0.04

Source: Jemimah Njuki etal(2011).

APPENDIX B: CONVERSION FACTORS

Used To Compute Adult Equivalent

Age group	Male	Female
<10 years	0	0
10-14 years	0.35	0.35
15-50 years	1	0.8
>50 years	0.55	0.5

Source: Strock et al. (1991) as sited by Seifu, 2018