THE IMPACT OF SMALL-SCALE IRRIGATION ON HOUSEHOLD FOOD SECURITY: THE CASE OF TULIGULED DISTRICT, FAFAN ZONE, SOMALI REGIONAL STATE, ETHIOPIA

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BY

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We hereby certify that we have read and evaluated this Thesis entitled 'The Impact of Small-Scale Irrigation on Household Food Security: The case of Tuliguled district, Fafan Zone, Somali Regional State, Ethiopia.' prepared under our guidance by Mubarak Abdulahi Mohamed. We recommend that it to be submitted as fulfilling the Thesis requirement

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I dedicate this thesis manuscript to my father and my mother for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

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ABBREVIATIONS AND ACRONYMS

ADLI	Agriculture Developments Lead by Industrialization
AfDB	Africa Development Bank
ATE	Average Treatment Effect
ATT	Average Treatment Treated
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agricultural Organization
LSI	Large Scale Irrigation
MoA	Ministry of Agriculture
MoWE	Ministry of Water and Energy
MSI	Medium Scale Irrigation
SSI	Small Scale Irrigation

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ABSTRACT

Ethiopia's agriculture is largely dominated by small-scale rain-fed production, which is vulnerable to irregular rainfall patterns. Small-scale irrigation is considered a key solution to mitigate these challenges, helping to reduce rural poverty and food insecurity while enhancing agriculture's contribution to the national economy. This study examined the impact of small-scale irrigation on household food security in Tuliguled District, Fafan Zone, Somali Regional State, Ethiopia. Using a multi-stage stratified random sampling method, data were collected from 224 households, including 109 irrigation users and 115 non-users. Both primary and secondary data sources were employed. Quantitative data were analyzed through descriptive statistics, binary logistic regression, and propensity score matching. The analysis showed that 45% of irrigation users accessed water from groundwater, while 33% relied on pumped river water. The average treatment effect on the treated (ATT) revealed that households participating in irrigation consumed 1,256.86 Kcal/AE/Day more than non-participants. Descriptive statistics indicated that 75% of participants were food secure, compared to 48% of non-participants. Sorghum and maize were the main staple foods, with food shortages occurring primarily from July to December. Key factors influencing participation in small-scale irrigation included education, household size, land size, distance to markets and water sources, access to extension services, and non-farm income. Households often coped with food shortages through government food aid and consuming less preferred foods. The study concluded that small-scale irrigation is a viable strategy for improving food security in the region. It recommends expanding access to irrigation through government and non-governmental efforts to enhance rural livelihoods.

Keywords*:* *Impact, food security, small-scale irrigation.*

1. INTRODUCTION

1.1 Background of the Study

Food insecurity and hunger are alarmingly increasing in the world. The number of people under acute food insecurity escalated from 80 million during 2015 to 108 million in 2016 and reached 124 million during 2017 (FAO, 2018). Moreover, the figure of undernourished people in the world has also increased to more than 820 million from 804 million during the same years, indicating one person out of nine is undernourished. These figures are clearly showing that the achievements of the Sustainable Development Goal, specifically that of goal-2 (Hunger Eradication) is at risk (FSIN, 2019).

The adoption of improved technologies, such as small-scale irrigation, plays a crucial role in transforming agriculture by reducing risks and uncertainties associated with rain-fed farming. In regions like Ethiopia, where rainfall is irregular and often insufficient, irrigation provides a reliable water source that stabilizes crop production throughout the year. This stability not only increases agricultural output but also enhances household income and food security, thereby contributing significantly to poverty alleviation. According to Hanjra and Gichuki (2008), irrigation has both direct and indirect impacts on household living conditions. Directly, it improves crop yields and enables multiple cropping cycles, which increases the quantity and diversity of food available to families. Indirectly, irrigation supports better nutrition, educational opportunities, and overall economic activities by generating surplus income that can be invested in health, education, and other social services.

Small-scale irrigation development receives special attention due to its low capital demand, despite this, the amount of attention paid to irrigation development in this sector has not improved (Bont et al., 2019). Additionally, current irrigation farms are operating at suboptimal levels, and many small-scale irrigation (SSI) projects are not operating at the required economic efficiency (Getaneh, 2011). Several studies have demonstrated the advantages and disadvantages of irrigation in terms of poverty reduction (Hussain I, 2004). Irrigation, according to most, can increase production and productivity. this, in turn, offers new job opportunities on and off the farm, potentially increasing rural income, livelihoods, and quality of life (Mdoda et al., 2022). Conflicts, climate variabilities, and extremities (severe drought, floods, and storms) are the major driving factors behind global hunger and severe food crises (World Bank, 2018).

These problems are even worse in agrarian countries like those in Africa, in which the larger proportion of the population depends on agriculture (World Vision, 2018). In Africa, about 20 percent of the population (257 million) were hungry, out of which 237 million were from sub-Saharan Africa during 2017 (FAO, 2018). The prevalence of undernourished people in the region was escalated from 181 million in 2010 to 222 million in 2016 and then raised to more than 236 million during 2017 (ECA, 2018).

In Sub-Saharan Africa, total irrigation potential is estimated 33.6 million hectares (FAO, 1996). Regarding the total irrigation area indicated that Africa south of the Sahara irrigates some 5 million hectares and the irrigated area has been growing at a rate of 5% per year. Meanwhile, Modern irrigation in Ethiopia began in 1950's by private and government owned schemes in the middle awash valley in which big sugar, fruit and cotton farms were established (FAO, 1997). In that, the main purpose of irrigation development was provision of industrial crops for the growing agro-industries. As a result, small scale irrigation has not been given much more consideration until the country's strategy i.e., Agricultural development led industrialization (ADIL) considers irrigation development as a key input for having sustainable development. That is why, irrigation development particularly small-scale irrigation is being planned to be accelerated and also improved to have impact on the livelihood of farmers who will engaged on it (MoFED, 2010).

Ethiopia’s agricultural activity is dominated by small farmers, who produce more than 95% of the country’s agricultural output (Zerssa et al., 2021). Agriculture, which accounts for 41.4% of Ethiopia’s GDP and 80% of total employment, is the country’s economic backbone (Matouš et al., 2013). Ethiopian agriculture and the national economy as a whole are characterized by the country’s inability to produce enough food to feed its population (Agidew & Singh, 2018). Famines have occurred in Ethiopia in the past due to high population pressure, resource depletion, and drought, all of which have a significant impact on rainfed agriculture (Taheri et al., 2018). The primary causes of rural poverty and food insecurity have been proven to be low farm production and productivity as a result of the use of outdated technologies and other modern inputs that improve productivity (Pawlak et al., 2021).

In Ethiopia, there is wider gap between irrigation potential and the current level of implementation in terms of irrigated land and the number of participating farmers. This is because of technical, physical and economic challenges. Unlike the potentials, about 97 percent of cereal production in the country is being produced using rainfed and irrigation is contributing only 3 percent for cereal production (FAO, 2015). According to some study, the challenges hindering farmers from fully utilizing the existing irrigation potential were not exhaustively identified in specific areas of the country (ATA, 2016),. But recently, efforts are being made to transform agricultural sector from traditional and rain-fed to technology intensive and mechanized, irrigated and market-oriented agriculture, with packages of post-harvest technologies (FAO and IFC, 2015).

FAO (2016) reports reveal that; in Ethiopia pastoralists are the first and hardest hit by drought in 2015. This implies, the household food security of the pastoral community is not realized in the absence of proper agricultural development and efficient utilization of its water resource for irrigation. Irrigation also allows poor people to increase their production and enhance opportunities to reduce vulnerability caused by the seasonality of agricultural production. Considering this fact the government of Ethiopia has been giving special emphasis to enhance irrigated agriculture in lowland area in order to improve the livelihood and ensure food security (MoA, 2011).

Small scale irrigation schemes enable greater agricultural production than is achieved with rain fed agriculture, help poor farmers overcome rainfall and water constraint by providing a sustainable supply of water for cultivation and livestock, strengthen the base for sustainable agriculture, provide increased food security to poor communities through irrigated agriculture, contribute to the improvement of poor nutrition level, provides a source of household income. However, there is limited evidence on the small scale irrigation schemes that may assist most households through generating sustained food security. As a result, this study can serve as a say for upcoming intervention programs, studies and policy making regarding food security improvements.

1.2 Statement of the problem

Even though, Ethiopia has the potential for development in terms of both vast suitable land and availability of fresh water resources suitable for irrigation purpose, irrigation development in the country is in its infancy stage and not contributing its share to the growth of the agriculture sector accordingly. Currently, limited land is being cultivated under irrigated agriculture and crop production was predominantly based on rain fed agriculture (MOA, 2015). There are a lot of challenges impeding the success of irrigation development are; lack of access to inputs and financing, inadequate farming skills, lack of resources for maintenance of irrigation structures, and resistance to the adoption of new technologies/crops by traditional cereal farmers, combined with Ethiopian farmers extreme risk aversion (Gebul, 2021; Meja, 2020).

A study have documented poverty-related benefits and costs of irrigation. Most of them indicated irrigation can increase production and productivity (Hussain I, 2004). Inversely, low access to new agricultural technologies, traditional methods of cultivation, and low institutional support are identified as factors that keep smallholder production at subsistence level in the country (MoFED., 2012). The use of small-scale irrigation also causes water-borne diseases like malaria, hepatitis, cholera, typhoid, guinea worm, schistosomiasis, sleeping sickness, yellow fever, etc, and increases the occurrence of water-borne diseases around the community(Demissew, 2020).

There are many empirical studies conducted on impact of small-scale irrigation on household's livelihood income like (Kuwornu, 2012) in Ghana, (Zhou, 2009) in China (Gathala, 2013) in India, (Abdissa, 2017) (Gebrehiwot, 2017) (Tesfaye, 2018) (Zeweld, 2015) in Ethiopia found positive impacts of using small scale irrigation on income. (Awulachew, 2010) also argues that water resource management in agriculture is a critical contributor to households' economic and social development of Ethiopia.

However, despite the fact that government established irrigation system in the area, the impact of small-scale irrigation on household food security was empirically not an in-depth study. Most previous studies have concentrated on well-experienced agrarian areas and explained the effects of irrigation primarily in terms of income improvement (Hanjra & Qureshi, 2010; Tadele, 2013; Alemayehu & Bewket, 2017). They did not examine the impact of irrigation on household food security using propensity score matching in Tulliguled woreda. Therefore, this study was done with the objective to analyse the impact of small-scale irrigation on household food security and associated factors in Tulliguled district to provide information for policy maker for further support and investment on small scale irrigation development in pastoral area.

1.3 Objective of the Study

1.3.1 General Objective of the study

The main objective of this research is to analyse the impact of small-scale irrigation agriculture on household food security in Tuliguled District, Fafan zone, Somali region, Ethiopia.

1.3.2 Specific objectives of this study

The specific objectives of the study were:

- To identify the current status of small-scale irrigation practices in the study area
- To determine the food security status of farm households in the study area
- To analyse the impact of small-scale irrigation on households' food security in the study area.
- To identify factors that determines household's participation in irrigation in the study area.

1.4. Research Questions

This study tried to answer the following questions:

1. What is the impact of small-scale irrigation agriculture on household food security in the study area?

2. What are the factors that affect households' food security in the study area?

3. What is the current status of small-scale irrigation agriculture practices in the study area?

4. What is the food security status of farm households in the study area?

1.5. Significance of the Study

The finding of this study can be used to provide baseline information for policy makers on status of agro pastoralist's food security in the study area. On top of this, the research work also provides information for researchers interested to study in another similar research theme.

Also, realizing the impact of irrigation on food security, identifying factors determining household participation in irrigation and also identifying factors affecting household food security in the study area will avail information for farmers, policy makers, researchers and other stakeholders for decision making and formulation of intervention policies and strategies.

1.6. Scope of the Study

The study analyzed the impact of small-scale irrigation on household food security in case of agro pastoralist farm community. It is limited to Tulliguled district, Somali regional state. This study does not represent the whole population of the region. Since assessing household food security status is a difficult issue, maximum effort was made to gather reliable information by convincing farm households to address the objective of the study. Methodologically, the study focused on collecting both qualitative and quantitative data from selected households, using stratified random sampling to ensure representativeness among irrigation users and non-users. The temporal scope of the study covered the agricultural seasons relevant to irrigation practices and food security assessment, primarily focusing on recent years to capture current conditions.

1.7. Limitation of the Study

The researcher encountered several limitations during the data collection period. One major limitation was the difficulty in accessing respondents, as many were engaged in various social duties and marketing activities, which limited their availability. Additionally, poor road infrastructure in the community restricted transportation options, forcing the researcher to cover long distances on foot. This extended the data collection timeline beyond the original p**lan.**

Furthermore, this study is limited in scope, as it focuses only on one district (woreda) and relies on data collected over a single year, which may not fully capture seasonal or long-term variations in household food security. Assessing food security status at the household level proved to be complex due to its multidimensional nature. Despite these constraints, maximum effort was made to collect reliable and accurate data by building rapport with farm households and encouraging their honest participation to meet the study’s objectives.

1.8. Definition of Key Terms

Irrigation: Irrigation is defined as application of artificial water to the living plants for the purpose of food production and overcoming shortage of rainfall and help to stabilize agricultural production and productivity (FAO, 2005).

Small-scale irrigation is a type of irrigation defined as irrigation, on small plots, in which farmers have the controlling influence and must be involved in the design process and decisions about boundaries (Tafesse, 2007).

Food security: Food security has been defined as a situation when all the people, at all times, have physical and economic access to sufficient, safe and nutritious food needed to maintain a healthy and active life (WB and FAO, 2010).

Food insecurity is defined as a situation where people, individuals at times, lack physical and economic access to sufficient, safe and nutritious food needed to maintain a healthy and active life (Frongillo and Nanama, 2012).

Dietary diversity refers to the number of different types of food or food groups consumed over a given reference period (Hodditt & Yohannes, 2002).

Household food security refers to the ability of a household to produce and/or purchase the food needed by all household members to meet their dietary requirements to achieve and maintain an optimal nutritional need.

Propensity Scores Matching: Propensity Scores Matching is a tool that creates a comparison group with the treatment group based on factors that influenced people's propensity to participate in irrigation.

1.9. Organization of the paper

This research paper is organized in Five chapters. Chapter one consists of background in which facts about agricultural production, food security and small-scale irrigation in the country, statement of the problem, objectives of the study and scope and limitation of the study significance of the study are described in detail. Chapter two deals review of related literature that are related to the research topic and its objective. The third chapter deals with design and methodology of the study. Chapter four consists data analyzation, data presentation and discussion. And Chapter five consists conclusions and recommendation.

2. REVIEW OF RELATED LITERATURE

2.1 food security and its measurements

According to Maxwell (1996), food security has evolved through three major paradigms: from focusing on global and national levels to household and individual levels; shifting from a food-first to a livelihood perspective; and moving from objective indicators to subjective perceptions. Between the 1950s and 1970s, the emphasis was on national food availability to meet population demands (Simon & Frankenberger, 1992). In the 1980s, attention shifted to individuals' access to food, while more recently, focus expanded to food utilization, including nutrition and stability over time (FAO, 2008).

The widely accepted definition from the 1996 World Food Summit states that food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food for a healthy life (FAO, 1996). This encompasses four pillars: availability, access, utilization, and stability (Mbaga, 2013; Upton et al., 2016).

Given food security's multidimensional nature, two key issues arise in studies: measurement and econometric modeling (Nkegbe et al., 2017). This discussion focuses on measurement approaches. Various indicators have been developed to capture different dimensions and levels of food security—from global to individual—and can be static or dynamic (Santeramo, 2015). No single measure covers all four pillars, so proxy indicators addressing one or more aspects are commonly used (Upton et al., 2016). Combining multiple indicators provides a more comprehensive understanding of food security in context (Carletto et al., 2013). Measurement methods vary depending on study goals and may include food consumption surveys, caloric intake, dietary diversity, and food insecurity access scales (Mota et al., 2019).Food security is a hard theme to measure since it deals too extensive terms agricultural sub system way with the production, consumption and distribution of all essential human food. On the other hand food insecurity lends itself more readily to measurement and analyzed. It should be emphasized which food security, famine and hunger are not to be complex. As (Marion., 2011), food security refers to the availability of food, whereas, famine and hunger are not the result of the non-availability of food, inappropriate consumption and insecurity through certain period, that mine the outcomes of food insecurity. In addition to the above description Marion Napoli putted Food security is a barometric concept as reflected by the numbers tries to set define it in policy usage and research.

According to Ethiopian national planning commission (2016) report 23.5 % Ethiopians are under poverty line. That mean all the above number people are food insecure. During the (2015/16) nearly one in five Ethiopians required food support drought demonstrates a too high level of food insecurity and a large portion of the population are vulnerable to becoming food-insecure (Cochrane, et 2017). Both the Ethiopian plan commission report and Cochrane agreed that Ethiopian food security problem is both extensive and intensive.

2.1. 1 Dimensions of food security

Callens and Seiffert defined a household as a unit of people living together headed by a household head. This is often a man or a woman, in case there is no man. Increasingly, grandparents are taking up this role, as well as adolescents, in those households where both parents have deceased (Callens, 2003). Apart from the head of the household, there may be a spouse, children and permanent dependents like elderly parents or temporary dependents like a divorced daughter or son. Ellis (1993) defines a farm household as an individual or a group of people living together under one hearth deriving food from a common resource, obtained mainly from farming activities (Ellis, 1993). Jrad et al. (2010) elaborated four dimensions of food security as food availability, food accessibility, food utilization and stability.

Food availability refers to the physical presence of food which may come from own production, purchases from internal market or import from overseas (Jrad et al., 2010; Gregory et al., 2011). On national level, food availability is a function of the combination of domestic food stocks, commercial food imports, food aid and domestic food production, as well as the underlying determinants of each of these factors.

Food access is the ability to obtain sufficient food of guaranteed quality and quantity to meet nutritional requirements of all household members (Jrad et al., 2010). On the other hand, Kuwornu et al. (2012) explained that food access is determined by physical and financial resources as well as by social and political factors.

Food utilization refers to ingestion and digestion of adequate and quality food for maintenance of good health. This means proper biological use of food, requiring a diet that contains sufficient energy and essential nutrients as well as knowledge of food storage, processing, basic nutrition, childcare and illness management (Jrad et al., 2010).

Stability of food is the continuous supply of adequate food all year round without shortages (Jrad et al., 2010). To be food secure a population, household, or individuals must have access to adequate food at all times. The concept of stability can therefore refer to both the availability and access dimensions of food security.

2.1.2 Determinants of Household Food Security

There are too numerous research studies has been conducted particularly in Ethiopia. According to (Abdi., 2015) farmland size, land fertility, irrigation access, household workforce, non-farm revenue, distance from market, education level, health status, volume of rainfall and spreading, adoption of new agriculture technology, crop pasties and diseases, institutional support, dependency ratio, amount and quality of livestock ownerships, and household size were identified as leading determinants factors to ensure household food security.

2.2. Types of Irrigation

Irrigation is defined as application of artificial water to the living plants for the purpose of food production and overcoming shortage of rainfall and help to stabilize agricultural production and productivity (FAO, 2005). According (MoIWE. (Ministry of Water and Energy), 2012) modern irrigation has been documented in the 1960s where the government designed large irrigation projects in the Awash Valley to produce food crops for domestic consumption and industrial crops for exports. Irrigation development is being suggested as a key strategy to improve agricultural productivity and to encourage economic development (Bhattarai, 2007). The adoption of new technology (e.g. irrigation) is the major powerful for agricultural growth and poverty reduction (Norton, 2010).

Irrigation structures can be divided into different scales based on their irrigating potential of a given land. For instance, in (IWMI, 2010) stated that there are three types of irrigation systems based on the size of area under irrigation. These are:

Small Scale-Irrigation (SSI): Small-scale irrigation is a type of irrigation defined as irrigation, on small plots, in which farmers have the controlling influence and must be involved in the design process and decisions about boundaries (Tafesse, 2007). Such schemes involved dams and diversion of streams and rivers. Small scale irrigation (SSI) schemes conventionally, are those cover an irrigated area of land up to 200 hectare. Method of small scale irrigation is often community based and traditional. Examples of SSIs include household based rain water harvesting, hand-dug wells, and shallow wells, flooding, individual household-based river diversions and other traditional methods.

Medium-Scale Irrigation (MSI): which is community based or publicly sponsored, covering 200 to 3,000 hectares.

Large-Scale Irrigation (LSI): Large scale irrigation (LSI) schemes are those irrigation systems that cover an area of 3000 hectares or more.

The success of small-scale systems is due to the fact that they are self-managed and dedicated to the felt needs of local communities. In reality, small-scale schemes are defined as schemes that are controlled and managed by users themselves (IWMI, 2010). The participation of farmers as direct beneficiaries in the construction of the schemes and their responsibility in the operation and management could considerably reduce development and management costs and improves performance. Accordingly, this study has the types of irrigation which is SSI for its appropriateness to specifics objectives desired to be achieved.

2.3. Small-scale Irrigation

Agriculture work is a risky business to it involves inconsistent factors such as erratic weather condition, natural disaster and market failure. Because of global warming and rising of world population number more than any time. Irrigation is the most vital important development investments issue that can have both direct and indirect impacts on reduction poverty and food security. To minimize particularly erratic weather, irrigation is key solution to supply water by artificial way. Irrigation brings a range of benefits to individuals and households that economists sometimes distinguish between primary and spillover effects (Shah, 1993). According to Shah Benefits to people in irrigated areas are increased and more stable flows of income from farming made possible by increased intensity of cropping, improved yields and new farm enterprise /

technology mixes, Appreciation of the value of land with access to water for irrigation. Globally irrigation has been using as a means of improving crop and forage production by heighten the production and productivity of available land as well as expanding aggregated agricultural production particularly to secure food in arid and semi-arid regions of the globe. Availability and access to irrigation had been considered key for crop production, asset creation; eradicate rural poverty, stabilizing food price, increase consumption and expansion of development frontiers. Irrigation is the supply of water to farming crops by artificial systems designed to allow farming in semi-arid and arid regions to minimize the effects of rainfall shortage semi-arid and arid regions. Even though in specific area the total seasonal i, and variable from year to year, irrigation is important for both areas (Wolde, 2003).

2.4 Empirical Review

2.4.1 Irrigation and Food Security

A good deal of research has conducted on impacts of irrigation to food security on household level, country level and regional level. The research conducted by (Desta, 2015) on Impact of Small Scale Irrigation in Household Food Security in Ethiopia concluded that irrigation had positive impacts to reduction in rainfall risk, increased water reliability, enabled households to diversify production to new types of marketable Crops like fruits, cash crops and vegetables, Increased yield of crops and marketing, reduced unemployment, Reduced inequality and poverty, high economic Growth and improve food security. This indicates irrigation has been impacting to nutritional and food security to rural household. In addition to that (Thinah et al., 2016) conducted on irrigation impacts to food security availability had concluded irrigation farming significantly contributes to household food availability and dietary diversity. Different research has ensured irrigation has positive impacts to food security demission that mean accessibility, availability utilization and stability.

According to (Muez, 2014) research held that the food security analyse indicates most non irritating households are poor compare with farmer who is using irrigation. The food insecurity occurrence in non-irrigating households was greater than in irrigating households (Muez, 2014).This is the big evidence to present that the contribution of small-scale irrigation on household food security. In addition to this, the research has been conducted on the impacts of irrigation to food security describes, it had both directly and in-directly impact on enhancing rural households food security through different dimensions. such as diversification of agricultural product, increased agricultural production yields, household income, increase permanent assets farm employment opportunity and participation in community decisions (Dereje, 2016). Many scholars and organization which conducted research on impacts of irrigation to food security had agreed by small-scale irrigation have significant impact to secure foods at all fours food security dimension. To support this explanation the research has been conducted on irrigation scheme in Ghana food security situation has improved after house hold small scale irrigation because agricultural related activities became all year round with dry season gardening providing the necessary ingredients (vegetables) to complement staple foods produced during the rainy season (Ernest, 2013)

According to (Berhane A., 2013); put that the emergence and spread of engagement on small scale irrigation that enable farmers to irrigate their small plots has begun to boost harvests and family income in some world's deepest packets of hunger, including parts of sub-Saharan Africa. Thus, small scale irrigation practice by farmers will result in resisting various problems particularly these related with shortage or absence of rainfall and can scale up their yield. According to (Asfaw A, 2014), stated that, farmers who engaged on small scale irrigation have been found out as being able to resist the frequently occurred drought and more yield. Irrigation contributes to agricultural productivity through solving the rainfall shortage, motivates farmers to use more of modern inputs and harvest throughout the year and creates employment to members of the households especially to wife and children (FAO, 2011).

Moreover, irrigation enhances farm output and thus, with prices remaining constant, raises farm incomes. Output levels may increase for any of at least three reasons. Firstly irrigation boosts yields by mitigating crop loss due to unpredictable, unreliable or inadequate rain water supply. Secondly, irrigation permits the possibility of multiple-cropping and a boost in total output. Thirdly, irrigation enables a greater area of land to be used for crops in times where rain-fed production is not possible or insignificant (Abdi., 2015). As a result, irrigation is expected to increase output and income levels.

Small scale irrigation is also an important driving tool to development effort to ensure better income (Sinyolo S., 2014). Accordingly, (Ahmed, 2014) estimation results indicate that there are significant differences in farm income and food security status between treatment and comparison households, which could be attributable to the participation in small-scale irrigation. Similarly, (Kinfe, 2012) had conducted a study by taking 130 households samples half engaged on small scale irrigation and the other half not and also by using Heckman two stage econometric model to analyse data and reported their findings that irrigation intensifies labor and irrigated farming households' labor consumption ratio is double as compared rain-fed framing households. Thus, small scale irrigation activities excluded households with small family size and high dependency ratio from participation.

2.4.2. Contribution of Irrigation to Household Food Security

Getaneh (2011) argues that irrigation plays a vital role in stabilizing agricultural production and mitigating the detrimental consequences of variable or inadequate rainfall. Both yields and crop quality can also be improved (Getaneh, 2011) (Awulachew et al., 2010). According to FAO (2010), as cited in Jemal (2019), the value of per hectare crop production in irrigated settings is about twice that of rain-fed settings.

Household income and consumption are much higher in irrigated settings than in rain-fed settings, and a 50 percentage point gap is standard. Investments in irrigation will have broader impacts on food security and poverty reduction if attempts are made to revitalize and upgrade existing conventional SSI systems, with funding for improved access to data supply, output marketing, and extension to promote access to information and creativity (Awulachew et al., 2010). Similarly, the impact assessed by Desta in 2013 showed that irrigated farming's contribution to income in highly irrigated settlements is about 70 percent compared with 60 percent in two other low-irrigated settlements. At the same time, the absolute size of agricultural production is still the largest in the heavily irrigated village, considering the smaller size of land ownership and cultivated holdings by more than 30% over the low-irrigated village.

The highly irrigated village has a higher per hectare agricultural income of over 50 percent than the low-irrigated village. Compared to subsistence farming, the cash crop economy with substantial cash flow provides a wide array of off-farm revenue opportunities (Kelilo et al., 2010). Compared to the situation before introducing the schemes, irrigation schemes improved household income and thus improved household food security (Mengistu, 2007).

Increased production, revenue, diet diversification, and decreased hunger months from 6 to 2 months (July and August) resulted in the construction of small-scale irrigation schemes, increased crop diversity, and a change from the cereal livestock system to the cereal-vegetable-livestock system (IFAD, 2011). Through increased demand, higher yields, lower chances of crop failure, and higher farm employment throughout the year, irrigation benefits the vulnerable (Asayehegn, 2011; et al, 2015). Farmers may diversify their planting patterns with irrigation and move from low-value staple agriculture to more valuable, market-oriented output using irrigation. Increased production makes food affordable and cheap for the poor. Irrigation improves livelihoods by improving incomes, food security, employment prospects, addressing social needs, and reducing poverty (MoARD, 2012).

2.4. Conceptual Framework of Household Food Security Determinant Factors

The irrigation and food security framework provides comprehensive and complex approaches in understanding how people make a living. As clearly discussed in literature review section and as revealed in figure 1 below, that household food security and irrigation participation were affected by different factors. The analytical frame work shows that the linkage between household food security and small-scale irrigation in study area. According to their nature, these variables are categorized under four categories. Demographic characteristics which include age, sex, educational status, family size, etc. Institutional factors category includes access to credit, health status, market distance, contact with development agent and food aid. socio-economic factors involve, farm size, livestock size and non-farm income activity and technology adoption such as access to irrigation.

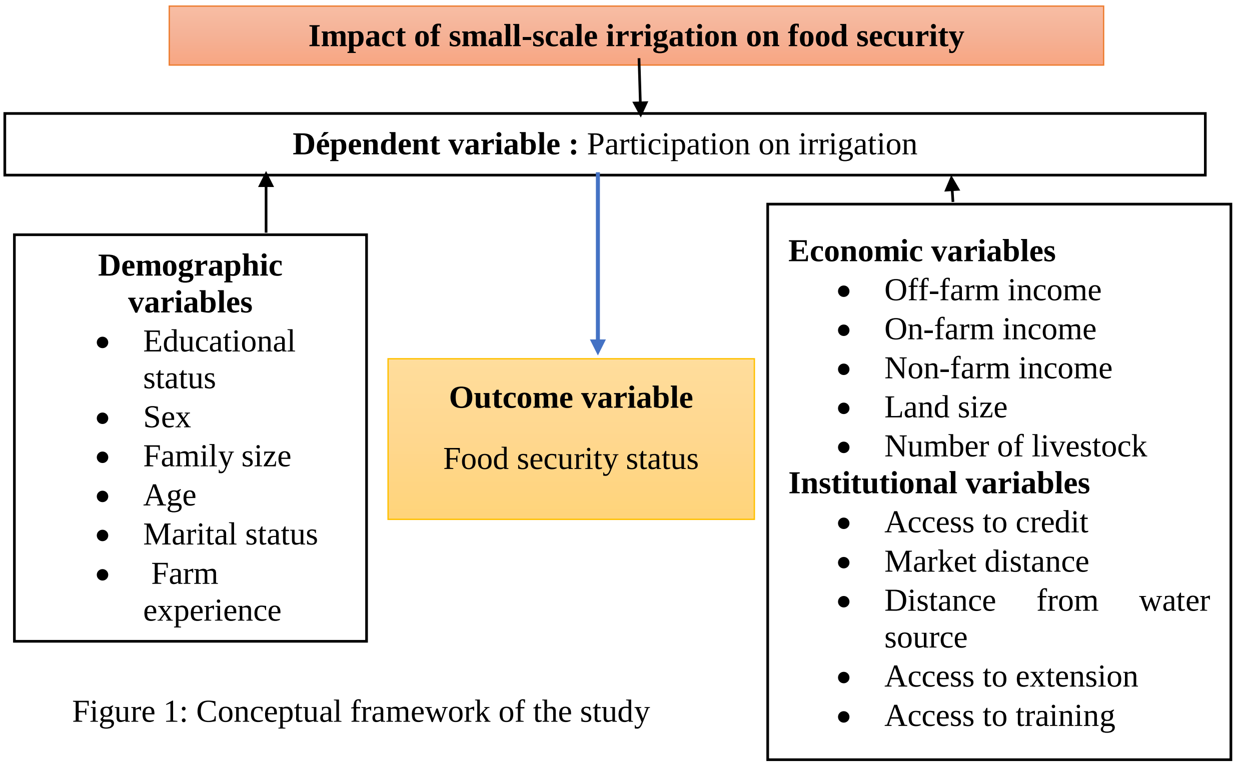


Figure 1: Conceptual framework of the study

Source: Issahaku (2018)

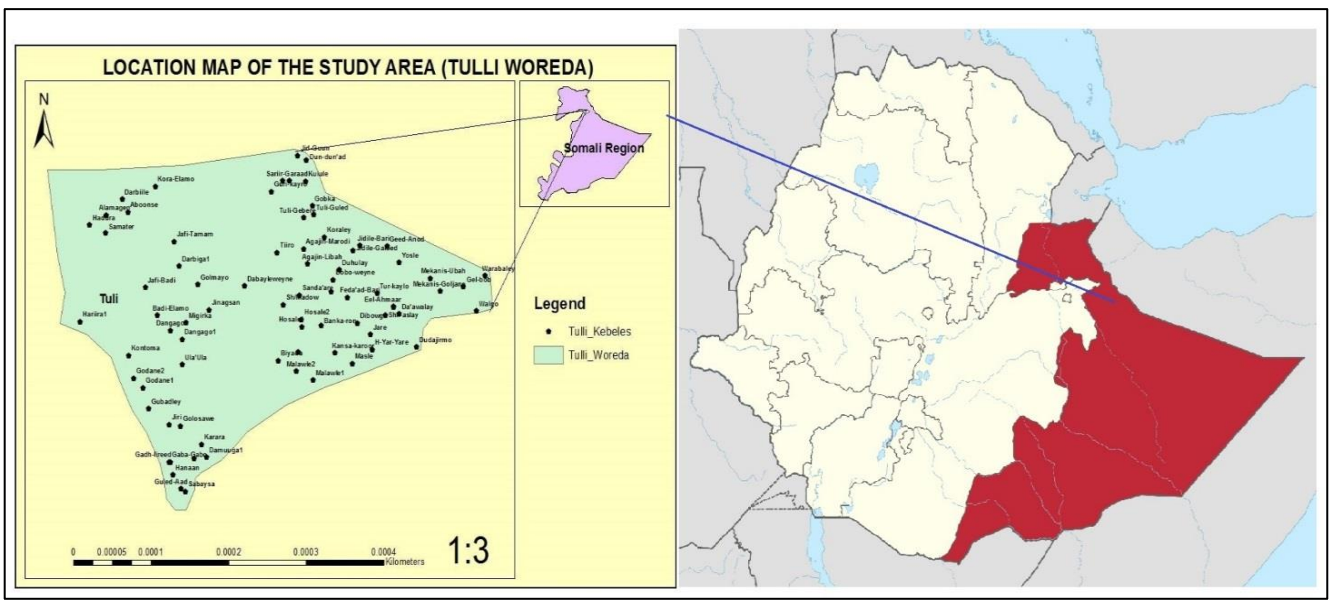
3. RESEARCH METHODOLOGY

3.1. Description of the study area

3.1.1. Location

The research was conducted in Tulliguled Woreda, which is located in the Fafan Zone of the Somali Regional State, Ethiopia. It lies approximately 30 km from Jigjiga city and about 650 km east of Addis Ababa, the capital of Ethiopia. The woreda is predominantly inhabited by agro-pastoralist communities who rely on a combination of farming and livestock for their livelihood. Geographically, Tulliguled is situated at approximately 9°36'54" N latitude and 42°45'11" E longitude. The woreda shares boundaries with Jigjiga to the northwest, Dembel to the northeast, and Gursum to the southwest.

Figure 2: Map of the Study Area, Tuli-Guled Woreda, Eastern Ethiopia

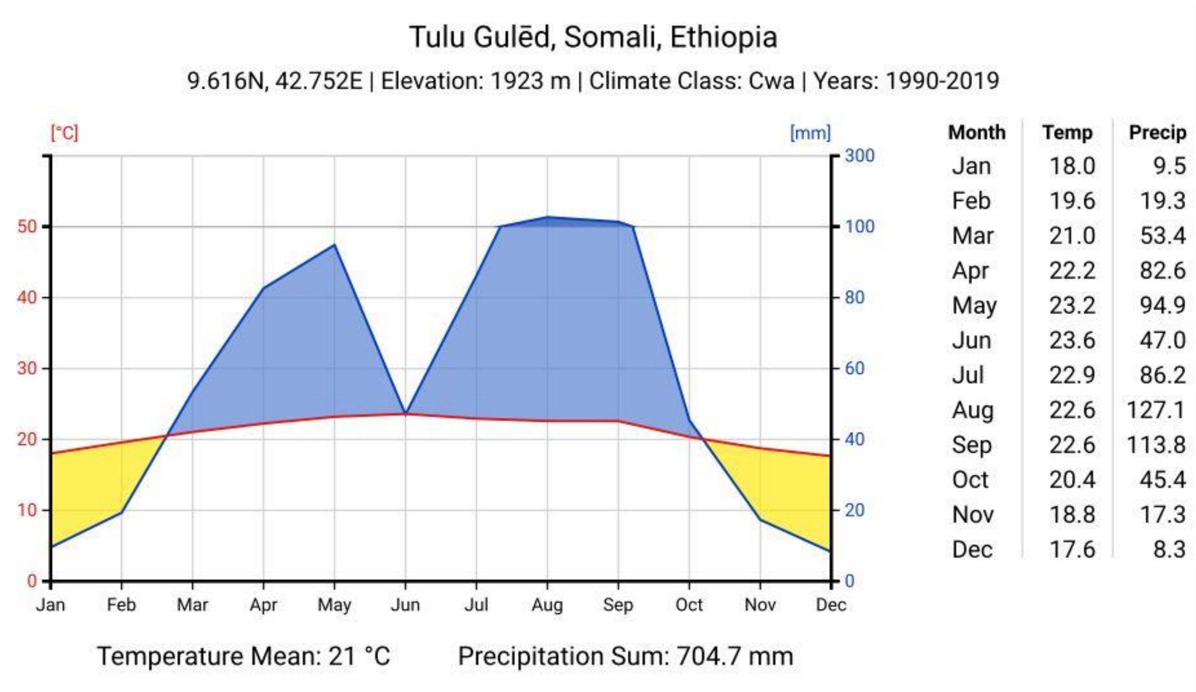


Source; Regional BOFED: 2018 et al (Ahmed,2018)

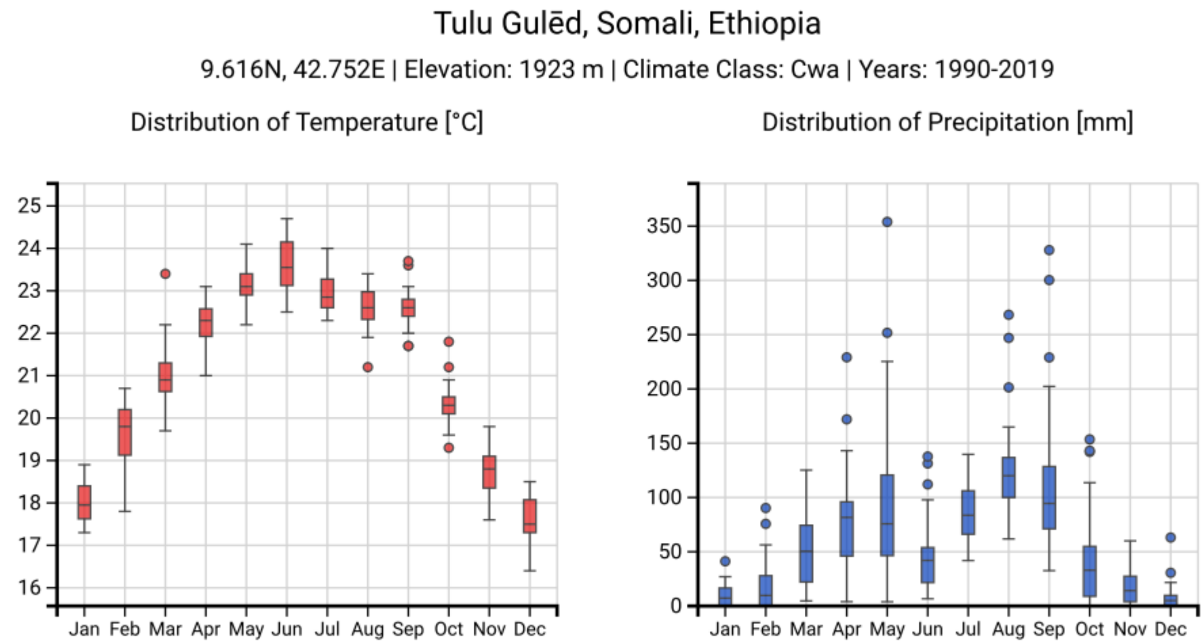
3.1.2. Climate

The annual rainfall in Tuli-Guled Woreda ranges from 500 to 600 mm. Data from the Ethiopian Meteorology Institute (2020) show that the average monthly maximum temperature fluctuates between 25 °C in July and 29 °C in March and April, while average monthly minimum temperatures fall from around 5.8 °C in November to approximately 14 °C between July and September (Ethiopian Meteorology Institute, 2020). Unlike most of the Somali Region, this woreda experiences three distinct sub-seasons during the rainy period (“Guʾ”): Diraʾ (April–May), Hagaa (June–July), and Karan (August–September), each critical for crop production, water availability, and livestock pasture (Hussein & Ali, 2023). The dry season, known locally as Jilaal, spans October to March and includes two shorter subdivisions: Deyr (October–November) and Kalil (December–March) (Ahmed, 2023).

Figure 3. Climate Chart of Tuli Guled district.



Source: https://doi.org/10.1080/17538947.2020.1829112.



3.1.3. Soil types and vegetation cover

The Tuli guled woreda is endowed with an abundance of lush, rain-fed, agriculture land that may be used for a variety of agro-ecological and climatic practices that promote the growth of different crop yields. Based on color, most farmers in the study area identify and name-based soil color and named as clay soil (Caro-Beereed) and sand soil (Caro-gaduud).

Popular tree species among the study areas are Acacia bussie, Acacia Nilotic, Terminalia, Acacia comiphora, and Combretumk collinum. Local people use different purpose for indigenous plants like medicine, fence, shade, charcoal, and fodder. There is some invasive species the most common are Parthenium hysterphorus and Golden Crown Beard are the most prevalent invasive species in the Tuliguled district, primarily affecting thousands of hectares of agriculture fields.

Tuli-Guled Woreda is characterized by gently undulating plains and low-lying hills, with elevations ranging from 1,200 to 1,600 meters above sea level. The topography is generally flat to slightly sloped, making it suitable for both crop production and grazing. The area is drained by seasonal rivers and dry streambeds (toggas) that flow mainly during the rainy season, although water retention is poor due to high evaporation and low infiltration capacity. These seasonal watercourses play a critical role in replenishing shallow groundwater sources used for small-scale irrigation and livestock.

The woreda is endowed with extensive rain-fed agricultural land that supports diverse agro-ecological practices. Farmers commonly distinguish soil types based on color and texture, identifying clay soils (Caro-Beereed) and sandy soils (Caro-Gaduud), both of which influence the type and productivity of crops cultivated.

The region hosts a variety of indigenous tree species, including Acacia bussie, Acacia nilotica, Terminalia, Acacia comiphora, and Combretum collinum. These species serve multiple purposes, such as traditional medicine, fencing, shade, charcoal production, and livestock fodder. However, the area is also increasingly affected by invasive plant species—particularly Parthenium hysterophorus and Golden Crown Beard (Verbesina encelioides)—which threaten thousands of hectares of farmland by displacing native vegetation and reducing soil productivity.

3.1.4. Population characteristics and Socio-economic activities

Based on the data collected by Bureau of Finance and Economic Development in 2016 report total population of Tulli-guled district are 24,412 (82,209 male and162,012 female). The Woreda's population is made up of about 75% sedentary farmers and the remaining people who work in trading and animal rearing (Lara, 2022).

The majority of Tuli-guled woreda population rely primarily on agro-pastoralism for their income. They raise a variety of animal species, such as camels, sheep, goats, and cattle, in addition to producing maize, wheat, and sorghum. Men work in agriculture, and women are frequently involved in small-scale trade. The livelihood of societies is varied like Sales of crops, livestock and livestock products. Crops are the main sources of income generated of this area.

3.2 Research Approach and Design

A research design is the program that guides the researcher in the process of collecting, analyzing and interpreting the data. A research design can be defined as the strategy, the plan, and the structure of conducting a research project majority (Mtonga 2014) citied (Carriger, 2000). The research design for this particular study was a cross-sectional survey study with both quantitative and qualitative components were conducted. For this study, the researcher used mixed approaches consisting of both quantitative and qualitative methods.

3.3 Data Sources and Types

The study used both primary and secondary data sources. Primary data were collected directly from the respondents who were selected from users and non-users of irrigation in each selected kebele. Key informants, focus group discussants and respondents for the questionnaires were the primary sources of this study. . Both qualitative and quantitative data types were used. Quantitative data were done by administering structured questionnaires and qualitative data were taken from focused group discussion and key informant interview. The quantitative data was used to assess socio-demographic, socio-economic characteristics, institutional aspect, technology and food security status of the households. Qualitative method used to capture data pertaining to local perception and opinions the impact of irrigation on household food security. This had done by using one FGD and KIIs in each of the selected Kebeles. Secondary data was reviewed and consolidated from different documents both published and unpublished materials, which are relevant to the study.

3.4. Methods of Data Collection Techniques

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 questionnaire was first prepared in English and later translated into the local language (Somali), so that the respondents can easily understand the questions. The enumerators, one for each kebele, was employed based on their ability of local language and culture, and experiences in data collection. Training was provided to the enumerators on the procedure to follow while conducting interview with respondents and deep discussion was also held to make the questionnaire clear.

Focus Group Discussions

The focus group discussions (FGD) members composed of both men and women those are not involved in the individual interviews, and other social groups in different age composition. One focus group discussion at each study areas were conducted and each focus group comprised eight individuals. The output of the discussion was used as a guide to the design of household questionnaire and to get additional supporting qualitative evidence of the on current situation of household food security and challenges that farmers have been facing in irrigation activity.

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 was conducted with key informants (KIIs). Thus, two experts from two different departments, such as irrigation and Productive Safety Net Program expert, one development agents (DA) from each kebele, one committee member of irrigation water user's association from each kebeles was included as a key informant interview.

3.5. Sampling Procedure and Sample Size Determination

The target population is the total group of individuals from which the sample might be drawn. In the study area 3794 rural households have been using small-scale irrigation on the other hand 4853 rural households have not been using small-scale irrigation. The two target group of the total population 8647 households in the study area.

In this study multi stage sampling procedure was followed to select the respondent household. In the first stage, three rural Kebeles administrations were selected randomly from five irrigation potential Kebeles of the study area. After randomly selecting the kebeles, the study had irrigation user and non-user group who are living in the selected Kebeles. So, in the second stage, the research used stratified sampling techniques. Because stratified sampling is a one type of sampling techniques in which the total population is divided in two small group or strata to complete this research sampling process. Therefore, in the three randomly selected Kebeles, households were stratified into two strata (small-scale irrigation users and non-users). To end with, the researcher selected respondent that are using or not using irrigation household sampling random technique from each stratum.

Then, sample size was determined by using the simple formula developed by (Yemane 1967) at precision level of 90 %. Following this, to identify respective sample for each stratum in each

Kebeles, sample proportion to the population was employed. Based on this, 99 households from irrigation users and 105 households from non-users total 204 and 10 % contingency 224 sample were identified. Finally, respondent households were selected by using the simple random sampling technique from each stratum.

n = N / 1+N (e) 2 (1)

Where, n= sampling size

N= total population e = error (above 90% level of confidence) the confidence level of this research is 90% The household of irrigation using in the study area are 3794 and nonuser are 9880. So the sample by the above equation

n = 3794

$1+3794(0.1)^2$ = 99 sample was used from the total irrigation user household

n = 4853

$1+4853(0.1)^2$ =105 sample was used from the total nonuser household.

Therefore, the total sample size for irrigation users and nonusers is 204 households. with a 10% contingency of 224 households (user= 109 and non-user = 115).

3.6. Method of Data Analysis

3.6.1. Descriptive statistics

The descriptive analyses tools used are mean, percentage mean, and standard deviation. The descriptive statistics was run to observe the distribution of the independent variables. The socio-economic and institutional characteristics of the respondents such as age, sex, level of education, farm experience, household size in adult equivalent, cultivated land holding, soil fertility, livestock holding, access to extension service, access to credit, distance to market, distance to farmer training center, and uses of household heads are analyzed.

T- statistics and chi-square (χ 2) tests was used to identify whether the variables are statistically significant or not. The t-test was used to test the significance of the mean value of continuous variables of the two groups of users and non-users and chi-square (χ2) is used to test the significance of the mean value of the potential discrete (dummy) explanatory variables.

3.6.2 Measuring Food Security

The measurement of food security has been performed according to the households' calorie intake on the calorie value of each food items, which was constructed from World Health Organization of the food nutrition table. The total calorie obtained from consumption of this basket of average quantity per adult by an individual is:

$$\sum_I q_i k_i = T^* \qquad \text{Equation (2)}$$

$T \approx T^*$, but $T \neq T^*$. Here T^* is total calorie obtained by individual adult from consuming the average quantities, q_i is average quantity per adult of food item i consumed by individual for seven days, K_i the caloric value of the respective food item i consumed by individual adult and T is recommended consumed calorie per day per adult for Ethiopia, i.e. 9210 kJ =2200 kcal (Source).

The average quantity per adult of each food item scales up and down by a constant value T/T^* so as to provide total of 9210 kJ = 2200 kcal per adult per day before doing any activities. Then, multiply each food items after scaling up and down by the median price and sum up to get a food insecurity line. A household was then considered food secure or insecure if the daily-recommended calorie was equal or above and below the food insecurity line respectively.

3.6.3 Measuring the impact of small-scale irrigation on food security

Propensity score method is a statistical tool, which uses a matching technique that attracted the attention of social program evaluators (Jalan and Ravallian, 2003; Degejia and Wahba, 1999). PSM is a non-parametric estimation method that works by re-weighting the comparison sample to provide an estimate of the counterfactual of interest- what the outcome of a beneficiary household would have been if it not received program benefits. Since productive safety net program has targeted poor, highly vulnerable and food insecure households in a non-random manner, comparison of mean outcomes between beneficiaries and non-beneficiaries would lead to biased estimates. In order to circumvent this problem, the study uses the matching technique called propensity score matching method, which is capable of extracting comparable pair of treatment. Comparison of households in a non-random program was setup the absence of baseline data.

The approach assumes that after controlling for all pre-program observable household and community characteristics that are correlated with technology participation and the outcome variable, non-participants have the same average outcome as beneficiaries would have had if they did not receive from the activity. PSM provides biased estimates of program impact if, for any chosen outcome, it is not feasible to control for enough observable characteristics. In other words, the outcomes in the untreated state are independent of irrigation participation conditional on a particular set of observable characteristics. This is conditional independence assumption, the ignorable treatment assignment (Rosenbaum and Rubin, 1985), and the assumption of selection on observables (Heckman and Robb, 1985), denoting by X the set of observables, the identification assumption can be expressed as

$$Yo \perp D|\mathrm{P}(x) \quad (2)$$

Where the symbol ⊥ denotes independence and P(x) is the propensity score. Actually, we require an even weaker condition to identify out treatment parameter, that of conditional mean independence:

$$E(Y\mathrm{o|D} = 1, \mathrm{P(x)} = \mathrm{E(Yo|D} = 0, \mathrm{P(x)} \quad (3)$$

By conditioning on we can get an estimate of the unobserved component in the TT parameter. In particular, we can identify the parameter as follows:

$$TT(x) = E(Y\iota|D = 1, P(x)) - E(Y\mathrm{o|D} = 1, \mathrm{P(x)}) \quad (4)$$

$$= (Y\iota|D = 1, P(x)) - E(Yo|D = 0, P(x)) \quad (5)$$

A valid measure of the effect of irrigation should compare outcomes in households that are beneficiaries to what those outcomes would have been had the same households which is not not participated non-beneficiaries. The estimator constructs a plausible comparison group by matching re-settlers to similar non-re-settlers using a rich set of control variables.

Following Smith and Todd (2005), let Y_1 be a household outcome if it is a re-settler and let Y_0 be a household's outcome if it does not benefit. The impact of small-scale irrigation is the difference in the outcome caused by practicing irrigation. To construct an estimate of the average impact of small-scale irrigation on those that receive it the average impact of the treatment on the treated (ATT):

$$ATT = E(Y\iota - Yo|S = 1) \quad (6)$$

$$= E(Y\iota|D = 1 - E(Yo|D = 0) \quad (7)$$

Let D be an indicator variable equal to 1 if the households participating in the small-scale irrigation and 0 otherwise. We can observe the first term of equation (3), but the second term is not observable, households participating in the program cannot be simultaneously observed in two states. A household can be either in the irrigation or outside the irrigation. Hence, this study applies a propensity score matching technique to estimate the impact of small scale irrigation on food security by estimating the counterfactual outcome for participant (beneficiary) (Rosenbaum and Rubin, 1983).

According to Caliendo and Kopeinig (2000), there are steps in implementing PSM. These are estimation of the propensity scores, choosing a matching algorism, checking on common support condition and testing a matching quality.

Estimation of the Propensity Scores

Propensity score matching estimators (Rosenbaum and Rubin, 1983) are widely used to estimate treatment effects. Rosenbaum and Rubin (1983) define the propensity score as the conditional probability of assignment to a treatment given a vector of covariates (Abadie and Imbens, 2012).

Propensity score matching involves a series of empirical steps. First of all a Logit model that predicts the probability of each household's participation (propensity score) as a function of observed household and community characteristics was estimated, using a sample of program participant and non-participant. In estimating the propensity score, the dependent variable used in the model was a binary variable taking a value of 1 for participants in the small-scale irrigation and 0 otherwise.

This involves running a logit model that predicts the probability of each household participating in the irrigation as a function of observed household and community characteristics using a sample of the irrigation participant and non-participant. The estimates of individual participation using Logit models are useful for two reasons. First, it gives some insight regarding the observable variables that should be included in the balancing function. Second, it provides a better understanding of participation of the kebeles people in the irrigation.

In estimating the Logit model, the dependent variable is participation, which takes the values of 1 if the household participated in the program and 0 otherwise. The explanatory variable in the model includes measures of household head age, sex, education, marital status, family size, annual income, livestock ownership, size of Cultivated land, distance from water source, Distance from market, Off and Non-farm activities, access to credit, access to extension and Access to training, etc.

The mathematical formulation of Logit model is as follows:

$$P_i = E(Y = 1 / X_i = \frac{1}{1+e^{(\beta_0 + \beta_1 X_1)}} \quad (8)$$

Equation 8 expresses the probability that a household is participated in the program as:

$$P_i = \frac{1}{1+e^{-Z}} \quad (9)$$

While, the probability for not being participated is expresses by:

$$1 - P_i = \frac{1}{1+e^{Z}} \quad (10)$$

Therefore, we can write it as:

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z}}{1+e^{-Z}} \quad (11)$$

Now, ($P_i/1-P_i$) is simply the odds ratio in favor of participating in irrigation i.e. the ratio of the probability that the household participated in the irrigation to the probability of not participating.

Finally, taking the natural log of equation 11 we obtain

$$L_i = \ln \frac{P_i}{1-P_i} = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (12)$$

where: P_i= is the probability of being participated in irrigation.

Z_i= is the function of explanatory variables (X_i) which is also expressed as β_o is an intercept.

β_1, $\beta 2 \ldots \beta n$ are slopes of the equation in the model.

L_i = is the log of odds ratio, which is not only linear in X_i but also linear in the parameters.

X_i= is pre-intervention characteristics.

If the disturbance term U_i is introduced the logit model becomes

$$Zi = \beta o + \beta\iota X\iota + \beta 2X2 + \cdots + \beta nXn + \cup i \quad (15)$$

The major concern of this regression is to predict the probability of a household to participate in the irrigation or to predict the propensity score, based on which the treatment and control groups have been matched. The independent variables are presented in Table 1 below. Other variables and relation within the model variables was tested and controlled by conducted or checked multicollinearity test and related tests.

Definition of variables

Dependent variable

The dependent variable for this study is participation in small-scale irrigation. It is measured as a dummy variable where the value 1 was given for household who are using irrigation on their farm and 0 otherwise

Outcome variable

For this study, food security status of households was taken as the outcome variable. This variable was measured by household calorie intake.

Table 1: Independent variables type and expected signs

Variables	Definition	Variable type	Hypothesis
SEX	sex of the household head	Dummy	+
Marital status	Marital status of household heads	Dummy	-
Age	Age of household heads	Continuous	-
Family size	Number of family members in the household	Continuous	+
Education status	Education status of the household head	Dummy	+
Credit access	Access to creadit for the household	Dummy	+

Land size	Landholding size of the household head	Continuous	+
Distance from market	Distance of household residence from market	Continuous	-
Distance from water source	Distance of household land from water source	Continuous	-
Extension access	Access extension to the household	Dummy	+
Training access	Training access to the household	Dummy	+
Farm experience	Farm experience of household head	Continuous	+
Livestock size (TLU)	Livestock holding of the household in tropical livestock unit	Continuous	-
Off farm income	Annual income of the household from off-farm income sources in ETB	Continuous	-
On farm income	Annual income of the household from on farm income sources in ETB	Continuous	+
Non-farm income	Annual income of the household from non-farm income sources in ETB	Continuous	-

4. RESULTS AND DISCUSSIONS

4.1. Demographic and Socio-economic characteristics of respondents

The demographic and socio-economic characteristics of the sample respondents was conducted using descriptive statistics such as percentage, mean, frequency, and standard deviation and inferential statistics such as Chi-square test for categorical variables and independent t-test for continuous variables. The two groups (participant and non-participant) of sample respondents were compared and contrasted with independent variables. A total of 109 users and 115 non-users of respondents were interviewed and used in this study.

In the study area, small-scale irrigation is increasingly playing a critical role in shaping household food security and livelihoods. Out of a total of 224 sampled households, 109 (48.7%) were identified as irrigation users, while 115 (51.3%) were non-users, reflecting a nearly balanced comparison between the two groups.

Sex: The results in Table 2 show that out of 224 respondents, 59.4% of them were males and 40.6% female respondents. From the total irrigation user households 61.5% were males while 38.5% were female headed. Similarly, 57.4% non-participant households in irrigation were males and 42.6% were female headed. The Chi-square test indicated that the sex of households had significant difference between being participant and non-participant in irrigation at 5% significant level. This can be explained that in the study area, division of labor is largely governed by gender, which allows men to be responsible for crop production while women are responsible for domestic work which is in line with Kedir et al. (2019).

Education: The results in Table 2 show that 81.3 % of the respondents in the area had no formal education whereas 18.7 % had formal education. Regarding irrigation participant households, 81.7 % had no formal education where the rest 18.3 % households had formal education. On the other hand, non-participant households 80.9% had no formal education while 19.1% had formal education. This indicates that households with better educational background are more engaged in small-scale irrigation than households with no education. The Chi-square value shows that the education level of households had significant difference between irrigation participant and non-participant household at 10% significant level. This is supported by Jambo et al. (2021) who found that education has positive contribution for participation of households in irrigation.

Marital status: The results in Table 2 show that 89.3 % of the respondents in the area were married whereas 10.7 % had formal education. Regarding irrigation user households, 90.8 % were married where the rest 9.2 % households were unmarried. On the other hand, non-user households 87.8% were married while 12.2% were unmarried. The Chi-square value shows that the marital status of households had no significant difference between irrigation participant and non-participant households.

Table 2: Categorical socio-economics characteristics of respondents

Variables	Category	Non-user		user		Total		χ^2
		F	%	F	%	F	%	
Sex	Female	49	42.6	42	38.5	91	40.6	38.6**
	male	66	57.4	67	61.5	133	59.4	
Education	Illiterate	93	80.9	89	81.7	182	81.3	2.2*
status	Literate	22	19.1	20	18.3	42	18.7	
Marital	Unmarried	14	12.2	10	9.2	24	10.7	0.5
status	Married	101	87.8	99	90.8	200	89.3	

****, ** and * significant at 1%, 5%, and 10% significance level*

Source: Sample Survey, 2024

Age: The mean age of non-user households was 41.99 years and that of user households was 41.28 years (Table 3). The statistical analysis revealed that there is no significant difference in the mean age of the household head between user and non-user households.

Family size: Family size in adult equivalents indicates the sample household's average family labor force for agricultural production and other income-generating activities. The average family size in adult equivalents in the study area was 6.84 with standard deviation of 2.95 for non-participant households. The result also shows that the mean family size of participant households was 6.7 with standard deviation of 2.82. The t-test shows that there is no significant difference between participant and non-participant households (Table 3).

Land size: The mean land holding of user households was 2.14 hectares while non-user households had 1.32 hectare. This shows that in the study area irrigation user households had larger land size as compared to non-user households. The t-value shows that there is significant mean difference in land holding between irrigation user and non-user households at 5% significant level.

Livestock holding: According to FGD and KIIs participants, livestock production plays an important role in the study area. Farmers rear livestock for various purposes such as for food (source of egg, milk and meat), means of transport, and source of cash for urgent needs. Livestock is also considered as a measure of wealth in the rural area. Farm households having a number of livestock are considered as wealthy farmer in the farm community. Livestock holding widely varied among the sampled households (Table 3). The average size of livestock holding in tropical livestock unit (TLU) for participant and non-participant households were 13.50 and 12.35 TLU with standard deviation of 9.35 and 8.79 respectively. The survey result shows that irrigation participant households possessed relatively higher number of livestock than non-participant households even though the t-value shows that there is no significant mean difference between two groups.

Table 3: Continuous socio-economic characteristics of respondents

Variables	Non-user (N=115)		User (N=109)		t-value
	Mean	SD	Mean	SD	
Age of household	41.99	11.47	41.28	12.78	0.44
Family size of the respondent	6.84	2.95	6.70	2.82	0.38
Land holding size	1.32	1.29	2.14	1.16	3.33**
Number of livestock owned (TLU)	12.35	8.79	12.50	9.35	-0.124

****, ** and * significant at 1%, 5%, and 10% significance level*

4.2. Access of different facilities

Distance from residence to market: The result showed that sampled participant households are located on average of 4.56 km away from market (Table 4). The mean distance of non-participant households from the market source was 9.86 km. The t-test below shows that there is a significant mean difference in distance from market between participant and non-participant households.

Distance from irrigation water source: The mean distance of participant and non-participant households from irrigation water source was 4.56 km and 5.15 km respectively and had a negative impact on irrigation participation at 1% probability level. The possible explanation is that; as a household far from irrigation water source, access to get enough water for irrigation is reduce as a result of cost of operation of labor and time is increase and reduce participation in irrigation. The result confirmed the study of Sinyolo et al., (2014) who found that distance of farmer's homestead from the irrigation scheme had a negative influence on the farmer being an irrigator.

Farm experience: The compression by the farming experience in small scale irrigation reveals those 32.81 participants and 31.1 non-participants are found to be farming experience. The average farming experience of the participant was higher than that of non-participant. However, the test statistical analysis revealed that there is no significant difference in farming experience between irrigation participant and non-participant households.

Table 4: Different access of households

Variables	Non-user (N=115)		User (N=109)		t-value
	Mean	SD	Mean	SD	
Distance from water sources	5.15	3.67	4.56	4.30	-1.76*
Distance from residence to market	9.86	8.50	6.22	4.85	4.57***
Farm experience in years	31.10	13.09	32.81	15.23	-0.90

***, ** and * significant at 1%, 5%, and 10% significance level, respectively.

4.3 Impact of small-scale irrigation on households' food security

4.3.1. Current Status of Household Well-being

This section compares the current status of key livelihood and food security indicators between irrigation users (n = 109) and non-users (n = 115**)**. The analysis focuses on actual household conditions—such as food security, employment status, aid dependency, and livelihood diversification—rather than self-reported improvements.

As shown in Table 5**,** 29.4% of irrigation users were classified as food secure compared to 15.7% of non-users, a statistically significant difference ($\chi^2 = 13.113$; $p < 0.01$), suggesting a strong association between irrigation use and household food security.

Likewise, a slightly higher percentage of users (39.4%**)** reported that at least one household member was currently employed in off-farm or wage work compared to 35.7% of non-users.

Though the difference is modest, the chi-square test shows that the variation is not statistically significant **(**χ^2 = 0.342; p = 0.559**).**

Aid dependency also differs notably: 23.5% of non-users reported relying on aid, while only 8.3% of users did. The difference is statistically significant (χ^2 = 9.164; $p < 0.01$), indicating that irrigation users are less likely to depend on external assistance.

In terms of livelihood diversification**,** 25.2% of non-users and 22.9% of users were engaged in diversified livelihood activities. However, the difference is not statistically significant **(**χ^2 = 0.179; p = 0.672), implying similar patterns across both groups.

These results, reinforced by Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs), suggest that small-scale irrigation is associated with greater food security and reduced aid dependency, though impacts on employment and livelihood diversification appear less distinct. These findings align with earlier studies (e.g., Kedir et al., 2019; Jambo et al., 2021), which found that small-scale irrigation enhances food security and household resilience.

Table 5: Current Status of Household Food Security and Livelihood Indicators by Irrigation Use

Indicator	Response Type	Non-Users (n = 115)	Users (n = 109)	Total (n = 224)	χ^2	p-value
Food Secure Households	Count	18	32	50	13.113	0.000***
	%	15.7%	29.4%	22.3%		
Households with Employment	Count	41	43	84	0.342	0.559
	%	35.7%	39.4%	37.5%		
Aid-Dependent Households	Count	27	9	36	9.164	0.002***
	%	23.5%	8.3%	16.1%		
Diversified Livelihoods	Count	29	25	54	0.179	0.672
	%	25.2%	22.9%	24.1%		

***, ** and * significant at 1%, 5%, and 10% significance level, respectively.

4.3.2. Impact for common support region

An essential step in propensity score matching (PSM) is to check the common support condition, which ensures that there is sufficient overlap in the distribution of propensity scores between treatment and control groups. Only observations that fall within this common support region are considered for matching. Those outside this region are excluded, as reliable estimation of the treatment effect is not possible for them.

As shown in Table 6**,** the estimated propensity scores for the treatment group (irrigation users, n = 109) range from 0.1435 to 0.9732**,** with a mean of 0.6731 and a standard deviation of 0.394. For the control group (non-users, n = 115)**,** propensity scores range from 0.0554 to 0.7615, with a mean of 0.345 and a standard deviation of 0.164**.**

Given these distributions, the common support region lies between 0.1435 and 0.7615**,** which is the overlapping interval of the two groups. This means that households with estimated propensity scores below 0.1435 or above 0.7615 were excluded from the matching procedure. However, after applying this criterion, no observations were excluded from the analysis all 224 households (109 treatment and 115 control) fall within the common support region. This result is consistent with the findings of Kedir et al. (2019)**,** who also reported full inclusion of observations within the common support region in a similar context.

Table 6: Estimated Propensity Score Distribution

Sample Group	Observations	Mean	Std. Deviation	Minimum	Maximum
Control Households	115	0.345	0.164	0.0554	0.7615
Treatment Households	109	0.6731	0.394	0.1435	0.9732
Total Households	224	0.673	0.241	0.1435	0.7615

To estimate the impact of small-scale irrigation on household food security, predicted propensity scores were used to match farmers with similar observable characteristics. This approach enables a valid comparison between irrigation users (treatment group) and non-users (control group). According to Rosenbaum and Rubin (1983)**,** only observations within the common support region are considered for matching; observations falling outside this region are excluded, as the treatment effect cannot be estimated for them.

In this study, the estimated propensity scores ranged from 0.1435 to 0.9732 for treatment households and from 0.0554 to 0.7615 for control households. Households with scores below 0.1435 or above 0.9550 were excluded from the matching process **(**Figure 4**).**

To assess the overlap between the treatment and control groups, a visual analysis of the propensity score distribution was conducted. This involved plotting the density and frequency distributions of the scores for both groups. The assumption of common support requires that the probability of receiving treatment, conditional on covariates, lies strictly between 0 and 1. Any household with a score outside this range was excluded from further analysis.

Figure 4 presents the histogram of propensity scores, showing the distribution for both treatment and control groups. The graph reveals a substantial region of overlap, indicating that the common support condition is well satisfied. This confirms the absence of a serious support problem and validates the matching procedure. Importantly, the purpose of this analysis is not merely to estimate treatment probabilities but to ensure credible matching of households.

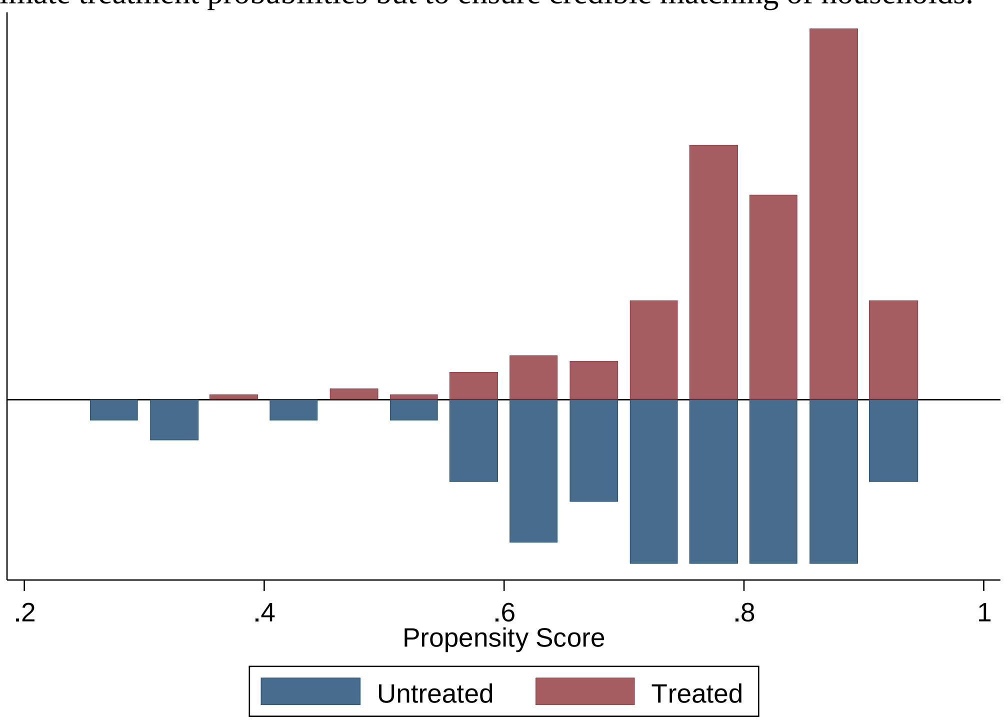


Figure 4: Common support region graph.

4.3.3. Balance test for propensity score and covariates

Following the selection of the best-performing matching algorithm, the next step was to assess whether the distribution of propensity scores and covariates was balanced between the treated group (irrigation users, $n = 109$) and the control group (non-users, $n = 115$). The primary aim of estimating propensity scores was not to achieve high prediction accuracy of treatment status, but rather to ensure comparability between the two groups based on observable characteristics after matching.

The matching procedure significantly improved covariate balance, as demonstrated by several diagnostic tests. First, the mean standardized bias across key covariates was substantially reduced after matching, indicating that the differences between treated and control groups were minimized. Second, independent sample *t*-tests revealed no statistically significant differences in the means of covariates between the two groups post-matching. This suggests that the matching was successful in equalizing the distributions of covariates. Third, a chi-square test for joint significance of all covariates showed that, after matching, the covariates jointly no longer predicted treatment assignment, confirming the effectiveness of the balancing process.

Table 7 presents a detailed summary of the balancing test results. For each covariate, the table reports two rows: one for the unmatched sample (“U”) and another for the matched sample (“M”). These rows show the covariate means, the percentage of standardized bias, the bias reduction achieved, and the *t*-test statistics. The fifth and sixth columns of the table summarize the average standardized bias before and after matching, and the total bias reduction achieved by the matching procedure.

Before matching, the standardized differences in covariates ranged from 3.7% to 45.2% in absolute terms, indicating substantial imbalance. After matching, the remaining differences ranged from 0.1% to 7.7%**,** all of which are well below the commonly accepted threshold of 20%, as recommended by Rosenbaum and Rubin (1985). This confirms that the matching process substantially improved balance across all observed covariates.

In addition, the pseudo-R^2 value dropped significantly from 0.287 (unmatched) to 0.019 (matched), and the likelihood ratio chi-square statistic became statistically insignificant (p = 0.359) after matching. This further indicates that the matched treatment and control groups are similar in terms of covariate distribution. These results provide strong evidence that the matching procedure effectively eliminated observable differences between irrigation users and non-users.

Given this high degree of covariate balance, we proceeded to estimate the Average Treatment effect on the Treated (ATT**)**. The matched sample allows for a valid comparison of food security outcomes between irrigation users and their statistically similar non-user counterparts, improving the credibility of the impact evaluation.

Table 7: Chi-Square Test for Joint Significance of Covariates

Sample	Ps R^2	LR χ^2	$p > \chi^2$	Mean Bias	Median Bias	B	R	%Var
Unmatched	0.287	140.18	0.000	35.3	23.0	139.1*	0.34*	60
Matched	0.019	10.98	0.359	6.4	4.3	31.8*	1.55	20

Source: Sample Survey, 2024

4.3.4. Estimating treatment effect on the treated

In this section, the impact of small-scale irrigation participation on two key outcome variables—daily calorie intake per adult equivalent and total household income—is estimated using the Propensity Score Matching (PSM) approach. This analysis controls for pre-intervention differences in observable characteristics between irrigation users (*n = 109*) and non-users (*n = 115*), allowing for a more accurate estimation of the program's effect on beneficiaries.

The results presented in Table 8 provide strong evidence of a statistically significant positive effect of irrigation participation on household food security, measured by calorie intake, as well as on total household income. After matching, it was found that irrigation participation increased daily calorie intake by 1,256.86 kilocalories per adult equivalent. This represents an average increase of approximately 12.36% over what the treated households would have consumed in the absence of the program. The difference in average calorie intake between treated and matched control groups was statistically significant, with a t-value of 2.63**,** indicating significance at the 1% level**.**

This result demonstrates that the estimated Average Treatment Effect on the Treated (ATT) is both economically and statistically meaningful. It suggests that participation in small-scale irrigation has had a substantial and positive impact on the dietary energy consumption of participant households, thereby improving their food security status.

Table 8: Estimated Average Treatment Effect on the Treated (ATT)

Outcome Variable	Sample Type	Treated	Control	Difference	Std. Error	t-Statistic
Calorie Intake (Kcal/AE/day)	Unmatched	3,041.29	2,011.23	103.06	487.36	2.11**
	ATT (Matched)	3,041.29	1,784.43	1,256.86	477.48	2.63***

4.4. Factors affecting household's participation in small-scale irrigation

The logit model was employed to estimate the effects of the hypothesized independent variables on the irrigation participation of households. Thus, the model estimated groups of irrigation users and non-user households. Seven significant variables were identified out of the hypothesized sixteen variables by estimating a logit model. Among the factors considered in the model, education, family size, land size, distance from water source, distance from market, extension access and nonfarm income significantly affected household participation in irrigation (Table 9).

Household Size: Household size was found to have a significant negative effect on participation in small-scale irrigation, at the 5% significance level ($p < 0.05$). The marginal effect indicates that an increase in household size by one adult equivalent reduces the likelihood of participating in irrigation by 12.1%, holding other factors constant. One possible explanation is that larger households are often associated with poorer socio-economic conditions. These households may lack the financial resources, social capital, or bargaining power required to influence the design and placement of irrigation infrastructure. In some cases, wealthier or more influential farmers may dominate such decision-making processes. This finding is consistent with Jambo et al. (2021), who reported a similar negative relationship between household size and participation in irrigation.

Education Status: The education status of the household head is positively associated with participation in irrigation and is statistically significant at the 10% level ($p < 0.10$). The marginal effect shows that as the education level of the household increased by one year the probability of irrigation participation will be increased by 6%. This suggests that educated farmers are more likely to understand and adopt new technologies, including irrigation systems, due to better access to information and higher levels of awareness. Education may also contribute to improved farm planning and management skills, which further enhance productivity. This result aligns with the findings of Kinfe et al. (2012) and Jambo et al. (2021), both of whom emphasized the critical role of education in technology adoption and food security.

Land Size: Land size shows a positive and statistically significant relationship with irrigation participation at the 1% significance level ($p < 0.01$). The marginal effect reveals that a unit increase in cultivated land size increases the probability of using irrigation water by 3%, all else being equal. Larger landholders typically have access to multiple plots spread across different locations, some of which may be closer to rivers or other water sources, enhancing their ability to adopt irrigation. Additionally, land near riverbanks offers direct physical advantages for irrigation. However, this result contrasts with the findings of Shiyani et al. (2015), who reported no significant link between landholding size and irrigation use. The discrepancy may stem from contextual or site-specific factors, such as land tenure systems, irrigation scheme design, or regional agro-ecological characteristics.

Table 9: Binary logit model estimation results

Variables	Coefficient	Std. err.	Marginal effect	z	P>z
Sex	0.061	0.314	0.015	0.19	0.847
Marital status	0.375	0.527	0.091	0.71	0.476
Age	0.011	0.014	0.003	0.80	0.424
Family size	0.491	0.322	0.121	1.52	0.028**
Education status	0.242	0.356	0.060	0.68	0.096*
Credit access	-0.038	0.332	-0.010	-0.12	0.908
Land size	0.123	0.140	0.030	-0.88	0.008***
Distance from market	-0.101	0.031	-0.025	-3.25	0.001***
Distance from water source	-0.049	0.040	-0.012	-1.24	0.013**
Extension access	0.073	0.328	0.018	1.22	0.024**
Training access	0.103	0.344	0.026	0.30	0.764
Farm experience	0.009	0.011	0.002	0.89	0.276
Livestock size (TLU)	-0.002	0.020	-0.001	-0.12	0.908
Off farm income	0.003	0.002	0.000	-1.18	0.039**
On farm income	0.002	0.00	0.000	-0.03	0.974
Non-farm income	0.034	0.012	0.023	1.64	0.001***
_cons	-0.304	1.054		-0.29	0.773
Number of obs	224				
LR chi2(16)	38.00				
Prob > chi2	0.0039				
Log likelihood	-136.18475				

Pseudo R2	0.1224

***, ** and * significant at 1%, 5% and 10% significance

Distance from market: Significantly and negatively influenced irrigation participation at 1% probability level. The marginal effect showed that market distance increased by one kilometer, the probability of participation in irrigation decreased by 2.5%. The possible explanation is household far from market has less probability to invest or engage in other source of livelihood. This result is against the study of Sinyolo et al. (2014), which suggests that the better the household head had the market they are more probable to participate in irrigation practices.

Distance from water sources: Had a negative impact on irrigation participation at 5% probability level. The possible explanation is that; as a household far from irrigation water source, access to get enough water for irrigation is reduce as a result of cost of operation of labor and time is increase and reduce participation in irrigation. The marginal effect showed that distance from water source increased by one kilometer, the probability of participation in irrigation decreased by 1.2%. The result confirmed the study of Sinyolo et al., (2014) who found that distance of farmer's homestead from the irrigation scheme had a negative influence on the farmer being an irrigator.

Extension access: Access of extension contact significantly and positively influenced participation in irrigation at 5% level of significance. The marginal effect indicates that, other factor being constant, a unit contact of household with extension agent, increase participation in irrigation by 1.8%. This is probably due to irrigation participation provide technical support or advice from extension worker. This result confirms with the study of (Sinyolo et al., 2014, Kedir et al., 2019; Jambo et al., 2021), found that farmers who directly contact with extension agent participate in irrigation than those who do not contact.

Non-farm income: Nonfarm income source: significantly and positively affected participation in irrigation at 1% probability level. The possible reason is that, household involve nonfarm income source more participant in irrigation. The result of this study is supported by the study of Hundush (2014) and Kedir et al. (2019), who found that households who participate in non-farm more probably encouraged participating and adopting irrigation systems because of the money that they earn from non-farm.

4.5 sources of water for small-scale irrigation practices

The survey result in figure 5 shows that out of the total irrigation user respondents, 45% had got irrigation water from ground water while 33% of respondents had got irrigation water from pump river. 15.6% of respondents had used their irrigation water from river diversion and 6.4% of households from pond. This result also shows that the majority of irrigation user respondents depend on ground water to irrigate their farm land. Farmers, who had farm lands absent ground water, also used pump river.

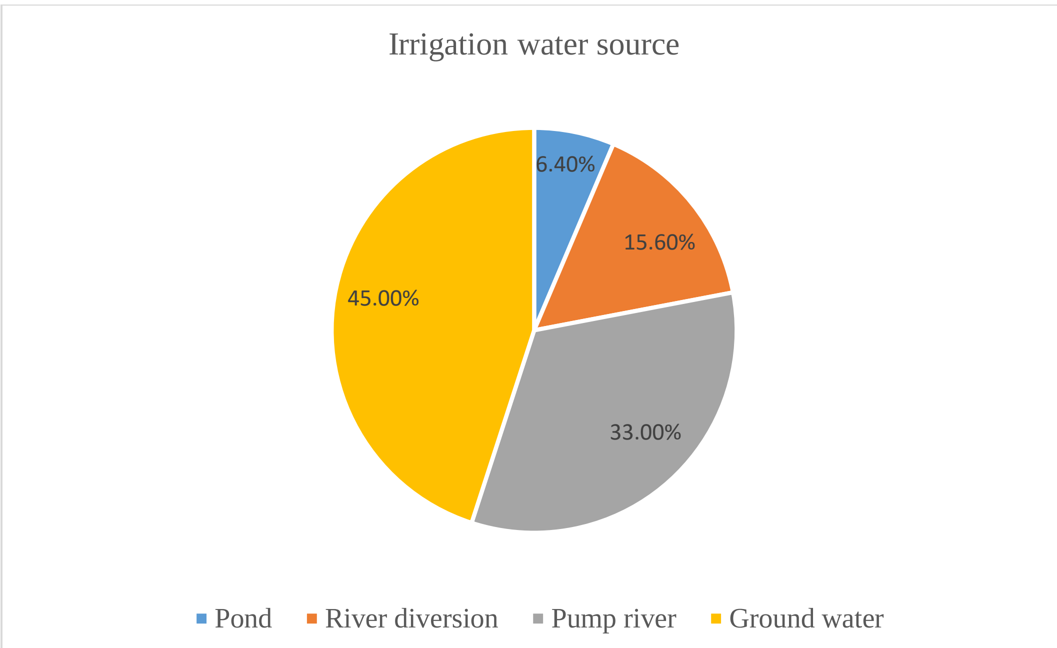


Figure 5: Water source for irrigation practices

4.6. Food Security Status of Households

The food security status of the sample households in the study area is presented in Figure 6. The categorization of household food security is based on the Household Food Insecurity Access Scale (HFIAS), developed by the Food and Nutrition Technical Assistance (FANTA) project of USAID. This scale provides a continuous measure of household food insecurity and classifies households into four levels of food insecurity (access): food secure, mildly food insecure, moderately food insecure, and severely food insecure. The results reveal that the majority (75%) of irrigation user households were food secure, compared to only 48% of non-user households. Among irrigation users, 8% were mildly food insecure, 13% moderately food insecure, and only 4% severely food insecure. In contrast, among irrigation non-users, 14% were mildly food insecure, 25% moderately food insecure, and 13% severely food insecure. These findings clearly indicate that irrigation user households are significantly more food secure than their non-irrigation counterparts, highlighting the positive role of irrigation in improving household food security in the study area.

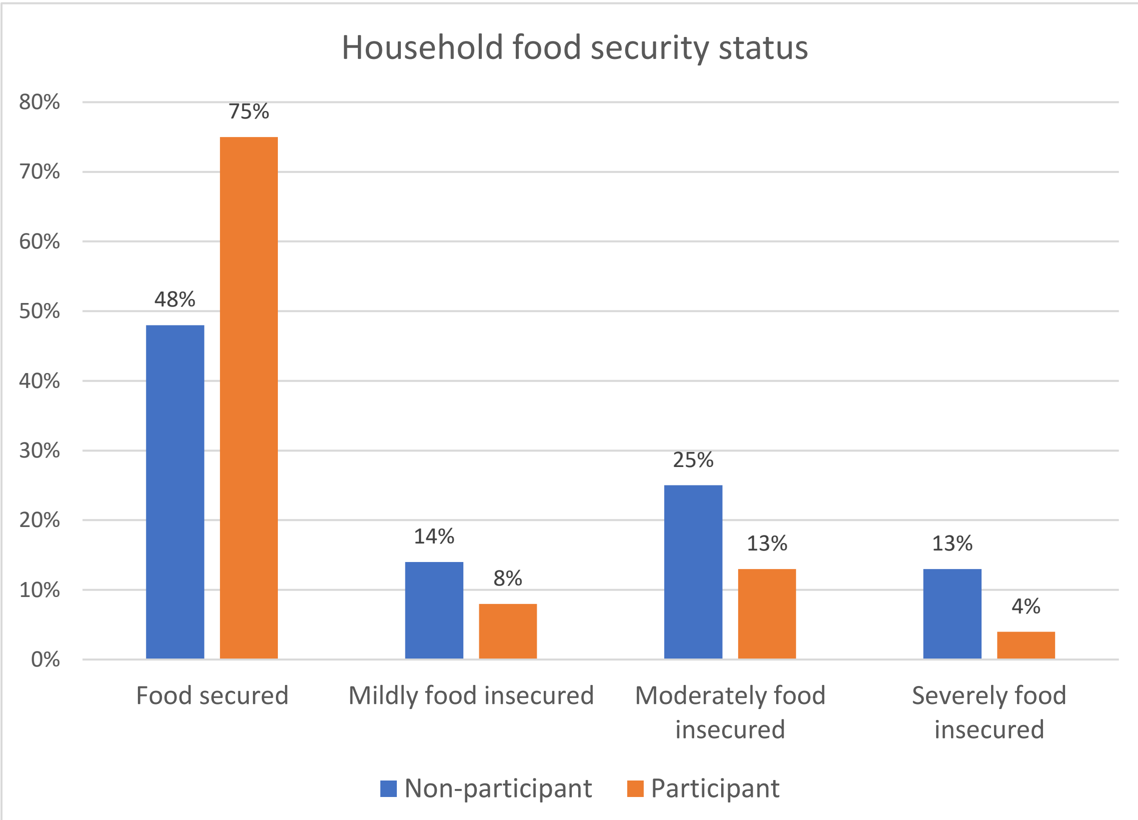


Figure 6: Food security status of households

Table 10 reported that the income and food requirement relationship of irrigation user and non-user households. This result shows that 45.9% of irrigation user households confirmed that their monthly income is insufficient for food requirements in the household (Table 10). The remaining 30.3% and 23.9% of households confirmed that their average monthly income is sufficient and excess of consumption for their family, respectively. On the other hand, 57.4% of irrigation non-user households confirmed that their monthly income is insufficient for food requirements in the household followed by excess of family consumption (24.3%) and sufficient consumption (18.3%). The chi squire (X^2) test showed that there is significance difference between irrigation user and non-user households at 10% level of significance (Table 10).

Table 10: Level of food production sufficiency for family

Variable	Response	Measurement	Non-user	user	Total	X^2
Level of production in the last three years	Excess of family consumption	Count	28	26	54	4.79*
		%	24.3%	23.9%	24.1%	
	Sufficient of household consumption	Count	21	33	54	
		%	18.3%	30.3%	24.1%	
	Insufficient for family consumption	Count	66	50	116	
		%	57.4%	45.9%	51.8%	
Total		Count	115	109	224	
		%	100.0%	100.0%	100.0%	

Figure 7 presents the severity levels of food insecurity among both irrigation user and non-user households. For irrigation participants, 35.5% reported that their food consumption level remained the same, while 30.3% reported an improvement, 26.9% experienced a decline, and 7.3% responded with "I do not know." In contrast, among non-participant households, 45.6% indicated that their food consumption level had not changed, 34.9% reported it had worsened, 13.4% noted an improvement, and 6.1% were uncertain. These results suggest that a higher proportion of irrigation users experienced improved or stable food security compared to non-users, highlighting the potential role of small-scale irrigation in mitigating food insecurity.

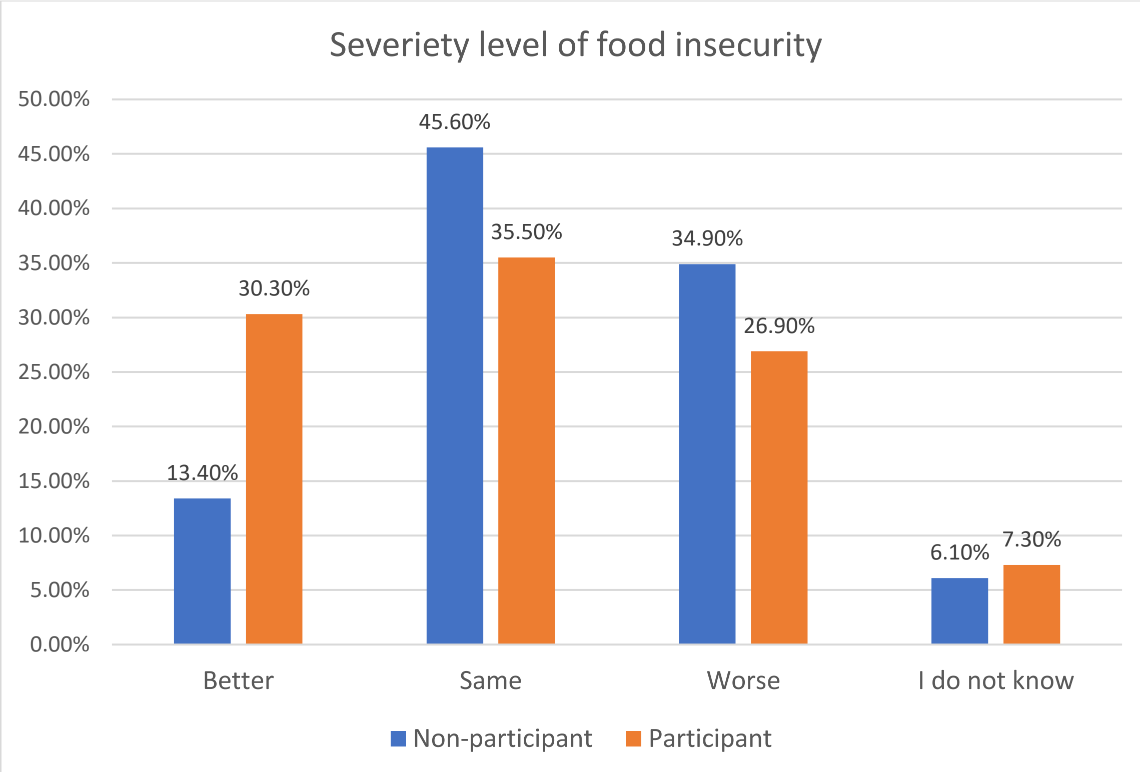


Figure 7: The severity level of food insecurity

Data on food consumption were collected from 224 households using a 7-day recall period to assess the variety and frequency of foods consumed. Table 11 presents the Food Consumption Score (FCS) results for both irrigation users and non-users. Based on standard FCS thresholds, households were classified into three categories: acceptable (food secure), borderline (moderately food insecure), and poor (food insecure).

Among irrigation users, 61.5% had acceptable food consumption, 27.5% fell into the borderline category, and only 11% were classified as having poor food consumption. In contrast, among non-users, only 42.6% had acceptable consumption, while 32.2% were borderline, and 25.2% had poor food consumption scores.

These findings indicate that a higher proportion of irrigation users are food secure compared to non-users. The chi-square test confirms a statistically significant difference in food consumption scores between the two groups at the 1% level of significance ($\chi^2 = 20.3^{***}$), suggesting that small-scale irrigation has a positive effect on household food security.

Table 11: Household food consumption score

Food consumption score	Non-user		user		Aggregate		X^2
	Freq.	%	Freq.	%	Freq.	%	
Acceptable food consumption >42	49	42.6	67	61.5	116	51.8	
Borderline food consumption (28.5-42)	37	32.2	30	27.5	67	29.9	20.3***
Poor food consumption (≤28)	29	25.2	12	11.0	41	18.3	

The household survey revealed that households in the study areas eat commonly different cereal crop foods. According to the result, 40.1% of respondents reply that sorghum is the major staple food for households followed by maize (31.5%) and rice (13%) (Figure 8). On the other hand, teff, barely and others eaten by small proportion which accounts 9.4%, 4.6%, and 1.4%respectively. The finding implies that sorghum and maize are the dominant commonly or staple food items for the majority of the households.

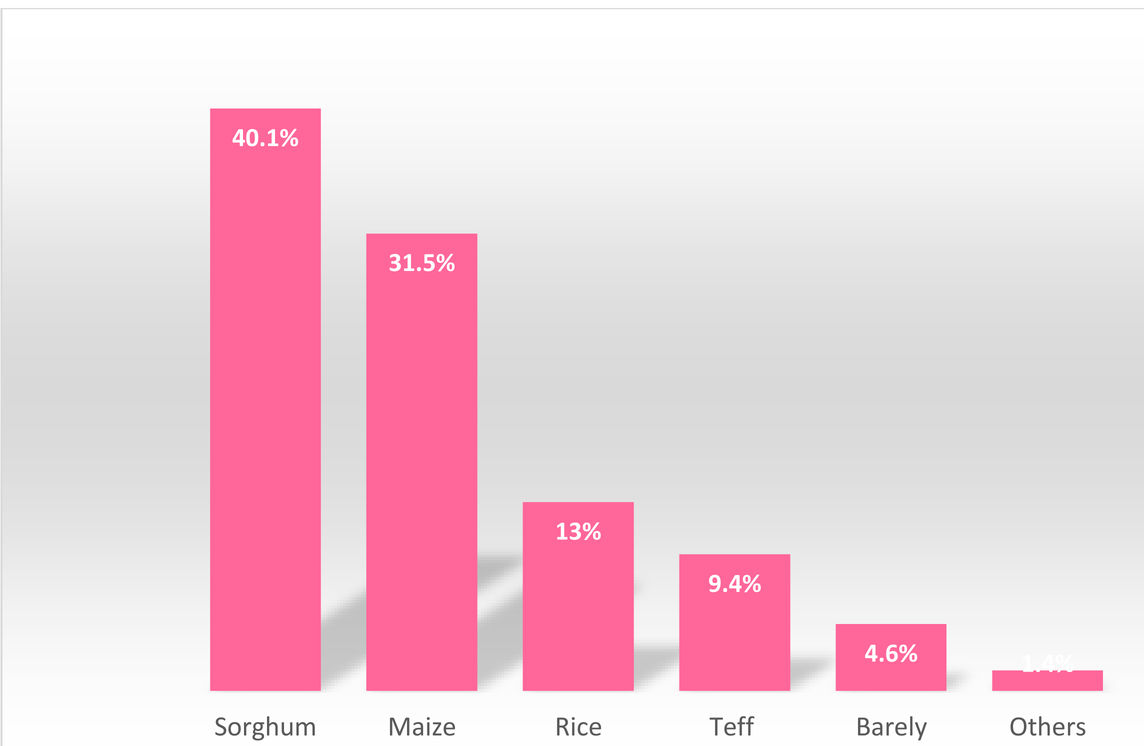


Figure 8: Kind of food you and your household members always eat at home (staple food)

The graph shows the monthly variation in a certain variable over the course of a year (Figure 9). The highest values are observed between August and December, with August having the peak at

62.9%, followed closely by September (59.7%), October (54.8%), November (51.6%), and December (48.4%). From January to April, the values drop significantly, with January and February recording the lowest values at 12.9% and 11.3%, respectively. March shows a slight increase to 30.6%, followed by April dropping back to 11.3%. After April, there is a steady increase again through May (21.0%), June (29.0%), and reaching 46.8% in July. Overall, the data indicates a seasonal pattern with high values in late summer and early autumn months, a sharp decline during the winter months, and a gradual rise beginning in spring and peaking again in summer.

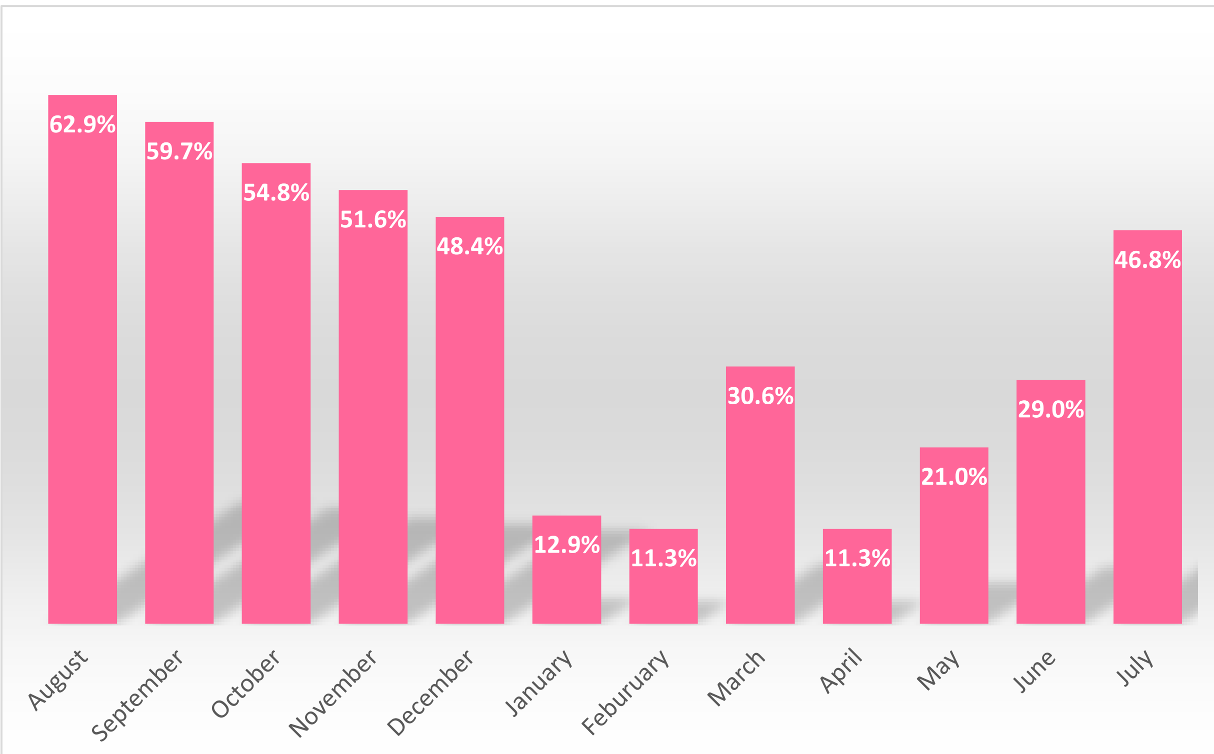


Figure 9: Months of inadequate household food provisioning

Figure 10 illustrates the consumption rates of various food groups among households. The highest consumption is seen in "peanuts, lentils and related" (close to 90%), followed by "Cereals" and "Fruits," each with consumption rates near 80%. "Oils and Fats" and "Orange fruits" also show relatively high consumption, slightly below 80%.

In contrast, "Flesh meat" has the lowest consumption rate, around 30%. Other food groups like "Green vegetables," "Organic meat," "Eggs," "Fish," "Vegetables," "Milk and dairy," "Meat," and "Pulses" fall roughly in the mid-range, with consumption rates varying between 40% and 70%.

Overall, the figure indicates that plant-based protein sources such as peanuts and lentils, along with cereals and fruits, are consumed more frequently than animal-based proteins like flesh meat.

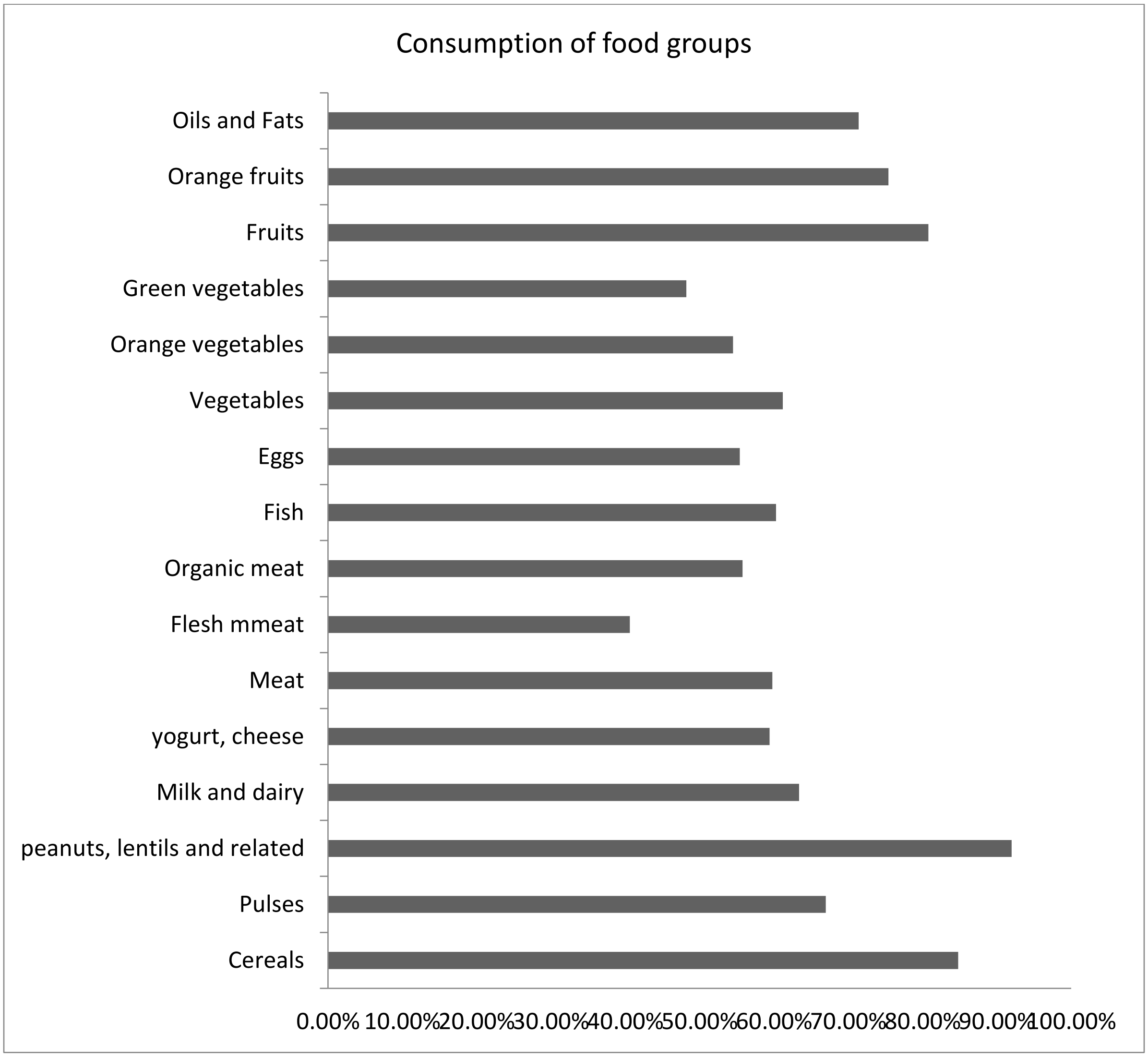


Figure 10: Households' Consumption of different food groups

The analysis of product transportation methods among irrigation user and non-user households reveals significant differences in how these groups transport their agricultural products (Table 12). Among irrigation user households, the predominant mode of transportation is by cart, with 43.1%

of households using this method, followed closely by vehicles at 34.9%. Animal power and man power are less commonly used by irrigation users, accounting for 15.6% and 6.4% respectively. In contrast, irrigation non-user households primarily rely on animal power, with 40% of households using it to transport their products. Man power is the second most common method among non-users, at 25.2%, followed by carts at 23.5%, and vehicles at only 11.3%. The chi-square test confirms that these differences in transportation methods between irrigation users and non-users are statistically significant at the 1% level, indicating a strong association between irrigation status and the choice of transportation. This suggests that irrigation users have greater access to more efficient and mechanized transportation options such as carts and vehicles, potentially reflecting differences in economic status, infrastructure, or resource availability. On the other hand, non-user households depend more heavily on traditional and labor-intensive means such as animal and man power. These disparities in transportation modes likely impact the efficiency and cost of moving agricultural products, influencing the overall productivity and market participation of these households.

Table 12: Means of transportation for household products

Variable	Transportation	Response	Non-user	user	Total	X^2
How to transport your products	Vehicles	Count	13	38	51	44.325***
		%	11.3%	34.9%	22.8%	
	Animal power	Count	46	17	63	
		%	40.0%	15.6%	28.1%	
	Cart	Count	27	47	74	
		%	23.5%	43.1%	33.0%	
	Man power	Count	29	7	36	
		%	25.2%	6.4%	16.1%	
Total		Count	115	109	224	
		%	100.0%	100.0%	100.0%	

As indicated in figure 11, 27.5% of participant households get food aid from government aid, consumption of less preferable food was adopted by 17.4%, 13.8% reduced amount of meals, 12.8% purchase food on credit, 9.3% skip meals and 9.2% limit amount size of meals to cope with food insecurity. On the other hand, 26.1% of non-participant households cop by consuming less preferred food proceed by selling assets (15.7%), borrow food from friends/relatives (15.7%), government aid (11.3%), purchase food on credit (11.3%) and limit amount of size meal time

(9.6%). The qualitative results from FGD and KIIs show that, both small-scale irrigation user and non-user households have different coping mechanisms during a time of food insecurity situation. The main coping mechanisms are food aid from government and NGOs, borrowing, selling of assets mainly livestock, consumed less preferred food items and shift/skip the type of food to the most price/cost affordable food types.

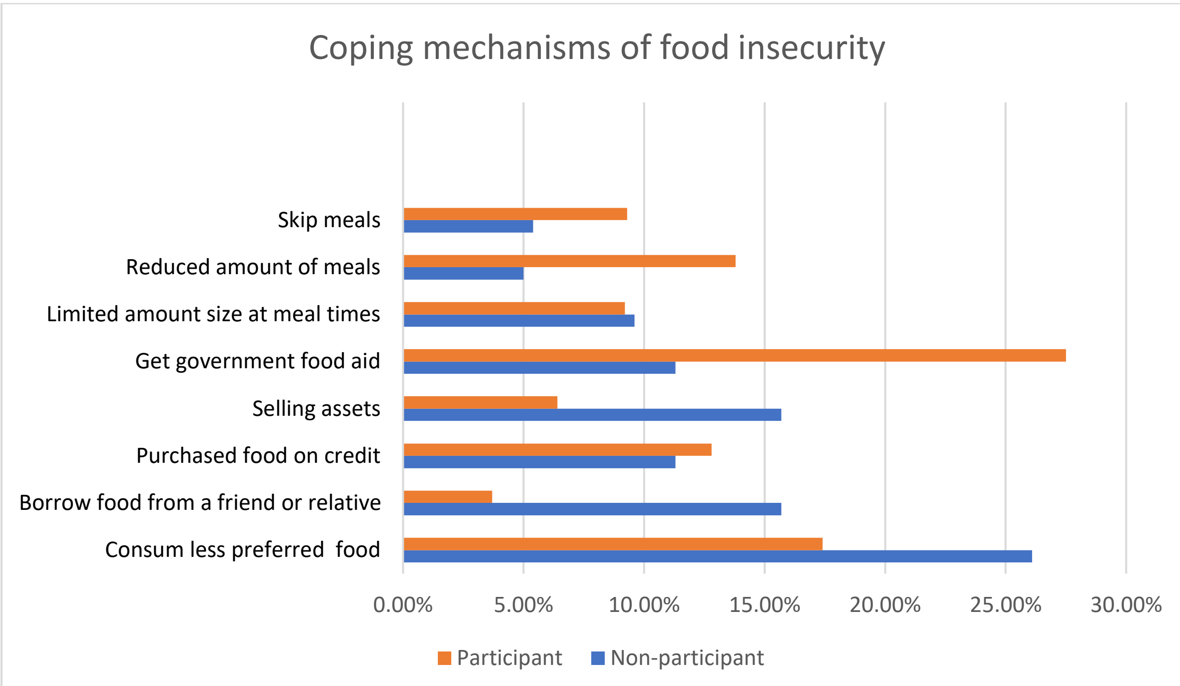


Figure 11: Sample Households Coping Mechanisms to Food Insecurity

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The findings of this study reveal significant differences in food security status and agricultural practices between irrigation user and non-user households. Results from the food security measurement indicate that 75% of irrigation users are food secure compared to only 48% of non-users, highlighting the positive impact of irrigation on household food security. Among irrigation users, 45% accessed irrigation water from groundwater sources, while 33% obtained it from Pump River. The average treatment effect on the treated (ATT) analysis shows that participation in irrigation increases household calorie intake by 1256.86 Kcal/AE/Day compared to non-participants, demonstrating a substantial nutritional benefit. Sorghum and maize remain the primary staple foods, with food shortages primarily occurring from July to December. Key factors influencing household participation in small-scale irrigation include education, household size, land size, proximity to markets and water sources, access to extension services, and non-farm income. Additionally, government food aid and the consumption of less preferred food items emerge as common coping mechanisms among households facing food insecurity. Participation in irrigation not only enhances food security but also enables households to generate additional income and diversify their food consumption, underscoring the crucial role of irrigation water utilization. Overall, irrigation user households exhibit higher food security levels than non-users, indicating that the absence of irrigation contributes to greater food insecurity in the study area. These findings suggest that small-scale irrigation is a viable and effective strategy for improving rural household food security and addressing food needs sustainably.

5.2. Recommendation

Based on the findings of this study, the following recommendations are proposed to enhance household food security in the study area:

- The results demonstrate a positive and statistically significant relationship between small-scale irrigation and household food security**.** Participation in irrigation not only increases household income but also promotes diversification in food consumption**,** thereby contributing to improved dietary quality and energy intake.
- Consequently, development strategies and food security programs aimed at improving agricultural productivity should prioritize the expansion and promotion of small-scale irrigation**.** Supporting irrigation development—through investments in infrastructure, technical training, and access to inputs—can serve as a key instrument in boosting rural livelihoods and achieving sustainable food security.

✓ Increasing efficiency of the existing small-scale irrigation schemes and designing and implementing the new schemes leads to sustainable production that could change the life of the rural poor.

✓ Strong regulatory mechanism should be designed to overcome problems related to irrigation use to provide incentives to committed and disciplined farmers.

✓ Therefore, conducting further investigation on the problem area by considering additional socio-economic, environmental and institutional factors of the study area could contribute more in raising the performance of small scale irrigation schemes on household food security.

REFERENCES

Abdi Etafa Regassa. (2015). Determinants of agro pastoralists' participation in irrigation scheme: The case of Fentalle agro pastoral district, Oromia regional state, Ethiopia. *International Journal of Agricultural Resource Innovation & Technology*, 5(2), 44–50. ISSN: 2224-0616.

Abdissa, F., Tesema, G., & Yirga, C. (2017). Impact analysis of small scale irrigation schemes on household food security: The case of Sibu Sire District in Western Oromia, Ethiopia. *Irrigation and Drainage Systems Engineering*, 6(187), 2.

Agidew, A. M., & Singh, K. N. (2018). Determinants of food insecurity in the rural farm households in South Wollo Zone of Ethiopia: The case of the Teleyayen sub-watershed. *Agricultural and Food Economics*, 6(1). https://doi.org/10.1186/S40100-018-0106-4

Ahmed, B., Mume, J., & Kedir, A. (2014). Impact of small-scale irrigation on farm income generation and food security status: The case of lowland areas, Oromia, Ethiopia. *International Journal of Economics and Empirical Research (IJEER)*, 2(10), 412-419.

Asfaw, A., & MW, B. (2014). Quantification of drought tolerance in Ethiopian common bean varieties. *Agricultural Crop Research*, 5(2), 124–139.

ATA. (2016). *Ethiopian Agricultural Transformation Agency Annual Report*. Addis Ababa, Ethiopia.

Awulachew, S. B., E. T., & N. R. E. (2010). Irrigation potential in Ethiopia: Constraints and opportunities for enhancing the system. *International Water Management Institute*, Addis Ababa, Ethiopia.

Berhane, A. (2013). Effects of planting methods on yields and yield components of rice (*Oryza sativa* L.) variety in Tathay Karoro Wereda, Northern Ethiopia. *International Journal of Technology*.

Bhattarai, M., B. R., & N. N. (2007). Who benefits from irrigation development in India? Implications of irrigation multipliers for irrigation financing. *Irrigation and Drainage*, 56, 207–225.

Bonhee Chung. (2016). Impact of irrigation extension on malaria transmission in Simret, Tigray, Ethiopia. *Korean Journal of Parasitology*, 54(4), 399–405.

Bont, C. de, Komakech, H., & Development, G. (2019). Neither modern nor traditional: Farmer-led irrigation development in Kilimanjaro Region, Tanzania. *Elsevier*.

Callens, K., & Seiffert, B. (2003). Participatory appraisal of nutrition and household food security situations and planning of interventions from a livelihoods perspective: Methodological guide. Rome, Italy.

Carletto, C., Zezza, A., & Banerjee, R. (2013). Towards better measurement of household food security: Harmonizing indicators and the role of household surveys. *Global Food Security*. https://doi.org/10.1016/j.gfs.2012.11.006

Demissew, A. H., & Kibret, D. (2020). Impact of sugarcane irrigation on malaria vector *Anopheles* mosquito fauna, abundance and seasonality in Arjo-Didessa, Ethiopia. *Malaria Journal*, 19(344), 1-8.

Dereje Mengistie, & D. (2016). Assessment of the impact of small-scale irrigation on household livelihood improvement at Gubalafto District, North Wollo, Ethiopia.

Desta Dawit, A. B. (2015). *Journal of Economics and Sustainable Development*, 6(21), 2222-2855.

ECA. (2018). Regional overview of food security and nutrition: Addressing the threat from climate variability and extremes for food security and nutrition. Accra.

Ellis, F. (1993). *Farm Household and Agrarian Development* (2nd ed.). Cambridge University Press.

Ernest Bagson, & Kuuder, C.-J. W. (2013). Assessment of a small scale irrigation scheme on household food security and leisure in Kokoligu, Ghana. *Research on Humanities and Social Sciences*.

FAO and IFC. (2015). *Irrigation Market Brief of Ethiopia*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2005). Agricultural trade liberalization: Implications for irrigated agriculture. Rome, Italy.

FAO, IFAD, UNICEF, WFP, & WHO. (2018). *The State of Food Security and Nutrition in the World 2018: Building climate resilience for food security and nutrition*. Rome: FAO. License: CC BY-NC-SA 3.0 IGO.

FAO. (2011). Independent evaluation of the programmers and cooperation of the Food and Agriculture Organization of the United Nations in Ethiopia.

FAO. (1996). Declaration on World Food Security. World Food Summit. FAO, Rome.

FAO. (2008). An introduction to the basic concepts of food security. Food Security Information for Action Practical Guides. EC – FAO Food Security Programme. http://www.fao.org/docrep/013/al936e/al936e00.pdf

Frongillo, E. A., & Nanama, S. (2012). Advances in developing country food insecurity measurement: Development and validation of an experience-based measure of household food insecurity within and across seasons in Northern Burkina Faso. *Journal of Nutrition*, 136, 1409-1419.

FSIN. (2019). Food Security Information Network: Global Report on Food Crises – Joint Analysis for Better Decisions.

Gathala, M. K., Kumar, V., Sharma, P. C., Saharawat, Y. S., Jat, H. S., Singh, M., Kumar, A., Jat, M. L., Humphreys, E., Sharma, D. K., & Sharma, S. (2013). Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. *Agriculture, Ecosystems & Environment*, 177, 85-97.

Gebrehiwot, K. G., D. M., & W. T. (2017). The impact of micro-irrigation on households' welfare in northern Ethiopia: An endogenous switching regression approach. *Studies in Agricultural Economics*, 119(3), 160–167.

Gebremedhin, B., & Pender, J. (2003). Policies and institutions to enhance the impact of irrigation development in mixed crop–livestock systems. *International Water Management Institute*, 168, 168-184.

Gebul, M. A. (2021). Trend, status, and challenges of irrigation development in Ethiopia: A review. *Sustainability*, 13(10), 5646.

Getaneh, K. (2011). Impact of selected small-scale irrigation schemes on household income and the likelihood of poverty in the Lake Tana basin of Ethiopia (Master's thesis). Cornell University.

Hanjra, M. A., & Gichuki, F. (2008). Investments in agricultural water management for poverty reduction in Africa: Case studies of Limpopo, Nile, and Volta river basins. *Natural Resources Forum*, 32(3), 185–202. https://doi.org/10.1111/j.1477-8947.2008.00191.x

Hoddinott, J., & Yohannes, Y. (2002). Dietary diversity as a household food security indicator. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Hussain, I. (2004). Assessing impacts of irrigation on poverty: Approaches, methods, case studies and lessons. *International Water Management Institute (IWMI)*.

IWMI. (2010). Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation and rainwater harvesting for food security in Ethiopia.

Jambo, Y., Alemu, A., & Tasew, W. (2021). Impact of small-scale irrigation on household food security: Evidence from Ethiopia. *Agriculture & Food Security*, 10, 1-16.

Kedir, A., Beyene, F., & Teshome, G. (2019). Impact of small-scale irrigation on household's food security in Fentale District, East Showa Zone of Oromia National Regional State, Ethiopia (Doctoral dissertation, Haramaya University).

Kinfe Aseyehegn, C. Y., & R. S. (2012). Effect of small-scale irrigation on the income of rural farm households: The case of Laelay Maichew District, Central Tigray, Ethiopia. *The Journal of Agricultural Sciences*, 7(1), 43-57.

Kuwornu, J. K., & Owusu, E. S. (2012). Irrigation access and per capita consumption expenditure in farm households: Evidence from Ghana. *Journal of Development and Agricultural Economics*, 4(3), 78-92.

Lipton, M., Litchfield, J., & Faurès, J. M. (2003). The effects of irrigation on poverty: A framework for analysis. *Water Policy*, 5(5-6), 413-427.

Matouš, P., Todo, Y., & Mojo, D. (2013). Roles of extension and ethno-religious networks in acceptance of resource-conserv

APPENDIX: QUESTIONNAIRES

Dear Respondent,

First of all, I would like to thank you for your willingness to participate in this study. The questionnaire is designed to collect the necessary information to undertake a research on the impact of small-scale irrigation on household food security in Tuliguled district. The study is conducted for the partial fulfillment of the requirements for the degree of Masters in Climate change and disaster risk management at Haramaya University.

The main objective of this research is to investigate the impact of small-scale irrigation on household food security and all your answers will be used for this purpose. So, please answer each question genuinely since your genuine responses are quite vital for the success of this study. Finally, I would like to confirm you that all the information you provide in this questionnaire will be strictly confidential and will exclusively use for this research purpose only.

Thanks in advance!

Survey Questionnaire on the Impact of Small-Scale Irrigation on Household Food Security: The Case of Tulliguled District, Fafan Zone Somali Region, Ethiopia.

1. **Household Characteristics**

1.1. Kebele ________________Interviewer ______________________Date

1.2. Code ___________________________________

1.3. Ethnicity: 1. Oromo 2. Amhara 3. Gurage 4. Other

1.4. Religion: 1. Orthodox 2. Muslim 3. Protestant 4. Other

1.5. Sex of the household 0. Female 1. Male

1.6. Age of the household head

1.7. Education level of the household head: 1.Formal 2. Informal

1.8. Marital status: 1. single 2. Married 3. Divorced 4. Widowed

2. **Livestock holding during 2016 E.C.**

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

2.2. If yes for Q#2.1, indicate the number of livestock in the following table **Table 1 Summary of Livestock holding**

Types of Livestock	**Number Owned**	**Number Sold**	**Income Obtained**
Oxen			
Cows			
Bulls			
Heifers			
Calves			
Horses (Adult)			
Horses (Young)			
Donkeys (Adult)			
Donkeys (Young)			
Goat (Adult)			

Goat (Young)			
Sheep (Adult)			
Sheep (Young)			
Poultry			
Bee colony			

3. **Land holding and usage**

2.3. Do you have your own land? 0. No 1. Yes

2.4. If yes, total land size _______ha; irrigable _______ha, and non-irrigable _________ha.

2.5. Do you think that your piece of land is enough to support your family? 0. No, 1. Yes

2.6. If no to Q#3.3, what are the reasons? 1. Low soil fertility, 2. Small land size,

3. Insufficient application of inputs, 4. Large family size, 5. others

2.7. What is the total land you cultivated in 2016E.C? total ___ha: irrigated ___rainfed

2.8. Did you shared-in/leased-in land during 2016 E.C? 0. No 1. Yes

2.9. If yes to Q#3.6, total land size_______ha; irrigated _______ha, and rainfed ________ha.

2.10. How do you evaluate your level of production during the last three years? 1. excess of family consumption, 2. sufficient for household consumption, 3. insufficient for family consumption, 4. Others

4.Farming experience, irrigation utilization and income from farming

2.11. How many years since you started farming (Farming experience) _________________years.

2.12. Did you produced crop under rain fed during 2016 E.C? 0. No 1. Yes

2.13. If yes to Q#4.2, what were the crops produced? Use the following table.

Table 3 Crop Production under Rainfed (Qt)

Crop	Total yield (Qt)	Own consumed	Sold	Given to others

Type	Amount	Value	Amount	amount	Income	Amount

2.14. Did you produced crop using irrigation during 2016? 0. No 1. Yes

2.15. If yes for Q#4.4, when did you started irrigation farming?

2.16. If yes for Q#4.4, what are the crops produced in 2016 E.C? use the following table **Table 4 Crop Production under irrigation**

Crop Type	Total yield (Qt)		Own consumed	Sold		Given to others
	Amount	Value	Amount	amount	Income	Amount

2.17. If yes for Q#4.4, what is the source of water for your irrigation?

2.18. 1. Gravity river diversion2. Pumping rivers, 3. Ground water, 3. Ponds, 4. Others

2.19. If yes for Q#4.4, how many times do you produce per year using irrigation?

2.20. Have you ever faced food shortage? 0. No1. Yes

2.21. If yes for Q#4.9, during which months? according to severity

2.22. How did you cope during food shortage? 1. Sale of livestock 2. Reduce the number of meals 3. Sale of Animal products 4. Wage employment 5. Other

3. **Distance from irrigation water sources __________**km, or _________minutes of walk.

5. Food Consumption Score Data Collection Question.

Table 6 Types and frequencies of Food items consumed during the last seven days.

S. N	Food Items	No of days the food item eaten	Weight	Food consumption score Value
1	Main staples (Maize, Rice, Sorghum, Pasta, Bread/Cake, Potato, Yam, Cassava, Sweet Potato, Taro, etc.)		2	
2	Pulses (Beans, Peas, Groundnuts and etc.)		3	
3	Vegetables (Carrot, Red Pepper, Sweet Potato, Onion, Tomato, Green Beans, Peas, Lettuce, etc.)		1	
4	Fruit (Mango, Papaya, Banana, Apple, Lemon, Orange)		1	
5	Meat and fish (Beef, Goat, Poultry, Pork, Egg and Fish)		4	
6	Milk (Milk, Yoghurt, Cheese, etc.)		4	
7	Sugar (Sugar, Honey,		0.5	

	etc.)			
8	Oil (Vegetable Oil, Palm Oil, Butter, etc.)		0.5	
9	Condiments (Spices, Tea, Coffee, Salt, Fish Power, etc.)		0	

6.Daily Calorie Intake Data Collection Question

Table 7 Types and Amounts of Food consumed during the past 24 hours

Food Type	Amounts consumed in the last 24 hours in Kg.
Tef	
Maize	
Wheat	
Barley	
Sorghum	
Rice	
Beans	
Peas	
Chickpea	
Meat	
Fish	
Chicken	
Egg	
Milk	
Butter	
Cheese	
Potatoes	
Sweet potato	

Tomatoes	
Onion	
Pepper	
Garlic	
Cabbage	
Sugar	
Honey	
Salt	
Oil	
Coffee	
Others	

7. Physical, Institutional and environmental factors

3.1. Did diseases and pests affect your crop production in 2011E.C? 0. No, 1. Yes

3.2. If yes for Q#7.1, what is the estimated loss occurred? ________________________birr.

3.3. If yes for Q#7.1, what percent of the total production is damaged? __________percent.

3.4. If yes for Q#7.1, how did you treat it? 1.spraying chemicals, 2. Cultural treatments, 3. No any treatment, 4. others____

3.5. Is there farmers training center (FTC) in your *kebele*? 0. No 1. Yes

3.6. How far is the FTC from your home? __________________________km.

3.7. Do you have contacts with DA? 0. No 1. Yes

3.8. If yes, how many times do you contact with them per month? ___________________

3.9. Do you get different advices/supports from DAs? 0. No 1. Yes

3.10. If yes to Q7.9, do you practically use their advices accordingly? 0. No, 1. Yes

3.11. If no to Q7.10, why? 1. is irrelevant 2. not timely, 3. not affordable, 4. Other ________

8.Distance to the nearest market

3.12. How far is your home from the nearest market? ___________________________________km.

3.13. Where do you sell majority of your farm products? 1. On farm, 2. at cooperative union shops, 3. at local markets, 4. Others ____________________

3.14. Do you get market information about price of inputs and outputs? 0 = No 1 = Yes

3.15. Did you get good price for your produce in 2011 E.C? 0. No 1. Yes

if no, what are the reasons? 1. low demand for the products, 2. higher supply of the products, 3 . Lak of information, 4. Lack of road access, 5. Others ___________

3.16. How do you transport your produce to the market? Using: 1. Vehicle 2. Animal power, 3. Cart, 4. Human power 5. Others _______________________________________

3.17. Checklists for Focus Group Discussion (FGD)

1. What are the major types of farming activities practiced by smallholders in the area?
2. How do you see the function of the small scale irrigation in availing of enough food for target community? 3. What are the major challenges observed underutilizing the small-scale irrigation?
4. What is the influence of access to irrigation on crop production for rural household in the area?
5. Does small irrigation have impact to food security? How?
6. Do they have used technology for irrigation?
7. Is there any difference between irrigation user and non-user regarding to food security? How?
8. What are the major constraints or draw backs of to use irrigation water in order of importance?
9. How is water distribution handled for all beneficiaries? Who is more favored and who is not? Why?
10. Are households making nonfarm business.

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. If yes, what are the main differences between these two groups?
4. What are the major determinant factors that affect the household food security?