EFFECT OF SMALL SCALE IRRIGATION ON HOUSEHOLD FOOD SECURITY IN THE CASE OF GOMBORA WOREDA, HADIYA ZONE, SNNPR, ETHIOPIA

A Thesis Submitted to the School of Graduate studies of Jimma University as a Partial Fulfillment for the Award of Degree of Master Science in Development Economics

BY;

ABRAHAM ABAYNEH

JIMMA UNIVERSITY

COLLEGE OF BUSINESS AND ECONOMICS

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CERTIFICATE

This is to certify that the thesis entitled "***Effect of Small-Scale Irrigation on Household Food Security in the case of Gombora Woreda***." submitted in partial fulfillment of the requirements for the MSc degree in development economics carried out by Abraham Abayneh, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit a thesis to the department of economics.

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THESIS APPROVAL SHEET

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As members of the board of examining of the final MSc thesis, we certify that we have read and evaluated the Thesis prepared by Abraham Abayneh entitled, "***Effect of Small-Scale Irrigation on Household Food Security in the case of Gombora Woreda"***, and recommend that the Thesis is accepted as fulfilling the thesis requirement for the degree of Master Science in Development Economics.

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DECLARATION

I, hereby declare that this thesis entitled "***Effect of Small-Scale Irrigation on Household Food Security in the case of Gombora Woreda***" has been carried out by me under the guidance and supervision of Mr. Tesfaye Maleku (Ass Prof), and Mr. Mohammedsan Ali (MSc).

The thesis is original and has not been submitted for the award of any degree or diploma to any university or institution.

Researcher's Name	Date	Signature
Abraham Abayneh	____________	_______________

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ACRONYM AND ABBREVIATION

ADLI	Agricultural Development Led Industrialization
AE	Adult Equivalent
ATT	Average Treatment Effect of the Treated
CC	Contingency Coefficient
CIA	Conditional Independence Assumption
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
GWARDO	Gombora Woreda Agriculture and Rural Development Office
GWFEDO	Gombora Woreda Finance and Economy Development Office
HFBM	Household Food Balance Model
HH	Household
MoANR	Ministry of Agriculture and Natural Resource
MoFED	Ministry of Finance and Economic Development
MoLF	Ministry of Livestock and Fisheries
PSM	Propensity Score Matching
SNNPRS	Southern Nations Nationalities and Peoples Regional State
STATA	Statistical Data Analysis
TLU	Tropical Livestock Unit
VIF	Variance Inflator Factor

ABSTRACT

Agriculture is the leading sector as a source of income, employment creation, source of foreign exchange, and national economic growth. The main objective of this study was to analyze the effect of small-scale irrigation on household food security in Gombora woreda. A multi-stage random sampling procedure *was used to select sample respondents. Data was collected from318 households and analyzed with the help of various descriptive and econometric analysis techniques. Propensity score matching model was used to achieve the objective of the study. The household food balance model result revealed that out of sampled households 56.29% were food secured while 43.71% were food insecure. The gap in food calorie availability was high ranging from 420-9513kcal/AE /day in the study area. Out of 121 irrigators, 71.07% of them were food secured; whereas only 47.21% of the total 197 non-irrigator were food secured. A study result also identified major constraints of small-scale irrigation as occurrences of pests and diseases, poor irrigation method practices, and lack of input supply and irrigation facilities. A binary logistic regression was applied to estimate factors affecting participation in small-scale irrigation and the result showed that gender, age, family labor, education, cultivated land size, access to credit services, oxen owned, and distance from irrigation site were the variables that significantly affected. To analyze the impact of small-scale irrigation on household food security, the propensity score matching method was applied. A kernel matching with a bandwidth of 0.1 was the matching algorithm used. The quality of covariate balancing was checked using pseudo-R^2, mean bias, and t-test. Finally, the Average Treatment Effect on Treated was estimated and the result revealed that irrigation users households on average intake daily calories of 863kcal more than non-users and, this result is statistically significant. The sensitivity analysis result revealed that the impact result estimated by this study was insensitive to unobserved selection bias. The study concluded that small-scale irrigation is one of the viable solutions for households to secure food. Therefore, it is recommended that Gombora woreda government and nongovernmental organizations should expand small-scale irrigation to farm households to improve their food security.*

Key Words; *Binary logit, Household Food Balance Model, Food security, Propensity Score Matching, Small-Scale Irrigation*

CHAPTER ONE

1. INTRODUCTION

This chapter consists of the background of the study, statement of the problem, objectives of the study, significance of the study, the scope of the study, and organization of the paper.

1.1. Background of the Study

Agriculture is the most important economic activity in many developing countries providing food, employment, foreign exchange, and raw materials for industries. Nearly 1.5 billion people are engaged in smallholder agriculture across the world. Agriculture comprises 75% of the world's poorest people, whose food, income, and livelihood prospects depend on agriculture (Ferris et al., 2014). Agriculture has a greater contribution to reducing poverty and food insecurity in a mass form than any other intervention(FAO, 2015). By 2050, Africa's population will be 2.1 billion people, and its food demand is expected to triple in response to this growth putting devastating pressure on agriculture to feed the people and create jobs (Jayne et al., 2017).

Agriculture is the mainstay of the majority of the population living in sub-Saharan Africa. However, Sub-Saharan Africa countries are characterized by low agricultural productivity. This is related to the fact the sector is predominantly rain-fed, which is in most cases unreliable resulting in poor yields, and the changing weather conditions would further aggravate the situation, exposing small farmers to the negative impact of climate change(Todaro, 2012).

Ethiopia is an agrarian country, where agriculture is that the leading sector as a source of income, employment for more than 80 percent of the population, source of foreign exchange, and national economic growth. The country's economy is decided by the performance of the agriculture sector. The Ethiopian agricultural production is characterized by smallholder rainfall-dependent cultivation practices, where a variety of crops are produced throughout the country that defined the success of the production, yield, and welfare outcomes Chamberlin and Schmidt, (2011). Within the past few years, the federal and the regional governments of Ethiopia, and donor agencies have been given attention to promoting small-scale irrigation schemes that were targeted to enhance the food security of the smallholder farmers(Abdissa et al., 2017). The dominant agricultural system in the country is a smallholder production of cereals under rain-fed conditions.

The variability of the Ethiopian economy growth emanates from dependence on natural factors of production as well as small and fragmented holdings, environmental degradation, rapid population growth, 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).

To deal with these issues, Agricultural Development Led Industrialization (ADLI) Strategy was designed in 1991 where the focus was given to the expansion of small-scale irrigation, formation of cooperative societies, and access to agricultural technologies to answer the food demand and convey about the socioeconomic development within the country. Irrigation is one among agricultural technologies defined as the man-made application of water to ensure double-cropping also a steady supply of water in areas where rainfall is unreliable. Hence, the development of small-scale irrigation is one of the main interventions to extend agricultural production within the rural parts of the country(Chazovachii, 2012).

Producing enough food for the fast-growing population continues to be the only most vital daunting challenge of the country. The agricultural sector pursued a spread of strategies to deal with the matter. Among others, these involved the horizontal expansion of land put under food production, increasing productivity per unit of land or animal, and therefore the introduction of some new avenues of food production e.g. home gardens and mushroom production in towns and cities(Bachewe et al., 2018).

For the rural and urban population, however, the mere increase in food production is not enough to ensure food and nutrition security. The affordability, availability, and wholesomeness of the locally produced food are as important as the production. As of recently, the need to give due consideration to the aspects of food products available in government and development partners financed programs and projects is gaining momentum. The underlining reason for this is that enhanced agricultural productivity and improved market access would ultimately lead to food security and/ or improved nutrition, provided it is guided by complimentary strategic actions and policies addressing the challenges of gender and other socioeconomic inequalities(MoANR and MoLF, 2016).

Gombora Woreda is found in Hadiya Zone. Small-scale irrigation is being practiced in the study area. Aware of this fact, farmers in Gombora woreda have been constructing different small-scale irrigation schemes to increase agricultural production and productivity to improve the food security situation of the farming communities and reduce dependency on rainfall. Therefore, in this study, household food security status, the impact of small-scale irrigation on household food security, factors affecting farmers' participation in small-scale irrigation, and constraints to use irrigation farming in Gombora woreda were analyzed.

1.2. Statement of the Problem.

Irrigation subsidizes agricultural production by increasing crop yields and enabling farmers to increase cropping intensity and switch to high-value crops(Zhou et al., 2009). In the same way, irrigated agriculture can reduce poverty through increased production and income, and reduction of food prices, that helps very poor households meet the basic needs by improving overall economic welfare, protecting against risks of crop loss due to insufficient rainwater supplies, promoting greater use of yield-enhancing farm inputs and creation of additional employment, which together enables people to move out of the poverty trap(Tigga et al., 2019).

Small-scale irrigation has direct and indirect impacts in enhancing the livelihood of farm households through diversification of crops grown, increased household income, increased agricultural production, and increased employment opportunities Dereje and Desale, (2016). This is why irrigation development is being viewed as a promising approach to ensure food security and improved livelihood under climate variability and increasing population growth(Passarelli, 2018). Irrigation is also promoted for its contribution to the seasonal food security of households, dietary diversity, health, and resilience to drought and climate changes (Domènech, 2015; Lefore et al., 2019). It has the potential of increasing agricultural yields by more than 50%, in which the majority of increased income helps smallholder farmers(Wielgosz et al., 2014).

The issue of food insecurity is the major policy issue for poor countries like Ethiopia as it is the problem of millions. Therefore, empirically analyzing such issues is very important for policy intervention. Recurrent drought, lower average land holding, higher average family size, and low soil fertility are among the factors contributing to food insecurity status in the country. The average land holding is about 0.9 hectares (FAO, 2015), the average family size is about 5 persons per household and the average cereal productivity is 22quintals per hectare(CSA, 2018).

Production and productivity-improving agricultural technologies like small-scale irrigation play an inevitable role to sustain household food security, and limited information on such technologies, seeds, pest management, markets, and modern equipment prevent farmers from making informed decisions, and it also prevents private investment from entering into the market, which again makes irrigation sector contributes less to food security, wealth creation and resilience(Lefore et al., 2019).

Even if Ethiopia has a huge potential in terms of surface and groundwater availability and land which are in most cases suitable for irrigation development is in its infant stage and the country is not benefiting from the sub-sector. The major constraints that slow down the development of the sub-sector among others are the predominantly primitive nature of the overall existing production system, shortage of agricultural inputs, and low level of user's participation in the development and management of irrigated agriculture, limited trained manpower, and inadequate extension services(Assef, 2019). Similar findings traditional farm tools, poor animal breeds, unimproved seeds, and fertilizers, are the major challenges to agricultural development in Ethiopia. The country's ability to support agriculture through the development of irrigation has been weak Shono and Kibret, (2020).

Use irrigation demonstrated a change in the livestock holding capacity of irrigator than pre-irrigation and it also signified that higher food availability, accessibility, and better income for irrigators than non- irrigator beneficiary households Ambe, (2018). The study area is one of the food-insecure areas in the Hadya zone, because of that government is implementing different agricultural development programs to achieve food security in rural households. There are different reasons for the occurrence of food poor living standards in the study area. Among others, inefficient use and depletion of natural resources, recurrent drought, and natural hazards, the erratic nature of rainfall, rainfall-dependent agricultural practices, aggravated soil erosion, and decline of crop production and productivity are the main ones(GWARDO, 2019).

Although there is the availability of ground water as well as river water in the study area, farmers have been practicing traditional irrigation systems such as a traditional river diversion, and nowadays, farmers are being practiced in some of the modern irrigation mechanisms especially using water pumps. However, it is not well known to what extent the households that are using irrigation are better off than those that depend on rainfall in the study area. The effect of small-scale irrigation on household food security is not yet well studied in the study area. Therefore, this study has analyzed the effect of small-scale irrigation on household food security in the study area.

1.3. Research Questions

In line with the above problem, the following questions were raised by the investigator. The research questions focus mainly on farmers' problems along with issues that are interrelated with small-scale irrigation's effect on food security.

- Are the current household food security status of irrigators and non-irrigators are the same?
- What are the major factors that affect households participation in small-scale irrigation?
- What is the impact of small-scale irrigation on household food security?
- What are the factors constraining irrigation use in the study area?

1.4. Objectives

1.4.1. General objectives

The main objective of this study is to analyze the effect of small-scale irrigation on household food security in the study area.

1.4.2. Specific objectives

The specific objectives of the is

- To measure household food security status of irrigation users and non-users in the study area

- To identify factors that affect households participation in small-scale irrigation in the study area
- To analyze the impact of small-scale irrigation on household food security
- To identify the major constraints encountered in irrigation use in the study area

1.5. Significance of the study

The findings of this study can assist development activities underway and to be planned in the future. Such information about decisions on matters of agricultural technologies is important for researchers and extension workers engaged in the development and diffusion of irrigation technologies. Because of they can utilize the results of this study in setting research and extension agenda. Furthermore, information on farmers' characteristics will give feedback and enable researchers to modify and redirect research activities towards the most important problems. It would also be useful to farmers in devising ways to increase their productivity and enhance income and reduce poverty. In addition, the findings of the research work give insight for researchers and students for further research interested in the issue of the study.

1.6. Scope and Limitation of the study

The study focused on analyzing the impact of small-scale irrigation on household food security status at pastoralist area. The scope of this study was Gombora woreda which is located in the Hadya zone. The study was limited to the impact of small-scale irrigation on the household food security status of *Gombora woreda* by only consider the 2012 E.C data year. From woreda, four kebeles and respondents were limited, which only represent the study area. Therefore, the result of this study does not represent the whole population of the region. Since, assessing household food security status is a difficult issue, mainly because of the availability of a wide range of alternative indicators at the household, individual, and community level, this study also limits the quality of information. The data of the study was based on a cross-sectional survey. The objective of this study was to analyze the effect of small-scale irrigation on household food security in the study area.

1.7. Organization of the Paper

This research thesis was divided into five chapters. The first chapter of the paper highlights the background of the study, statement of the problem, objectives of the study, significance of the study, scope, and limitation of the study. The second chapter of the study addresses some empirical evidence about the subject under study and the conceptual framework of the study. The third chapter deals Research methodology of the study while the fourth chapter explains the result and discussion of the study and finally, the conclusion and recommendation clarifies on the fifth chapter of the research.

CHAPTER-TWO

2. REVIEW OF LITERATURE

This part attempts to present related literature reviewed household food security concepts and definitions, and measuring of it and small scale irrigation. Subsequently, it tries to discourse the major theoretical perspectives on food security and small-scale irrigation giving particular emphasis on the effect of small-scale irrigation on household food security. Synthesis of a few relevant and related empirical studies undertaken on irrigation and food security is also highlighted in this chapter.

2.1. Theoretical Literature

This section mainly aims at reviewing major definitions and concepts of food security and small-scale irrigation in general and then state the adopted working definition of food security and small-scale irrigation at the household level for this study

2.1.1. Definitions and Concepts of Food Security

The Food and Agricultural Organization (FAO) has estimated that the total number of undernourished people in the world will decline by 9.6 percent to 925 million in 2010, after continuously increasing during the preceding five years(FOA, 2010). Though this is often a positive sign and a welcome respite, this number remains unacceptably high at 16 percent of the world's population and far above the hunger-reduction targets set at the World Food Summit in 1996, as well as by the MOOs. Developing countries account for 98% of the world's undernourished people and have a prevalence of undernourishment of 16%. The origin of the operative term food security' may be traced back to the Universal Declaration of Human Rights in 1948, under the aegis of the United Nations, which recognized the right to food as a core element of the standard of living. However, the literature on food security exploded since the publication of the report of the World Food Conference held in 1974 consequently to the global food crisis of 1972-74 (FAO, 2011).

According to(Masters, 2009) food security is generally assessed in terms of four component concepts: namely Food Availability, Food Access, Food Utilization, and Food Stability (*versus* Vulnerability) which are explained very briefly in the succeeding paragraphs.

Food Availability means that food is physically present because it has been grown, processed, manufactured, and/or imported. For example, food is available because it can be found in markets and shops; it has been produced on local farms or in-home gardens, or it has arrived as part of food aid. This refers to all available food in the area and includes fresh, as well as packaged, food. Many factors can affect the availability of food directly or indirectly. For instance, food availability can be affected by disruptions to the food transport and production systems, due to blocked roads, failed crops or a switch from food crops to cash crops, changes in import and export tariffs, amongst other factors. Such occurrences can influence the amount of food coming into an area. In addition, food availability is dependent upon seasonal patterns in food production and trading Masters, (2009).

Food Access: refers to how different people obtain available food. Normally, the way of accessing food is through a combination of means. This may include home production, use of left-over stocks, purchase, barter, borrowing, sharing, gifts from relatives, and provisions by welfare systems or food aid. Food access is ensured when everyone within a community has adequate financial or other resources to obtain the food necessary for a nutritious diet(El Bilali et al., 2020).

Similar to availability, access also depends on various factors like the household's available income and its distribution within the household, as well as on the price of food. It also depends on markets. Food access can be negatively influenced by unemployment, physical insecurity (e.g. during conflicts), loss of coping options (e.g. border closures preventing seasonal job migration), or the collapse of safety-net institutions which once protected people on low incomes.

Food Utilization: is how people use food. It is dependent upon some interrelated factors: the quality of the food and its method of preparation, storage facilities, and the nutritional knowledge and health status of the individual consuming the food. For example, some diseases do not allow for optimal absorption of nutrients, whereas growth requires increased intake of certain nutrients.

Food utilization is often reduced by factors such as endemic disease, poor sanitation, lack of appropriate nutritional knowledge, or culturally prescribed taboos (often related to age or gender) that affect a certain group's or family member's access to nutritious food. Food utilization may also be adversely affected if people have limited resources for preparing food, for example, due to a lack of fuel or cooking utensils(Masters, 2009).

Food Stability: To be food secure, a population, household, or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security Masters, (2009)

2.1.2. Household Food Security

Studies on the assessment of food security can take a different level of the unit of analysis, at national, regional, community, household, and individual levels. Since collecting precise information for each individual might be impossible or too costly, especially in poor countries like Ethiopia, there is an option that is widely practiced in food security research. This is study starts at household level analysis by applying weight (Adult equivalent scale or ratio) to adjust to its composition and drives weighted per capita estimate Jacobs, (2009). Hence, it is worthwhile to look at the concept of household food security since this study's center of attention is at the household level.

2.1.3. Definition and concepts of irrigation

Irrigation is defined as the application of artificial water to the living plants for food production and overcoming shortage of rainfall and help to stabilize agricultural production and productivity. Irrigation has been practiced in Egypt, China, India, and other parts of Asia for a long time. Ethiopia also has a long history of traditional irrigation systems (mainly diversion schemes). It enables farmers to increase crop production and achieve higher yields, food availability, and affordability for non-irrigators and reduces the risk of crop failure if rain fails Hussain and Hanjra, (2004).

Irrigation contributes to agricultural productivity by solving the rainfall shortage, motivates farmers to use more modern inputs and harvest throughout the year, and creates employment for members of the households. According MoIWE (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 et al., 2007). The adoption of new technology (e.g. irrigation) is the major power for agricultural growth and poverty reduction(Norton, 2009).

Small Scale Irrigation(SSI): The artificial application of water to a small plot of land ranging from 0.2 to 0.5 ha, comprising a small number of farmers containing 200 users, using relatively small reservoirs- rivers, dams, or a cluster of wells controlled by the farmers using technology. In highland areas like Ethiopia, where water is delivered through gravity, small-scale irrigation schemes concern the upgrading of irrigation works, where the simple diversion structures, micro dams constructed by traditional communities with local means such as stone and brushwood (Gebremeskel Gebremichael, 2013). It is a means by which agricultural production can be increased to meet the growing food demand through increasing agricultural yield, increase the productivity of arable land and increase cropping intensity(Hamdu, 2014).

Small-scale irrigation schemes have command areas below 200 hectares; medium scale schemes that can supply an adequate amount of water to an area between 200 and 3000 hectares whereas water availability for over 3000hectare command area is considered as large-scale schemes(Awulachew et al., 2005).

2.2. Theoretical Framework of Utility maximization theory of the Study

Utility maximization theory refers to the concept in which individuals and firms seek to get the highest satisfaction from their economic decision makings. In this study, it is assumed that from their experience, farmers know major irrigation-related benefits and problems, and they can state their preferences. They are expected to rationally reveal their preference in line to improve their welfare. This preference can be represented by a utility function and the decision problem can be modeled as a utility maximization problem Bekele, (2012).

Suppose that the farmer drives utility from using small-scale irrigation and his resource endowment. Let farmer’s participation in small scale irrigation be represented by k, where k=1 if the farmer decides to participate in small scale irrigation to maximize his utility and k=0, otherwise. Resource endowment of the farm household is represented by r, and ‘X' represents other observable attributes of the farm household that might potentially affect participation in small-scale irrigation.

If a farmer participates in small-scale irrigation for crop production, the farmer's utility is given by the function, $U_1 = U(1, r, x)$, and if the farmer does not participate in small scale irrigation, the farmer’s utility is given by $U_0 = U(0, r, x)$**.** Thus, based on this economic theory, the farmer chooses the best alternative that offering the best value, subject to his/her constraints. According to Bekele, (2012) and as it is most common in the specification of a utility function, we assume additively separable utility function in the, “deterministic and stochastic components where the deterministic part is assumed to be linear in the explanatory variables’’. Functionally, it can be expressed as

$$U_1 = U(1, r, x) = t(1, r, x) + \varepsilon_1 \ldots\ldots\ldots\ldots \mathbf{1}$$

And

$$U_0 = U(1, r, x) = t(0, r, x) + \varepsilon_0 \ldots\ldots\ldots\ldots \mathbf{2}$$

Where, $\mathbf{U_k}(,)$ is the utility from the use of small-scale irrigation water (yield and income) and $\mathbf{t_k}(,)$ is the deterministic part of the utility, and $\boldsymbol{\varepsilon_k}$ is the stochastic component representing the component of utility known to the farmers but is unobservable to the economic investigator. It is obvious that farmers are assumed to know their resource endowment, r, and the implicit cost of using irrigation water or practicing irrigation in terms of engagement of their resources and can make a decision whether to use it or not. Assume that farmer’s implicit cost of deciding and using small scale irrigation is represented by ‘C’

Therefore, a farmer will decide to participate in small-scale irrigation if the utility from participation exceeds the utility from not participating. Functionally

$$U_1(.) \geq U_0(.)$$

$$t(1, r - C, x) + \varepsilon_1 \geq t(0, r, x) + \varepsilon_0 \ldots\ldots\ldots\ldots \mathbf{3}$$

The existence of the random element permits us to make probabilistic statements about farmers’ decision behavior. If the farmers participate in irrigation, the probability distribution is given by:

$$P = \Pr(t(1, r - C, x) + \varepsilon_1 \geq t(0, r, x) + \varepsilon_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

And if the farmer did not participate in irrigation, it will be given by the function

$$P = \Pr(t(0, r, x) + \varepsilon_0 \geq t(1, r - C, x) + \varepsilon_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

By the assumption that the deterministic component of the utility function is linear in the explanatory variables, the utility functions of small-scale irrigation participation and non-participation can be expressed as

$U_1 = \beta'_1 X_i + \varepsilon_1$, for participation

$U_0 = \beta'_0 X_i + \varepsilon_0$, for non-participation

Where; $\beta'_1$and β'_0 are the vectors of the response coefficients and ε_1 and ε_0 are random disturbances

Similarly, the probabilities of participation and non-participation in small scale irrigation can be given as:

$$P = \Pr(\, U_1(.) \geq U_0(.))$$

$$P = \Pr(\beta'_1 X_i + \varepsilon_1 \geq \beta'_0 X_i + \varepsilon_0)$$

$$P = \Pr(\beta'_1 X_i - \beta'_0 X_i) \geq \varepsilon_0 - \varepsilon_1$$

$$P = \Pr(X_i(\beta'_1 - \beta'_0) \geq \varepsilon_0 - \varepsilon_1$$

$$P = \Pr(X_i \alpha \geq v_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where: P = is the probability function,

v_i= $(\varepsilon_0 - \varepsilon_1)$ is a random disturbance term

α =$(\beta'_1 - \beta'_0)$ is a Qx1 vector of parameters to be estimated

X_i= is n x Q matrix of explanatory variables

$\mathbf{Pr}(\mathbf{X_i \alpha})$ is the cumulative distribution function for vi evaluated at $\mathbf{X_i \alpha}$

The probability that a farmer will use the irrigation technology is then a function of a vector of the explanatory variables, the unknown parameters, and the disturbance term

2.3. Measuring Household Food Security

There is no single indicator to measure food security. Many different indicators are needed to capture the various dimensions at country, household, and individual levels(Hoddinott, 1999). Since food security is influenced by different interrelated socio-economic, physical, institutional, and political factors, it requires an understanding of the multidimensional contexts of the target area. Hence, combining both qualitative and quantitative household data sources in studying food security activities allows knowing the holistic nature of the study area comprehensively as argued by (Degefa, 2006) since some indicators are only appropriate for assessing the process while others monitoring of the outcomes of certain project goals. It is up to the researcher to select a combination of indicators that suit the objectives of the investigation, the level of aggregation, and the specific circumstances of the study and study area(Prasad, 2011).

Generally, the most common indicators of household food security are food availability, food consumption or access, and composite food security. Measuring food security in terms of food availability focuses on national or household agro-food output or supply(Jacobs, 2009). The table below it was illustrated these three common indicators.

Table 2.1: Mapping Security Indicator

Indicator/measure	Focus	Example
Food availability	National or household Agro-food output/supply	Food Balance Sheets
Food consumption/access	Food demand or consumption at the household level (ways in which institutions regulate access to food)	Household expenditure models; food expenditure ratio; income elasticity

Composite food security	Simultaneously captures each dimension in a single indicator	Poverty Hunger Index; Food Security Gap Index

Source: (Jacobs, 2009)

The Household Food Balance Model (HFBM) is developed by Degefa in 1996, which is adopted from FAO, to simplify the method of gathering data in food security research nationally as explained by (Mesay, 2010). The same author conveyed that the food balance sheet tool has been used by many scientific studies to measure the contribution of development projects mainly in the agriculture sector. Hence, this research is used HFBM analytical tool to measure the household food security status of the proposed area of study.

2.4. Impact Assessment Methods

There are different methods that we can use to impact evaluation. These methods are; Propensity Score Matching (PSM), Difference in Difference (DID), Randomized Selection Methods (RSM), and Regression Discontinuity Design (RDD) Abadie et al., (2004).

Propensity score matching (PSM)

Propensity score matching is a statistical matching technique that estimates the effects of a treatment given the covariates. It allows finding a control group from a sample of non-participants closest to the treatment group in terms of observable characteristics so that both groups are matched based on the propensity score. A propensity score is a predicted probability of participation given observed characteristics Ravallion, (2008). The propensity score is estimated using statistical models, logit or probit, and the average treatment effect (ATE) of the outcome of the two groups in absence of baseline data is calculated Abadie et al., (2004).

It is used when it is possible to create a comparison group from a sample of non-participants closest to the treated group using observable variables. Both groups are matched based on propensity scores, predicted probabilities of participation in a program given some observed variables. Propensity score matching consists of four phases most common are: estimating the probability of participation, that is, the propensity score, for each unit in the sample; selecting a matching algorithm that is used to match beneficiaries with non-beneficiaries to construct a comparison group; checking for balance in the characteristics of the treatment and comparison groups, along with estimating the program effect and doing sensitivity analysis(Caliendo & Kopeinig, 2008). Propensity score matching (PSM) has two key underlying assumptions. These are conditional independence (CI) and the existence of a common support region Baum, (2013).

Conditional Independence: It states that there exists a set of 'X' observable covariates such that after controlling for these covariates, the potential outcomes are independent of treatment status.

The Common Support: It states that for each value of "X", there is a positive probability of being both treated and controlled. It is used when creating a comparison group that is possible from a sample of non-participants closest to the treated group using observable variables.

Difference-in-difference (DID)

The difference in difference (DID) is designed for empirical analysis of causal effects, and has a long history in and outside econometrics, and is one of the most heavily used empirical research designs to estimate the effects of policy changes or interventions in empirical microeconomics nowadays. The difference in difference is a method in which we compare treatment and control groups before the project (first difference) and after the project (second difference). Comparators should be dropped when propensity scores are used and if they have scores outside the range observed for the treatment group. In this case, potential participants are identified and data are collected from them. However, only a random sub-sample of these individuals is allowed to participate in the project. The identified participants who do not participate in the project form the counterfactual Ravallion, (2008).

Randomized selection methods (RSM)

A randomized selection method (RSM) is the process of randomly selecting a group, treatment, and control, from a clearly defined population to evaluate the outcome of the intervention. Based on this, the control group is similar to the treatment group, and the only difference is the participation in the required program. This method can do before and after or pre and post matching and this leads to the matching of variables that change due to participation. Furthermore, randomization also does not require the untestable assumption of conditional independence on observables Abadie et al., (2004).

Regression discontinuity (RD)

The regression discontinuity (RD) method is one of the rigorous non-experimental impact evaluation approaches that can be used to estimate program impacts in situations in which candidates are selected for treatment based on whether their value for a numeric rating exceeds a designated threshold or cut-point Howard et al., (2012). It allows us to account for observed and unobserved heterogeneity. It initially assigns scores for the intervention unit and then compares the outcome of individuals above the cut-off point with a group of individuals below it. Individuals around the cut-off point are similar.

Regression discontinuity is based on the cut-off point in observable characteristics, often called the rating variable. RD techniques are considered to have the highest internal validity (the ability to identify causal relationships), but their external validity (ability to generalize findings to similar contexts) may be less impressive, as the estimated treatment effect is local to the discontinuity Baum, (2013).

Therefore, for this study purpose, Propensity Score Matching (PSM) is selected and used for analyzing the impact of small-scale irrigation on household food security for several reasons. Firstly, there is no baseline data on participants and non-participants to compare before and after as it is common in many researchers that are conducted on impact evaluation. Second, the participants in small-scale irrigation are self-selected to participate in the program and this leads to bias. Furthermore, the data to be used is cross-sectional survey data. Finally, it is possible to identify some features, in these cases socio-economic, institutional, and physical characteristics, to match the participants and non-participants.

2.5. Empirical Review of Irrigation and household food security

2.5.1. Challenges of Small Scale Irrigation

According to (Selesh, 2010), there are four challenges of irrigation in terms of institutional, human, and technical capacity, capability, policy context, and funding. The constraints are explored at each decision-making level. On the other hand, the study by Haile and Kassa, (2015) shows that the major challenges of small-scale irrigation are explained as technical constraints and knowledge gaps as inadequate awareness of irrigation water management, inadequate knowledge on improved and diversified irrigation agronomic practices, shortage of basic technical knowledge on irrigation, inadequate baseline data and information on the development of water resources, lack of experience in design, construction and supervision of quality irrigation projects, low productivity of existing irrigation schemes, inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development, poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers.

Irrigation may worsen absolute poverty for some if it reinforces processes of land consolidation in which poor households lose land rights, or if it is associated with displacement of labor by mechanization or herbicide use. Poor people may be displaced by the construction of reservoirs and canals, or their livelihoods may be adversely affected by upstream or downstream impacts. Badly designed or managed irrigation can negatively impact public health and human capital through the spread of Water-borne diseases, usually with a greater incidence for the poor. The consumption linkages that are major drivers of poverty reduction are likely to be less effective when income and land distribution are highly skewed. This is because the consumption patterns of the 'wealthy' may be oriented to imports and capital-intensive goods and services, rather than the offerings of rural non-farm suppliers. Barriers to entry in nonfarm employment and micro-enterprise can arise from ethnicity or caste, gender, skill and education levels, access to information, mobility, transaction costs, and risks(Asayehegn, 2012).

Tesgera and Guluma (2020) the core constraints and challenges of irrigation are associated with socio-cultural, physical, economic, biological, and political issues. Besides, soil salinity, depletion of water, flood and erosion, drainage challenges, maintenance challenges quality of design, pest infestation and input shortages as well as water-borne diseases are some of the biological and physical challenges for irrigation practice. The study by Tesgera and Gulma expresses the above as economic constraints are linked with the market price for irrigation crops, change in an interest rate, and market accessibility. Social and cultural issues like land tenure policies are a significant challenge for the performance of irrigation schemes, especially in developing countries. In addition, the cooperation of a larger range of government institutions and individuals such as irrigation departments, extension and rural works, banks, and planning bodies.

2.5.2. Measuring food security

Mitiku et al (2013), Conducted a study in the Shashemene district of Oromia regional state in Ethiopia about determinants of rural household food security. The study found that the prevalence of rural food security was 36% with a 12.4% depth of food insecurity and 7.4% severity of food insecurity.

Meskerem and Degefa (2015), conduct research on, household food security status and its determinants in the Girar Jarso Woreda. The household balance model result shows that available dietary energy of study households met only 45.3% of the minimum daily allowance, 2100kcal during the study year, and indicating the remained 54.7% of households were insecure.

Abayineh and Belay (2017), presented the food security status of farm households that had been determined using descriptive analysis. The result of the household food balance model revealed that from the total sample households, 57.8% households were found to be food secure who fulfill the minimum recommended daily calorie (2,100 kcal/AE/day, while 42.2% of them failed to supply this daily minimum requirement.

Mesfin (2019) tried to examine the extent of households' vulnerability to food insecurity in urban and rural areas of Amhara regional state of Ethiopia and the descriptive result revealed that about 48% of households were able to meet 2100 kcal per day per adult recommended calorie requirement, with higher prevalence in rural households than urban households.

2.5.3. Determinants of Participation Household Small-Scale Irrigation

Yihdego et al., (2015) applied descriptive statistics and Heckman's two-stage to estimation effect of small-scale irrigation on the income of rural farm households found that household head leadership, access to extension services, irrigable land availability, family size, family size square, distance to the market, number of oxen determine the participation of households in irrigation.

Regassa, (2016) using the logistic regression model revealed that; the age of household head, sex of household head, income, input use, and participation in a cooperative organization are among the factors that significantly and positively affect irrigation participation. On the other hand, farm experience, distance to the district market, and total livestock holding significantly and negatively affected households' decision to participate in irrigation.

Wassihun, (2016) using the probit model found that distance from the nearest market, education level of household head, total livestock holding, distance to water sources, access to information, family labor, access to credit, and gender of household head were significantly affected participating in small scale irrigation scheme. The result of the research conducted by Astatike, (2016), used Heckman's two-staged model, and the result of the probit model indicated that; ownership of irrigation land, pumping motor, and dissatisfaction with the existing irrigation schemes are among the most determinant factors that influence irrigation participation.

Agidew, (2017), employed the binary logistic regression analysis to recognize the determinant factors that influence the use of irrigation water conducted at Arba Minch Zuria Woreda. The results show that the sex of households', household size engaged in the agricultural labor force, and several contacts of respondents with agricultural development agents per month had a significant positive effect on the use of irrigation water. However; educations level and attending training had a significant positive effect on the use of irrigation. And also, farm distance from the river and the main irrigation canal had a significant negative effect on the use of irrigation water.

According to Ambe, (2018), his study applied binary logistic regression analysis to examine the determinants of the performance of small-scale irrigation in improving household farm income in the Hadiya zone. The result shows that five determinant factors, education level of respondents', land holding size, household labor, and household income had a significant positive effect on the use of irrigate on water. While the age of respondents and farm distance from the river had significant negative effects on the use of irrigation water.

Kedir and Beyene (2019) carried research at Fentale District, East Showa Zone of Oromia National Regional State, Ethiopia, on the impact of small-scale irrigation on household food security. The binary logit model was fitted with variables, of which six were found to be significant. The educational level of household heads, livestock ownership, distance from the local market center, non-farm income, dependency ratio, and distance from irrigation water source were significant variables. From these variables, educational level of households, distance from the local market center, and frequency of contact to the extension were significantly and positively influenced irrigation participation, but livestock ownership, dependency ratio, and distance from irrigation water source had a negative impact on irrigation participation.

Bedasso et al., (2020) study were conducted at Deder district of East Hararghe administrative zone, factors affecting smallholder farmers' participation and level of participation in small-scale irrigation. A Heckman model applied in the study and found that sex of the household head, availability of family labor force, perceived soil fertility status, size of cultivated land, total livestock holding, and access to extension services were affected participation in small-scale irrigation positively and significantly while a distance of households' residence from the water source was negatively and significantly participation in small-scale irrigation.

Jambo et al., (2021) conducted a study on the impact of small-scale irrigation on household food security evidence from Ethiopia by employing a binary logit model based on a primary survey. The model result showed that age household head, education of household, access to extension service, land size, and participation in off or non-farm activities were positively affected participation in small-scale irrigation. In contrast to this, distance from farm plot to a water source, and distance from the main market negatively affected participation in small-scale irrigation.

2.5.4. Impact of Irrigation use on household food security

Irrigation development has a profound impact on alleviating poverty. Because small-scale irrigation increases mean annual household income, irrigating households have a lower probability of being poor than non-irrigating households. Irrigating households' average income is higher, while non-irrigating households' average income is 50 percent less than the average income of irrigating households. There is also a difference in total household consumption expenditure between the control and treatment groups(Asayehegn, 2012).

According to the finding of (Asayehegn, 2012) the ratio of the mean income of irrigation users to non-users exceeds 37.03%, and the nutritional status and standard of living of the users also increased by the same factor as income. Moreover, irrigation use greatly supports the livelihood and reduces household poverty of the users through creating employment opportunities. Irrigation use has a positive impact on households earning from a crop, livestock, and provide additional income by selling maram grass from their irrigation site, this increased income, as well as reduced poverty and, remunerative off-farm income sources like cart and trade, were the results of irrigated agriculture whereas inferior livelihood activities like fire wood, and charcoal selling, and causal work were dominated by non-irrigators.

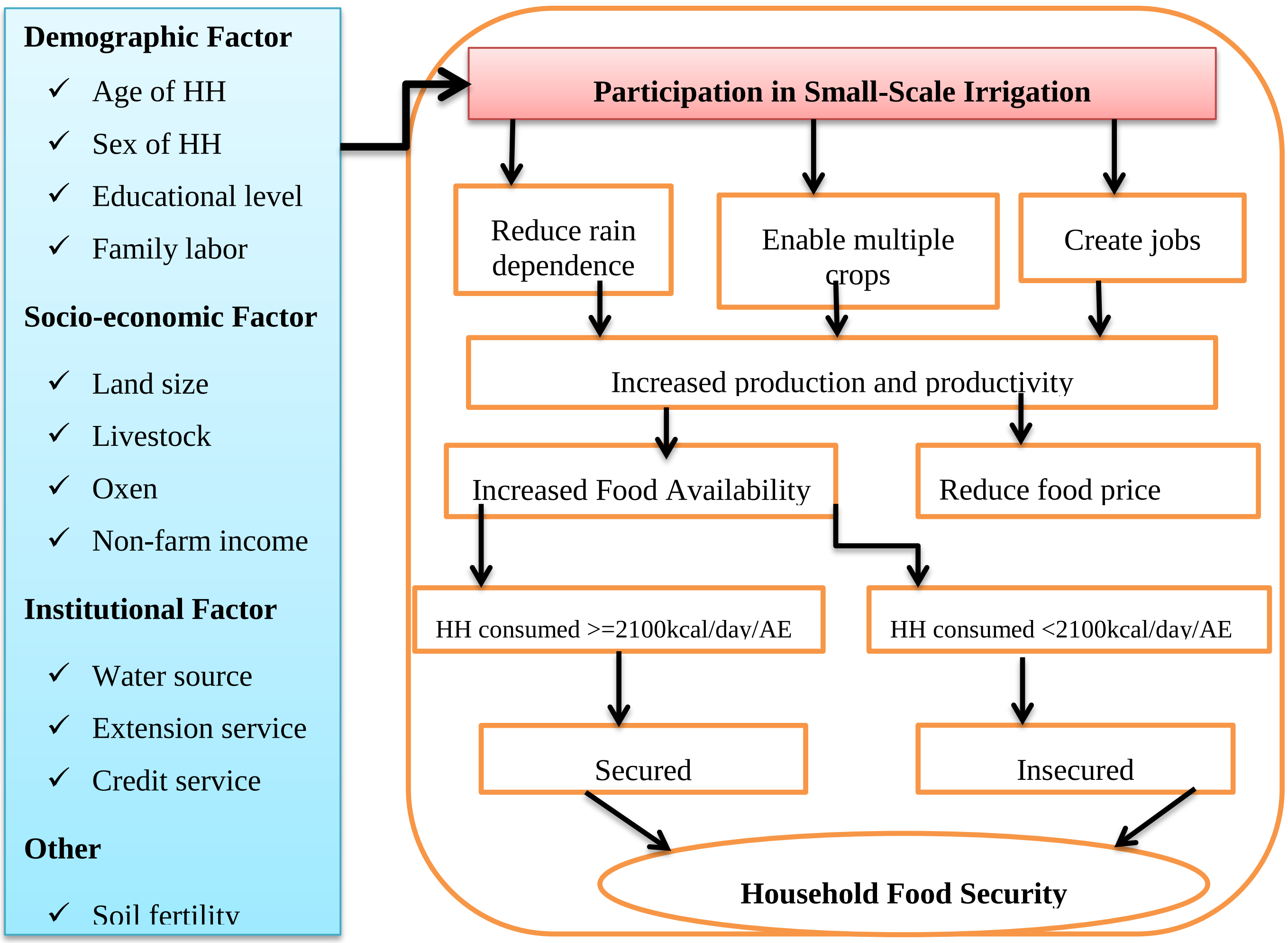
Muleta and Milkias, (2021) used PSM and Logit model to assess the impact of small-scale irrigation on household food security in Central Highlands of Ethiopia: Evidences from Walmara District. The result shows that participation has a significant positive impact on the outcome variables such as daily calories intake and food consumption scores. The logit regression result revealed that the sex of the household head, age of the household head, educational level of the household head, land owned, distance of irrigation site crop pests, livestock holding, and credit access were significantly affected the participation decision of households in small-scale irrigation.

2.6. Research Gap

Regarding the above theoretical and empirical literature reviews, it can be understood that most of the studies focused either on identifying the determining factors or implications of rural household participation in small-scale irrigation. Likewise, this study has been examining factor that affects the participation of small-scale irrigation, but the impact of small-scale irrigation on household food security, factors affecting farmers' participation in small-scale irrigation in the study area is not empirically analyzed and this study is proposed with this background.

2.7. Conceptual Framework

The identification of determinants related to participation in small-scale irrigation among rural households is subject to the application of a research framework. Based on empirical studies a framework is presented in figure 2.1. As shown in the figure below, the well-being of a household is influenced by various factors like demographic, socio-economic, institutional factors, and other factors. The analytical framework shows that the linkage between household food security and variables assumed that affect household participation in small-scale irrigation in the study area. According to their nature, these variables are categorized under four categories. Demographic characteristics include; gender of household head, age of household head, educational level of the household head, and family labor. Institutional factors category includes access to credit, water source, and extension service. Socio-economic factors involve farm size; livestock excluded oxen, non-farm income, and oxen owned.



Source: Adopted from Demisse, (2020)

Figure 2.1: Conceptual framework

CHAPTER-THREE

3. RESEARCH METHODOLOGY

3.1 Description of the Study Area

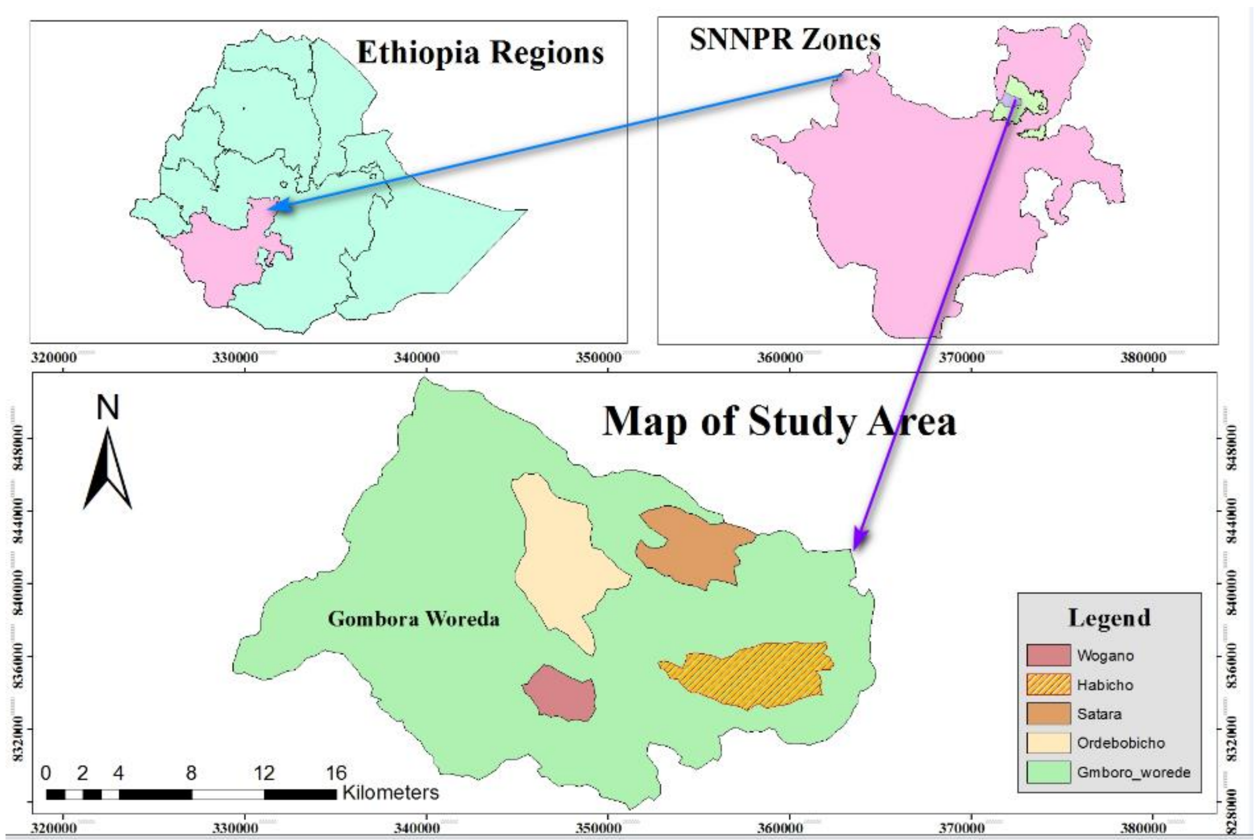
This study would be conducted in Gombora Woreda, Hadiya Zone, Southern Nations, Nationalities, and Peoples Regional State (SNNPRS) of Ethiopia. Gombora Woreda is located about 259 km south of Addis Ababa and 27km away from Hossana, the capital city of Hadiya Zone and it is one of the 11Woredas of Hadiya Zone. It is geographically located between 7^0 49′, 7” N, latitude, and 37^0 45′, 37” E, longitudes. Gombora woreda is bordered in the North by Gibe woreda, in the North-East by the Misha woreda, and on the South Soro woreda, in the East by the lemo woreda, and in the West by Omo River Yam special woreda and Oromiya National Regional States. This woreda has 23 rural Kebeles and 1 urban Kebeles. The administrative center of this Woreda is Habicho; other towns in Gombora Woreda include Bushana(GWFEDO, 2019).

Topographic features of the Gombora Woreda were mostly by flat and moderately gentle lands. This Woreda is characterized mostly by lowland altitude site (1600-2000m.a.s.l) 46.5%, and middle altitude site (2000-2400.m.a.s.l) 53.5% (Ibid).

Gombora Woreda has two agro-ecological Zones, namely *Kolla* (low land and warm) 46.5% and *woina-dega* (moderate) 53.5%. These agro-ecological zones differ in altitude and rainfall distribution. The rainfall distribution is bimodal type, which occurs in two main rainy seasons *Belg* and *Maher*. *Belg* is a short rainy season from occurs from the beginning of January to April and that of *Maher* occurs long rainy season that May to the end of September. The mean minimum and maximum annual precipitation vary between 500 - 2200mm. The mean minimum and maximum temperature are 15 - 25°C(GWFEDO, 2019)

The demographic characteristics of the study area can be described as follows: Gombora Woreda has 23 Kebeles (KAs) with a total population of 92,332; with 46,225 males and 46,107 females (CSA, 2007). The population density of Gombora Woreda is 270 persons per square kilometer (GWARDO, 2019).

The livelihood of the people in the Woreda depends mainly on mixed agriculture (crop-livestock production). It is characterized by mixed farming of rain-fed crops and livestock production associated with tree species on farmland. The most commonly cultivated crops in the study sites include enset, teff, wheat, maize, sorghum, beans, coffee, barley, and chat in order of their importance, respectively. Enset is the staple food crop for the majority of the community, while coffee and chat are the dominant cash crops in some Peasant Associations (PA). Fruits such as avocado, banana, mango, papaya, and are also cultivated for household consumption and to some extent income generation GWARDO, (2019).



Source, Ethio-GIS data

Figure 3.1. Map of the location of the study area

3.2 Research Design

This study has a cross-sectional research design-with a semi-structured interview schedule for a sample of irrigation user and irrigation nonuser household was conducted. Qualitative and quantitative data collection methods were administered to address objectives; to measure the household food security status in the study area, to identify the factors affecting the households' participation in small scale irrigation in the study area, to identify the factors constraining irrigation use in the study area, and to analyze the impact of small-scale irrigation on household food security.

3.3. Types of Data, Data Sources

For this study, both quantitative and qualitative data from primary and secondary sources were collected. The source for primary data is the sample farmers in Gombora woreda and the source for secondary data are local offices, higher governmental organizations, different publications, and policy documents. To obtain primary data, a semi-structured questionnaire, with both closed and open-ended questions was used as a tool to collect data from sample households. For the sake of conducting this study, important variables on economic, social, and institutional factors related to the households in the study area were collected.

3.4. Sampling Technique and Sample Size Determination

3.4.1. Sampling technique

The sampling procedure that was followed for this study is the multi-stage sampling procedure. Firstly, Gombora woreda was selected as it is identified as one of the food insecure woreda in the Hadya zone. Then, out of 23 total kebeles within the woreda four kebeles were selected purposively considering factors of the presence of small-scale irrigation and its accessibility.

In the second stage of the sampling procedure, a stratified random sampling technique was used to select sample respondents. Households were categorized into two strata: irrigation users and non-user. Household heads from the four kebele's with respective irrigation schemes were identified and stratified into two strata user and non-user households. In the third stage, sample household heads from both irrigation users and non-users would be selected using a proportionate random sampling technique considering the total sample determining for the survey.

3.4.2. Sample size determination

The sample size is often restricted by the available fund, time, and other related reasons. It is often not feasible to study the entire population because of the following reasons; the physical impossibility of checking all items in the population, the cost of studying all the items in the population, the adequacy of sample results, to contact the whole population would be time-consuming and the destructive nature of certain tests. Therefore, considering financial constraints, time shortages, lack of transportation, and other facilities, the households sample size would be determined by using a simplified formula for proportion suggested by, Cochran, (1977) which is used to determine sample size as below;

As per data sources of the woreda agriculture development office (2019), the target population of the study covered 983 irrigation user households and 1603 households that are not using small-scale irrigation for farm practices. P=0.38 variability is taken as an assumption. Furthermore, it was supposed that a 95% confidence level and 5% precision enable a sound sample size. Accordingly, the resulting sample size is demonstrated

$$n_o = \frac{Z^2pq}{d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

$$n_o = \frac{(1.96)^2(0.38)(0.62)}{(0.05)^2} = 362$$

To slightly reduce the sample size and make a given sample size provide proportionately more information for a small population than for a large population. The sample size (n_o) can be adjusted using the following equation

$$\mathbf{n} = \frac{\mathbf{n_o}}{1+\frac{(\mathbf{n_o}-1)}{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

$$\mathbf{n} = \frac{362}{1+\frac{362-1)}{2586}} = \mathbf{318}$$

After determining the total sample size, a proportional sampling technique has been used to select the sample from each of the kebeles. The sample selected from each selected kebeles was proportional to the sample population in strata in each Kebele and the formula for this purpose was determined by the formula

$$\mathbf{N = N_1 + N_2}$$

$$\mathbf{N_1 = \sum_{i=1}^{4} N_{1i}} \quad ; \quad \mathbf{N_2 = \sum_{i=1}^{4} N_{2i}}$$

$$\mathbf{n_1 = \frac{n * N_1}{N}} \quad ; \quad \mathbf{n_2 = \frac{n * N_2}{N}}$$

$$\mathbf{n_{1i} = \frac{N_{1i} * n_1}{N_1}} \quad ; \quad \mathbf{n_{2i} = \frac{N_{2i} * n_2}{N_2}}$$

Where p is the proportion of farmers who use small-scale irrigation

q = the proportion of farmers who does not use small-scale irrigation (1-p)

Z = Z- Score associated with the appropriately chosen level of confidence (95%) with the table value of $((Z\alpha/_2) = 1.96$ at $\alpha = 0.05$ level of significance.

d=5% degree of accuracy, with 95% level confidence.

n = a total sample size

n_1 = total sample size households irrigation non-user in selected Kebele

n_2 = total sample size households irrigation users in selected Kebele

n_{1i} = a sample of household's irrigation non-user to be selected from i's Kebele

n_{2i} = a sample of household's irrigation users to be selected from i's Kebele

N = a total household in selected Kebele

N_1 = total households irrigation non- user in selected Kebele

N_2 = total households irrigation users in selected Kebele

Lastly, a simple random sampling technique would be employed to select 318 households

Table 3.1: Sample frame and sample size determination

Kebele	**Total number of households**			**Sampled households**		
	Non-user	**User**	**Total**	**Non user**	**User**	Total
Ordebobicho	449	392	841	55	48	**103**
Habicho	312	180	492	39	22	**61**
Wegeno	440	209	649	54	26	**80**
Satara	402	202	604	49	25	**74**
Total	**1603**	**983**	**2586**	**197**	**121**	**318**

3.5. Method of Data Collection

To get data on the determinants of participation in small-scale irrigation, the questionnaire covered a range of topics including demographic characteristics of households and socioeconomic structure; market access, access to credit, area of irrigated land, a distance of farmland from a water source, educational status, cultivable land size, and other related factors were considered. So, primary data was collected through various data collection instruments such as a questionnaire.

For the collection of primary data, enumerators, with at least secondary education that can speak local languages would be employed. Necessary care was taken in recruiting the enumerators. They give intensive training on data collection procedures, interviewing techniques, and the detailed contents of the questionnaire. The households' questionnaire was translated into the Amharic language, to convey the questions effectively to the rural interviewees, and it was pre-test, administered, filled by the trained and experienced enumerators. Strict supervision was made by the researcher during the survey. Secondary data would be collected from documents and publications of different organizations and relevant local offices as well as journal documents.

3.6. Method of Data Analysis and Model Specification

After data was collected from both primary and secondary sources, it would be analyzed using different methods of data analysis. Before analysis, quantitative data gathered using the survey were coded and entered into statistical software such as Microsoft Excel and STATA Version 16.0 would be used.

Both descriptive and econometric data analysis techniques would be employed. Descriptive statistical techniques such as mean, percentage, mean difference, and standard deviation were used for presenting differences in socioeconomic variables between irrigation users and nonusers.

3.6.1. Analysis of food security status

Food security is important to measure the availability, accessibility, consumption, and stability of global, national households, and individual households. The food security status of sampled households in the study area was analyzed using the Household Food Balance Sheet Model (HFBM). The model was initially formulated by Degefa Tolossa (1996) adapted from FAO Regional Food Balance Model and then used by various researchers (Demeku et al., 2015; Woldeamanuel and Simane, 2017; Wondimagegnhu and Bogale, 2020). The household food balance sheet equation tries to include all the available cereal and non-cereal food items as stated below

$$NGA_{ij} = (GP_{ij} + GB_{ij} + GA_{ij}) - (GS_{ij} + GR_{ij} + GV_{ij} + HL_{ij}) \ldots\ldots \mathbf{9}$$

Where, NGA_{ij} is net grain available per year per household

GP_{ij} is total grain produced per year per household

GB_{ij} is total grain bought per year per household

GA_{ij} is total grain obtained from aid per year per household

GS_{ij} is quantity grain sold per year per household

GR_{ij} is quantity grain reserved for seed per year per household

GV_{ij} is quantity grain given for others per year per household

HL_{ij} is post − harvest loss per year per household

$i = 1,2,3, \ldots, 318,$ and $j = 2012$ E.C

3.6.2. Measuring food security status of sample household

In assessing the food security status of sampled households in the study area, the following steps follow. First, all stable food sources of cereals and non-cereal grains available to sample households for the past year were collected. Secondly, the collected data will be structured in the HFBM equation to determine the net food availability situation of the sampled households. Finally, the food energy requirement for each sampled household member was calculated by converting it into an adult equivalent ratio.

Because the survey would be made immediately after the main harvesting/production period of the area it is preferred to use HFBM than other food security measurement tools. From experience, it is observed that local communities in the study area have been involved in performing culturally accepted social activities like wedding ceremonies during this time. Hence, taking food consumption data using 24 hours recalls method or other techniques may not be appropriate and even lead to come up with counterfeit results. Accordingly, for measuring the annual food availability status of sampled households HFBM tool was selected.

As mentioned above, the method has to derive separately the number of grains available for domestic utilization (food use) and other secondary components (grain uses for other purposes/losses). Hence, the net quantity of food available was calculated and converted into dietary calorie equivalent based on Ethiopian Health and Nutrition Research Institute (EHNRI)'s food composition table. The calculated calorie would be compared against the national average daily caloric requirement for a moderately active adult (≤ 2100 kcal) to look into the dietary calorie status of the resettled households in the study area. Therefore, based on this information, those households who have to meet the above-estimated caloric requirement were categorized as food secure and otherwise food insecure.

3.6.3. Model of specification

Regression models in which the dependent is dichotomous can be estimated by linear probability model (LPM), logit, or probit. Although the linear probability model is the simplest method, it is not logically attractive in that it assumes that the conditional probability increases linearly with the value of explanatory variables. Unlike linear probability, the logit model guarantee that the estimated probabilities increase but never step outside the 0 – 1 interval and the relationship between probability (P_i) and explanatory variable (X_i) is nonlinear (Damodar N. Gujarati, 1995). To test the hypothesis, a probabilistic model is specified with participation in small-scale irrigation as a function of a series of household characteristics as explanatory variables. The dependent variable, in this case, is dummy, which takes a value of zero or one depending on whether or not a household is food insecure. Thus, the main purpose of a qualitative choice model is to determine the probability that an individual with a given set of attributes will fall in one choice rather than the alternative. Logistic and cumulative normal functions are very close in the midrange, but the logistic function has slightly heavier tails than the cumulative normal distributions. (Müller, 2003) also illustrated that the logistic and probit formulations are quite comparable. The main difference is that the former has slightly flatter tails, that is, the normal curve approaches the axis more quickly than the logistic curve. Therefore, the choice between the two is one of convenience and availability of computer programs. Thus, a binary logistic model would be specified to identify the determinants of participation in small-scale irrigation and to assess their relative importance in determining the probability of being participated in small-scale irrigation at the household level. The analysis of the logistic regression model indicated that changing an independent variable alters the probability of a household being food insecure.

A logistic model is used to identify the determinants of participation in small-scale irrigation and to assess their relative importance in determining the probability of participating in small-scale irrigation situations. Binary choice models are appropriate when the decision choosing between two alternatives (participated in small-scale irrigation and otherwise). Household participation in small-scale irrigation is a dependent variable, which takes a value one household participated in irrigation and zero otherwise. The functional form of the logit model is specified as follows (Gujarati, 1995)

$$\mathbf{P_i = E\left(Y = 1/X_i\right) = \frac{1}{1+e^{-(\beta_0+\beta_i X_i)}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{10}$$

Taking $\beta_0 + \beta_i X_i$ to be Z, we write (1)

$$\mathbf{P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^{Z_i}}{1+e^{Z_i}}} \quad \text{...}\mathbf{11}$$

The probability that a given household has participated in small-scale irrigation is expressed by (2).

Where, P_i is the probability that an individual is being participated in small-scale irrigation for the i^{th} household and ranges from 0 to 1. e, represents the base of natural logarithms and. The probability that a given household is not participating in small-scale irrigation is

$$\mathbf{1 - P_i = \frac{1}{1+e^{Z_i}}} \quad \text{...}\mathbf{12}$$

Therefore, the probability of participating in small-scale irrigation to not participate in small-scale irrigation can be written as:

$$\mathbf{\frac{P_i}{1-P_i} = e^{Z_i}} \text{..}\mathbf{13}$$

Finally, taking the natural log of the equation

$$\mathbf{L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \ln e^{Z_i} = z_i} \quad \text{...}\mathbf{14}$$

Where, Z_i= is the function of a vector of n- explanatory variables(x) and expressed as

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + Ui \text{ ....}\mathbf{15}$$

P_i =is a probability of participating in small-scale irrigation ranges between 0 and1

β_0 = is an intercept

$\beta_{1,}\beta_{2,\dots\dots,}\beta_n$ =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 the parameters

X_i=is an explanatory variable

Marginal effect

In most of the applications, the primary goal is to explain the effect of X_i on the response probability Pr (Y = 1)

$$\frac{\partial \Pr(Y_i=1)}{\partial X_j} = \frac{\boldsymbol{\beta_j e^{z_i}}}{\mathbf{(1+e^{z_i})^2}} \text{ ....}\mathbf{16}$$

$$\beta_j(\Pr(Y_i = 1)(1 - \Pr(Y_i = 1))$$

Thus, one unit increase in X_j leads to an increase of $\beta_j(\Pr(Y_i = 1)(1 - \Pr(Y_i = 1))$ in the response probability. The effect of each significant qualitative explanatory variable on the probability of participation is calculated by keeping continuous variables at their mean values and the dummy at their most frequent values (zero or one).

3.6.4. Impact of small-scale irrigation on household food security

Propensity Score Matching (PSM) is used to compare irrigation user households (treatment group) and non-irrigation user households (control group) lying in the common support region. Propensity Score Matching (PSM) is a statistical matching technique that estimates the effect of treatment or intervention given covariates. It allows a comparison group from a sample of non-participants closest to the treatment group in terms of observable characteristics so that both groups are matched based on the propensity score, which is a predicted probability of participation given observed characteristics Shenyang Guo and Mark W, (2015). Propensity value is estimated using logit or probit and used to estimate the average treatment effect of the outcome in absence of baseline data using observable variables Abadie et al., (2004).

Propensity score matching (PSM) is used in this study for different reasons i.e., there is no baseline data to see the difference between before and after, there may be self-selection bias as small-scale irrigation participant households may be self-selected to participate, the cross-sectional survey data is used for matching the participant and non-participant groups, etc. PSM controls for self-selection bias by creating a statistical comparison group by matching every individual observation of the treatment group with individual observations from the control group with similar observable characteristics Shenyang Guo and Mark W, (2015).

These groups are matched based on the propensity scores, which is the predicted probability of participation given some observed variables. Even though PSM has many advantages, it has limitations such as requiring large samples, lack of common support region, and hidden bias since matching controls only for the observables.

The Propensity score is defined as the probability of receiving treatment based on measured covariates (Furtwengler, 2015).

$$E(X) = P(D = 1 | X) \quad \ldots\ldots 17$$

Where, $E(X)$ =propensity score,

P = Probability,

$D = 1$ Treatment indicator with values 0 for control and 1 for treated

"|" = is a symbol that stands for conditional on (predicted), and

X = is a set of observed covariates

According to (Caliendo and Kopeinig, 2008), there are five steps to performing Propensity Score Matching. These steps are: Estimating Propensity Score, Choosing matching algorism, Restricting common support region, Balancing test, and Sensitivity analyzing. The necessary steps to implement the PSM method are:

Step 0: Decide between Propensity Score Matching and Covariate Matching

Step 1: Propensity Score Estimation

Step 2: Choose the Best Matching Algorithm

Step 3: Check Overlap/Common Support

Step 4: Matching Quality/Effect Estimation

Step 5: Sensitivity Analysis

Step 1: **Estimation of Propensity Scores**

A Logit model is used to estimate Propensity Score (PS) for both participants and non-participants. Using the logit model has an advantage since the probabilities are limited between zero and one. The dependent variable takes the values of one if an individual is participating in small-scale irrigation and zero otherwise.

Step: 2 Choosing the Matching Algorism

The idea of matching is identifying control and treated individuals with the same or similar propensity score. Once an estimated propensity score is obtained, different matching algorism was used to match comparison units with treated units. The most commonly employed matching algorisms are the nearest neighbor, kernel matching, stratification matching, caliper matching, and radius matching (Caliendo and Kopeinig, 2008). For this study, the PS of treated households would be matched with non- households using the nearest neighbor, kernel, caliper, and Radius matching estimator methods. To do the matching, three important tasks should be done first. The first task is, generating a propensity score (probability of participation) based on the selected covariates.

The second task is imposing the common support condition on the propensity score distribution of the sample households. The common support region is a region between the higher value of the minimum and the lower value of the maximum propensity score of the treated or control groups. The last task before matching discarding observations whose propensity score is outside the common support region.

Nearest Neighbor Matching: The most straightforward matching estimator is nearest neighbor (NN) matching. The individual from the comparison group is chosen as a matching partner for a treated individual that is closest in terms of the propensity score. Several variants of NN matching are proposed, e.g. NN matching 'with replacement' and 'without replacement'. In the former case, an untreated individual can be used more than once as a match, whereas in the latter case it is considered only once. Matching with replacement involves a trade-off between bias and variance.

If we allow replacement, the average quality of matching will increase and the bias will decrease. This is of particular interest with data where the propensity score distribution is very different in the treatment and the control group.

Kernel Matching: The matching algorithms discussed so far have in common that only a few observations from the comparison group are used to construct the counterfactual outcome of a treated individual. Kernel matching (KM) is a non-parametric matching estimator that use weighted averages of all individuals in the control group to construct the counterfactual outcome. Thus, one major advantage of these approaches is the lower variance which is achieved because more information is used.

Caliper and Radius Matching: NN matching faces the risk of bad matches if the closest neighbor is far away. This can be avoided by imposing a tolerance level on the maximum propensity score distance (caliper). Imposing a caliper works in the same direction as allowing for replacement. Bad matches are avoided and hence the matching quality rises. However, if fewer matches can be performed, the variance of the estimates increases Huber et al., (2015). Applying caliper matching means that those individuals from the comparison group are chosen as a matching partner for a treated individual that lies within the caliper (‘propensity range’) and is closest in terms of the propensity score. A benefit of this approach is that it uses only as many comparison units as are available within the caliper and therefore allows for usage of extra (fewer) units when good matches are (not) available.

Furthermore, radius matching -specifies a “caliper” or maximum propensity score distance by which a match can be made. It uses all of the comparison group members within the caliper.

According to Caliendo and Kopeinig, (2008) to estimate the impact of a program correctly; PSM requires two main conditions, the conditional independence assumption, and the common support condition.

The choice of the matching algorithms will be based on the most important tests to reduce the bias and inefficiency simultaneously. These tests include mean bias, number of matched samples, the value of pseudo-R^2, and number of the balanced covariates. When considering the mean bias, the one with the lowest mean bias is a better matching algorithm. Based on several samples matched, the one with the highest matched number of observations is the best and selected. When coming to the value of the pseudo-R square after matching, the matching algorithm with the lowest pseudo-R square is the best matching algorithm. On the other hand, the matching algorithm with the highest number of balanced covariates is more appropriate Dehejia and Wahba, (2002).

Step3: Restricting Common Support Region

Identifying the common region is a critical step. In fixing the common support region, two guidelines might be helpful to do it more precisely; the first is comparing the maxima and minima of the p-score in both groups and the second is estimating density distribution in both groups. The overlap condition is the area that contains the maximum and minimum propensity scores of the control and treatment groups. It ensures that any combination of characteristics observed in the control group is also observed in the treatment group Caliendo and Kopeinig, (2008).

Step: 4 Testing Matching Quality

When using the PSM method, a balancing test is very important. The quality of matching depends on the ability of the procedure to balance the relevant covariates. Rosenbaum and Rubin, (1985) proposed a standardized bias which is a commonly used method to quantify the bias between control and treated groups. The comparison of the pseudo-R^2 before and after matching, in which the value of pseudo-R^2 after matching should be lower because of the matching use those households that have similar characteristics which mean that no significant difference of covariate of treated and the control group is also proposed. In another word, the t-test value of all covariates after matching is insignificant.

It helps us to evaluate the impact of treatment on the treated groups. It is the difference between the outcomes of treated and the outcomes of treated observations had they not been treated (counterfactual) computed as

$$\mathrm{ATT} = \mathrm{E}(\mathrm{Y}_{i1} - \mathrm{Y}_{i0} | \mathrm{D} = 1) \quad \ldots\ldots\mathbf{18}$$

$$\mathrm{ATT} = \mathrm{E}(\mathrm{Y}_{i1} | \mathrm{D} = 1) - \mathrm{E}(\mathrm{Y}_{i0} | \mathrm{D} = 1)$$

Standardized bias

One suitable indicator to assess the distance in marginal distributions of the X variables is the standardized bias (SB) suggested by (Rosenbaum and Rubin, 1985). It is used to quantify the bias between treated and control groups.

The standardized bias before matching is given by;

$$SB_{before} = 100 * \frac{\overline{X_1} - \overline{X_0}}{\sqrt{0.5(V_1(X) + V_0(X))}} \quad \ldots\ldots\mathbf{19}$$

The standardized bias after matching is given by;

$$SB_{after} = 100 * \frac{\overline{X_{1M}} - \overline{X_{0M}}}{\sqrt{0.5(V_{1M}(X) + V_{OM}(X))}} \quad \ldots\ldots\mathbf{20}$$

Where $\overline{X_1}$ and $\overline{X_0}$ are the sample means for the treated and control group respectively

Where X (V_1) and X (V_0) are the mean (variance) in the treatment and control group before matching respectively, X_{1M} (V_{1M}) and X_{0M} (V_{0M}) are the corresponding values for the matched samples.

T-test

A two-sample *t*-test to check if there are significant differences in covariate means for both groups (Rosenbaum and Rubin, 1985). Before matching, differences are expected, but after matching the covariates should be balanced between the two groups, and hence no significant differences should be found. The ***t***-test might be preferred if the evaluator is concerned with the statistical significance of the results. The shortcoming here is that the bias reduction before and after matching is not visible.

Joint Significance and Pseudo-R^2

Additionally, Sianesi, (2001) suggests re-estimating the propensity score on the matched sample that is only on participants and matched non-participants and comparing the pseudo R^2 before and after matching. The pseudo-R^2 indicates how well the explanatory variables explain the participation probability. After matching there should be no significant differences in the covariates between the two groups and the pseudo-R^2 should be fairly low.

Step: 5 Sensitivity Analyses

The main question that needs to be answered in sensitivity analysis is how strongly an unmeasured variable influences the selection process to undermine the implication of matching analysis Heller et al., (2009). Hence, sensitivity analysis was undertaken to detect the identification of CIA (conditional independence assumption) is satisfactory or affected by the dummy confounder.

The estimation of treatment effects with matching estimators is based on the CIA that is a selection of observable characteristics. However, if there are unobserved variables that affect assignment into treatment and the outcome variable simultaneously, a ‘hidden bias’ might arise. It should be clear that matching estimators are not robust against this ‘hidden bias’. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, we address this problem with the bounding approach proposed by(Rosenbaum, 2002). The basic question to be answered is, if inference about treatment effects may be altered by unobserved factors. In other words, we want to determine how strongly an unmeasured variable must influence the selection process to undermine the implications of matching analysis.

3.7. Diagnostic Test

Multicollinearity test: It is important to run the logistic regression model; both the continuous and dummy explanatory variables were checked for the existence of a multi-colinearity problem. The problem arises when at least one of the independent variables is a linear combination of the others. The existence of multi-collinearity might cause the estimated regression coefficients to have the wrong signs and smaller T-ratios that might lead to the wrong conclusion. Gujarati, (2004) has suggested that the two techniques are conducted to test the existence of a multi-co-linearity problem. Variance inflation factor (VIF) would be employed to detect the problem of multi-co- linearity among the continuous variables. VIF can be defined as

$$\mathbf{VIF(X_i) = \frac{1}{1-R_i{}^2}} \text{..} \mathbf{21}$$

Where, $\boldsymbol{R_i}^2$ is the square of multiple correlation coefficients that results when one explanatory variable ($\boldsymbol{X_i}$) is regressed against all other explanatory variables. The larger the value of VIF ($\boldsymbol{X_i}$) the more "troublesome" or collinear the variable $\boldsymbol{X_i}$ is. As a rule of thumb, if the VIF of a variable exceeds 10, there is a multi-colinearity problem. Likewise to test the multi-collinearity problem for dummy variables contingency coefficient (CC) was computed and the value of the contingency coefficients was less than 0.5, which indicates an absence of multicollinearity problem.

$$\mathbf{CC = \sqrt{\frac{\chi^2}{n+\chi^2}}} \text{ ....}\mathbf{22}$$

In this formula,

CC is the contingency coefficient.

n is the number of observations in the analysis.

$\boldsymbol{\chi^2}$ is the chi − squared value.

Heteroscedasticity test: One of the problems commonly encountered in cross-sectional data is heteroscedasticity (unequal variance) in the error term. There are various reasons for heteroscedasticity, such as the presence of outliers in the data, or incorrect functional form of the regression model, or incorrect transformation of data, or mixing observations with different measures of scale, etc… (Gujarati, 2012). Therefore, we must check for heteroscedasticity. To detect heteroscedasticity Breusch–Pagan (BP) test was used. According to Gujarati, (2012), this test involves the following steps.

Step 1: Estimate the OLS regression and obtain the squared OLS residuals, ${e_i}^2$ from this regression.

Step 2: Regress ${e_i}^2$ on the *k* regressors included in the model.

Step 3: The null hypothesis here is that the error variance is homoscedastic – that is, all the slope coefficients are simultaneously equal to zero. We can use the F statistic and if the computed F statistic is statistically significant, we can reject the hypothesis of homoscedasticity. If it is not, we may not reject the null hypothesis.

Step 4: Alternatively, you can use the chi-square statistic. If the computed chi-square value of p-value is less than 5%, we can reject the null hypothesis of homoscedasticity.

3.8. Variables Description and Expected Sign

Dependent variable

Participation in Small-Scale Irrigation: It is a dummy variable taking a value of 1 for irrigation users and 0 otherwise. Irrigation user is a household owning land, rented in, shared in, shared out, or obtained land through a gift for irrigation during 2012 E.C and non-user otherwise.

The outcome variable: Daily calorie intake per adult equivalent is the outcome of the study. Daily calorie intake per adult equivalent is an important indicator of Food security status at the household level. To measure the food security status of households in the study area information concerning the type and amount of food items consumed by each household preceding the survey were collected from both participant and non-participant households. Then the calorie content of food items consumed by sample households' was calculated using calorie conversion factor per adult equivalent. And then compared with recommended Kcal per adult equivalent per day (2100Kcal) set by the Ethiopian Government (FDRE, 2010), this value of minimum subsistence requirement was used as a cut-off point between food security and insecure households. Thus, those households beyond this threshold level seemed to be food secure otherwise insecure.

Explanatory Variables (X's): These variables were included various socioeconomic characteristics expected to affect household participation in small-scale irrigation. Based on the available information from related literature, previous small-scale irrigation studies, and the researcher's knowledge about the area, explanatory variables, which are anticipated to have a significant impact on household food security were selected and hypothesized. The explanatory variables that are hypothesized to have a positive or negative influence on household participation in small-scale irrigation status are described below.

Gender of a Household Head (GENDHH): This is a dummy variable that is measured as 1if the household head is male and 0, female. Since females are responsible for many household domestic activities, they may not accomplish the farming activities on time and efficiently Bedasso et al., (2020). Furthermore, men can participate in *kebele* meetings and more communicate within the community that enhances the household's access to information and external service, and accumulate more knowledge than women in terms of method of farm techniques have greater chance credit access procedure and crop management practices. Regarding the study area, it was hypothesized that gender of a household head has a positive effect on participation in irrigation.

Age of a Household Head (HHAGE): Age is a continuous variable measured in years. It is one of the factors that determine household participation in small-scale irrigation. Thus, younger farmers are more innovative and open to technological advances and are more willing to adopt new technology. Ambe, (2018), and other related studies stated that young heads of households are stronger and are expected to cultivate larger-size farms than old heads. Hence, the expected effect of age on participation in small-scale irrigation could be positive or negative.

Education Level of a Household Head (HHEDUC): This variable refers to the formal schooling grades that the household head completed. Human capital is assumed to be a key source of income, growth and an important block for building wellbeing. Education is assumed to improve the attitudes and awareness of farmers towards the adoption of new agricultural technologies, which is irrigation in the context of this work**.** Households head with better education levels were believed to have a chance to apply scientific knowledge and better manage their farm activities in a good manner hence boosting domestic production to fulfill household consumption needs. Based on Ambe, (2018), and other works of literature, the higher the educational level of household head, the more to participation in irrigation the household is expected to be. Hence, education has a positive contribution to participation in irrigation.

Available Family Labor (FAMLAB): Family labor plays an important role, particularly in rural families as a factor of production. Therefore, a household with more agricultural labor results in more profitability in food grain production if available farming land can accommodate household productive labor force appropriately otherwise they will a burden to the family. Hence, increasing by one household labor has a positive influence in increasing agricultural production and has a positive contribution to participation in irrigation Mekonen, (2020).

Livestock holding excludes oxen (TLU): This is continuous variable refers to the total number of livestock in TLU. Total livestock unit is calculated by each type of animal is multiplying by their conversion factors and finally summing. Livestock improves the source of income, consumption, and plow power for agriculture production in Ethiopia. More the number of livestock is expected to increase the probability of participation in small scale irrigation also increase. Livestock owner is led to an ability to plow more farmland in a given time, thereby meeting crop production and earning higher income to ensure food security Regassa, (2016). In these studies, it is hypothesized that a high amount of TLU has been a positive relationship with farmers' decision to participate in small-scale irrigation.

Oxen Owned (NOXEN): The number of draught oxen-owned households during the survey periods. Oxen are one of the basic farm assets and are a predominant source of traction power in the study area. Households that own more oxen have a better chance to be participating in irrigation than others reported in Yihdego et al., (2015). This is because oxen possession allows undertaking farming activities on time and when required. The number of oxen available to a household is, therefore, hypothesized to enhance the probability of being participated.

The Size of Cultivated Land (CLSIZE): The size of cultivated land has a positive impact on household food security. This variable represents the total cultivated land size which is owned, rented in, contracted in, and obtained through the gift of a household measured in a hectare. Households with larger farm sizes are more likely to be participation in small-scale irrigation compared to those with smaller farm sizes. The large size of cultivated land implies more production and availability of food grains and the possibility that the household gets more output is high as it remains the basic capital input in food production also reported in Bedasso et al., (2020). It is hypothesized that farmers who have larger cultivated land are more likely to participate in small-small irrigation than those with a smaller area.

Access to credit service (ACCS): It is a dummy variable taking the value 1 if the household takes credit, 0 otherwise. The credit provides the opportunity to use inputs and this promotes production. Households that have easy access to credit services can invest in different farming and some other income-generating activities and improve their production. As a result, a household's income and food consumption pattern will improve. According to the research finding reported by Wassihun, (2016), households with access to credit services are more likely to participate in irrigation. Therefore, access to credit is hypothesized to positively affect households' decisions to participate in irrigation. Therefore, it is rational to expect a positive association between access to credit service and the probability of being participated in small-scale irrigation.

Access to extension service (EXSEVCE): Extension services play an important role for rural farmers in terms of providing advice and information. Among these, training is one of useful service to introduced and develop practices of modern technologies (proper types and rates of fertilizer, improved varieties of seeds, agro-chemicals, etc.) Hence, those household's participated in training organized at farm demonstrations are supposed to apply their knowledge to increase farm production Yihdego et al., (2015). Thus, households will be in a better position of the probability of being participated.

Distance of Farm Land to Water Source: This variable is a continuous variable measured in kilometers. Sinyolo et al., (2014) reported that the distance of the households to the water source is expected to determine the household's use of irrigation. The residence of households nearby the irrigation scheme is expected to have a positive relation to the probability of use of irrigation. The nearer the household's residence to a water source, the higher the probability he/she has to use irrigation, because of the opportunity cost of time lost in traveling to and from an irrigation farm for households. Hence, it is expected that the distance of residence from the scheme and the use of irrigation is negatively related.

Non-farm Income (NONFARM): It is a measure of any household member participated in non-farming activities and generated an income in Birr. It will assume that non-farm income earned by a household is primarily spent on food items such as on food grains, and nonfood items required for household members Kedir and Beyene (2019). Therefore, this study will hypothesize that non-farm income is positively associated with a household probability of being participated.

Soil Fertility Status (SOILFTS): it is a dummy variable which takes value 1 if the land is fertile and 0 infertile, where soil fertility is determined based on the response of the surveyed households, Fertility of land has a direct relationship with productivity, if the farmland is fertile the household can produce more production and if the land is infertile less will be produced affecting the household income level, thus, it is expected that households with fertile land have produced more production Bedasso et al., (2020). Therefore, this study will hypothesize that the fertility of the soil is positively associated with a household probability of being participated.

Table 3.2: Description of dependent and independent variables

s.no	Code	Description	Variable type	Measurement	Expected sign
I	**Dependent variable**	Participation in small-scale irrigation	Dummy	1 and 0	
II	**Independent variables**				
1	GENDHH	Gender of HH head	Dummy	1 and 0	+
2	HHAGE	Age of HH head	Continuous	Year	+/-
3	HHEDUC	Education level of HH	Continuous	Class Year	+
4	FAMLAB	Family labor	Continuous	Man Equivalent	+
5	TLUEOX	Livestock	Continuous	TLU	+/-
6	NOXEN	Oxen	Continuous	Number	+
7	CLSIZE	Cultivated land size	Continuous	Hectare	+
8	ACCS	Access to credit service	Dummy	1 and 0	+
9	EXSEVCE	Access to extension service	Dummy	1 and 0	+
10	DISWAFAL	Distance to water source	Continuous	Kilometer	-
11	NONFARM	Non-farm income	Continuous	ETBirr	+/-
12	SOILFTS	Soil fertility status	Dummy	Fertile and infertile	+

CHAPTER FOUR

4. RESULT AND DISCUSSION

This chapter gives details of the research findings divided into three sections. The first section describes the household food security status of sampled households and the study area food availability situation, which is constructed by using the household food balance model. In the second section, farmers' perception and their challenges in utilizing the irrigation scheme are explained. The third section is the econometric model, mainly binary logistic regression and Propensity score matching models. The binary logistic regression model was used to determine the factors affecting participation in small-scale irrigation, while the Propensity score matching model was used to analyze the impact of small-scale irrigation on household food security.

4.1. Descriptive analysis

4.1.1. Measuring of Food Security Situation of the Study Area

In assessing the food security situation of the study area, the following steps were followed. First, the study was fixed the past one-year cropping period (2012E.C) as a frame of analysis. Secondly, all staple food sources of cereals and non-cereals grains available for sample households in the study area were collected. Thirdly, the collected data was structured into a household food balance model equation to determine the net food availability status of the household. Finally, the food energy requirement for each household member was weighted by converting it to Adult Equivalent.

The average availability of food for food-secure households was 3623.305kcal/day/adult equivalent while it was 1279.597kcal/day/ adult equivalent for food-insecure households. The result shows that there was a shortage of food energy for a considerable portion of the community in the study area. Besides, the survey result showed that the overall average food energy was 2598.854 kcal, which was higher than the national minimum recommended value, i.e., 2100 kcal. Moreover, household food energy calorie availability ranged from 420.6502 kcal to 9513.044 kcal. This indicates that there was a big gap in food energy availability among sample households Table 4.1.

The main food energy source in the study area was from own production of different food grains that accounted for 78.33% of the total available food calorie during the study time which is compared to domestic purchase that covered 36.39% of a calorie per capita. The government-initiated productive safety net program is the only program supporting the food insecure households in the study area. Food-secure households accommodated 88% of their food from their production and only 12% from the domestic purchases while food insecure households gained and of their food grain from their production and domestic purchase, 58%, and 41% respectively. The survey result clearly showed that domestic agricultural food production was the main source of food grain supply. In other words, it substantiates that the local agricultural production situation largely affects the food availability and food security status of the local community of the study area.

Table 4.1: Construction of food balance sheet of the study area

Household dietary energy availability is expressed in Kilocalories per person per day

No	**Household Food Balance Model Attributes**	**(179)HH Secured**	**(139)HH Insecure**	**Total Household(318)**		
				Min	**Max**	**Average**
1	Food grain produced	2838.674	1200.602	133.4964	8583.521	2122.662
2	Food grain bought	1680.732	856.5543	4.573431	7517.298	1320.478
3	Quantity of food aid obtained	5.413244	10.79361	0	473.7618	7.765038
I	**Subtotal I (1+2+3)**	**4524.819**	**2067.95**	**883.3986**	**10370.78**	**3450.905**
4	Qty of grain reserved for seed	261.2881	256.4377	0	3096.062	259.1679
5	Amount of grain sold	605.2792	492.4797	78.44819	4271.806	555.9738
6	Post- harvest losses a year	0	0	0	0	0
7	Grain given to others a year	34.94652	39.4361	0	1543.049	36.90895

II	**Subtotal II (4+5+6+7)**	**901.5137**	**788.3535**	**107.4631**	**6596.496**	**852.0506**
	Net grain available (I -II)	**3623.305**	**1279.597**	**420.6502**	**9513.044**	**2598.854**

Source: Own computation based on survey data, (2021)

In figure 4.1, the result of the household food balance model revealed that from the total sample households those 56.29% (179) households were food secure while 43.71% (139) households were food insecure. However; compared to irrigation user and irrigation non-user: 71.07% of irrigation user households were found to be food secure who fulfill the minimum recommended daily calorie (2100 kcal/AE/day) (FDRE, 2010); whereas 47.2% of irrigation non-user households were food secure those who fulfill a minimum requirement.

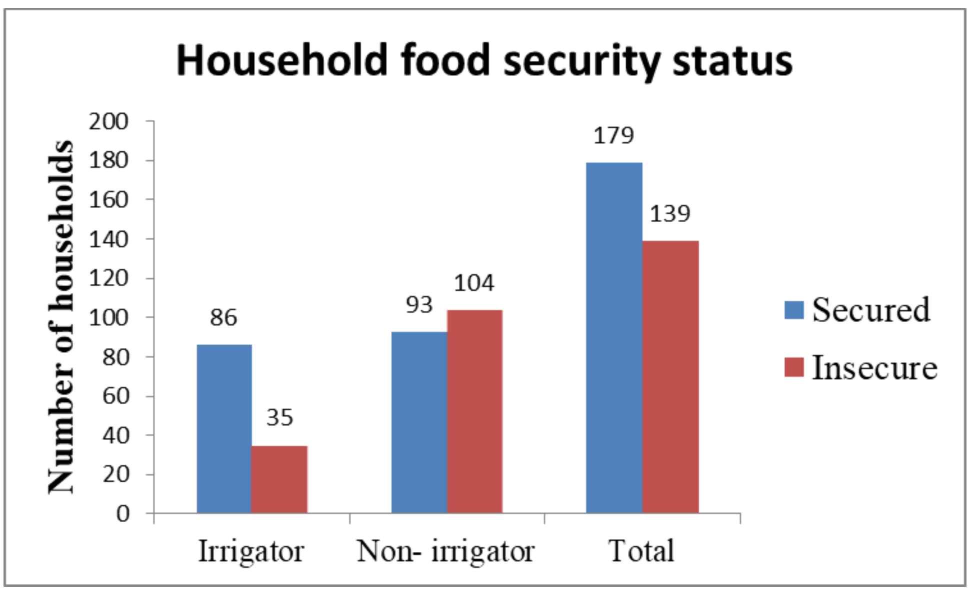


Figure 4.1: Household food security status sampled respondents

Source: Own computation based on survey data, (2021)

4.2. Descriptive analyses of both continuous and categorical variables

The results of descriptive analyses were presented in Table 4.2, and Table 4.3. Table 4.2 presents the results from continuous variables while Table 4.3 presents the results from categorical variables. The t-test results, presented in Table 4.2 indicate that there were no statistically significant differences between livestock and non-farm income among the groups, and χ^2-test results, present in table 4.3 show that there were no statistically significant differences between gender of household head, contact to extension service, soil fertility. Since these households are from one community, it is expected that do not vary significantly.

Table 4.2: Summary statistics for continuous variables of the household characteristics

Variables	Irrigation Non-users(N=197)	Irrigation User(N=121)	Total HH (N=318)	Mean Difference of the Two Group	T-value
	Mean (St. dev)	Mean (St. dev)	Mean St.dev		
Age of HH Head in year	45.25 (6.379)	43.90 (4.923)	44.74 (5.897)	1.34**	1.988
Education of HH Head in Grade	3.42 (2.152)	4.13 (2.781)	3.692 (2.431)	-.7109**	-2.553
Family labor in Men Equivalent	3.77 (1.160)	4.07 (1.194)	3.88 (1.181)	-.304**	-2.246
Livestock in TLU	3.23 (1.498)	3.17 (1.449)	3.21 (1.478)	.0597^{NS}	0.349
Land size in Hectare	1.38 (.798)	1.61 (.6446)	1.47 (.7508)	-.230***	-2.679
Oxen in number	1.75 (1.003)	2.07 (1.081)	1.87 (1.044)	-.328***	-2.748
Non-farm income	1879.19 (2213.254)	1617.77 (1861.595)	1779.72 (2087.284)	261.41^{NS}	1.084
Water distance in KM	2.13 (.6323)	1.69 (.4689)	1.96 (.6146)	.447***	6.7250

Note: Mean difference=Mean non-user minus Mean user

***, **, and ^{NS} represents level of significance p<0.01, p<0.05, and Not Significant respectively

Source: Own computation based on survey data, (2021)

Age of household head: The average age of household heads of the irrigation user is nearly 43.90 years while that of the non-user is approximately 45.25years. In table 4.2 the mean comparison test shows there is a statistically significant difference in the distribution of household head age between the user and non-user household heads at 5% significance level.

The educational level of household head: Table 4.2 shows that the mean value of the education level of sampled household heads was 3.692. From these, the average value of education of irrigation users was 4.13 while 3.42 for non-users household heads. The t-test indicates that there is a statistical mean difference in education between irrigation users and non-users at 5% significant level. The hypothesized households with higher education backgrounds were probability to use small-scale irrigation than non-users. This might be because education creates awareness of the benefits of irrigation and helps for better innovation and invention for rural households.

Family Labor: Labor is one of the major input resources on which the farming activities of the study households are established like any other part of Ethiopia. The computed average family size in the man equivalent of the study household as presented in Table 4.2 was 4.07 for irrigation users and 3.77 for non- users. The t-test result shows that irrigation-user has higher available family labor compared to the non-user at a 5% significant level. This significant value shows that small-scale irrigation users and non-users households had different family labor. Labor force availability is an important factor influencing household decisions to participate in irrigation practice. Households that have many members have a better advantage of being able to use labor resources at the right time.

Cultivated Land: Cultivated land appears to be the most important scarce factor of production. In the study area, own land rented and shared lands were used for cultivation. The average owns cultivated landholding of the sampled households was 1.47hectare. In comparing with the non-user and user, the average cultivated land size of the irrigation non-user was 1.38hectare and the user was 1.61hectare (Table 4.2). The mean comparison test revealed that the means difference between the two groups regarding landholding size is statistically significant at a 1 % significance level.

Oxen owned: As shown in Table 4.2 numbers of oxen owned have a statistically significant difference between users and non-users of small-scale irrigation. This indicates households with more oxen are more likely to participate in small-scale irrigation because ox serves for plowing. On average the users and non-users of irrigation have 2.07, and 1.75 oxen's respectively. The users are 0.328 much greater than the non-users in having oxen on average. It might be because of the reason that owning oxen have a direct impact on participating in small-scale irrigation of the household mainly in performing a farming operation. The mean comparison t-test revealed that the means the difference between the two groups regarding oxen owned is statistically significant at a 1 % significance level.

Distance of irrigated land from water sources in comparison with irrigation status, non-irrigation users are located far away from the irrigation scheme with an average distance of 2.13km compared to users 1.69km. The mean comparison test result of the two groups concerning distance to the irrigation scheme is statistically significant at a 1% significance level in Table 4.2.

Access to credit: Credit is an important institutional service to finance poor farmers for input purchase and ultimately to adopt new technologies. However, some farmers have access to credit while others may not have due to problems related to repayment and down payment to get input from the formal and informal sources. In a table, 4.3 surveys result revealed that 66.35 % of the sample households take credit. The comparison by access to irrigation the survey result revealed that 75.21% of irrigation users and 60.91% of irrigation no-users have taken credit. Irrigation users have had better access to credit than non-users. The chi-square test result shows statistically significant interdependence between irrigation participation and access to credit of household heads at a 5% probability level.

Table 4.3: Summary statistics for categorical variables of the household characteristics

Variables	**Category**	**Non-users (N=197)**		**User (N=121)**		**Total HH (N=318)**		**χ^2-Value**
		Count	(%)	Count	(%)	Count	(%)	
Gender of HH Head	0=Female	25	(12.69)	11	(9.09)	36	(11.32)	0.9674^{NS}
	1=Male	172	(87.31)	110	(90.91)	282	(88.68)	
Access to credit	0=No	77	(39.09)	30	(24.79)	107	(33.65)	6.8589**
	1=Yes	120	(60.91)	91	(75.21)	211	(66.35)	
Access to contact extension	0=No	21	(10.66)	10	(8.26)	31	(9.75)	0.4889^{NS}
	1=Yes	176	(89.34)	111	(91.74)	287	(90.25)	
Soil fertility	0=infertile	17	(8.63)	12	(9.92)	29	(9.12)	0.1500^{NS}
	1=fertile	180	(91.37)	109	(90.08)	289	(90.88)	

*****, **,** and ^{NS} represents level of significance p<0.01, p<0.05, and Not Significant respectively

Source: Own computation based on survey data, (2021)

4.2.1: Descriptive Result of Outcome Variable

Table 4 shows that, the descriptive result of the outcome variable (calorie intake/AE per day). The result shows that there is a significant deferent between the two groups.

Calorie intake per adult equivalent: - It refers to the total caloric consummation of each sample household per adult equivalent per day measured in kilo caloric (kcal). If look at the descriptive statistics of the participant and non-participant groups, the mean Calorie intake per adult equivalent of participant household is more than that of Calorie intake per adult equivalent of the non-participant household (3157.88kcal and 2255.49kcal respectively). As indicated the mean difference in Calorie intake per adult equivalent between the participant and the non-participant households was 902.39kcal. This result showed that there is a significant difference between participant households and non-participant households. The t-test also revealed a statistically significant difference at a 1% probability level (Table 4.4).

Table 4.4: Descriptive statistics outcome variable

Variable	Participant households mean	Non- Participant households mean	Combined mean	Mean difference	T- value
Calorie intake/AE/day	3157.88	2255.49	2598.85	902.39	5.54***

******* represents a level of significance p<0.01

Source: Own computation based on survey data, (2021)

4.3. Constraints of irrigation farming

The survey tried to identify major constraints of irrigation practice to contribute to household food security requesting sample households to respond based on their perceptions and experiences. Furthermore, the sample respondents were asked to rank the problems in order of importance. The results of the subjective assessment of the sample farmers are summarized in table 4.4

The result of the descriptive statistics indicated that 43.8%, 30.6%, and 9.9% of the sample farmers reported that pests and diseases occurrences, poor irrigation method practices, and the long-distance between irrigation land and their residence were the first and the most important problems in the study area, respectively. Similarly, the result of descriptive statistics showed that a very small proportion of the sample framers, 7.4% and 8.3%, reported that lack of irrigation input supply, Lack of getting efficient extension service were their first problems, respectively.

In addition, the result of the descriptive statistics showed that lack of input supply and irrigation facilities, the long-distance between irrigation land to their residence, Poor irrigation method practices were the second uppermost problems to be considered in their irrigation activities as reported in table 4.4, 27.3%, 20.7%, and 19.0 % respectively, sampled drawn from the study area. Likewise, the result of the assessment on challenges by target beneficiaries has shown that 27.3%, 19.8%, and 19.0% of farmers perceived that lack of input supply and irrigation facilities, occurrences of pests and diseases, and distance to irrigable land to home was considered as the top problems ranked as the third important constraints in their priority setting.

Generally, the summary result of the survey shows that the occurrences of pests and diseases, poor irrigation method practices, and lack of input supply and irrigation facilities were the three most important challenges that the community largely faces in their irrigated agriculture at 26.2%, 21.5%, and 20.7% as reported by interviewed households in their order of priority respectively in table 4.4 column 9 shown. Alongside these, all problems the importance of small-scale irrigation in the study area has significantly increased year after year. The result in line with Anteneh Astatike,(2016); Damtew, (2017); Tolera, (2017); Terefe, (2019); Demisse, (2020).

Table 4.5: Constraints of irrigation farming in the study area

Constraints	Ranking Responses							
	1st		**2nd**		**3rd**		**Summary**	
	No.	%	No.	%	No.	%	No.	%
Pests and diseases occurrences	53	**43.8**	18	14.9	24	**19.8**	95	**26.2**
Poor irrigation method practice	37	**30.6**	23	**19.0**	18	14.9	78	**21.5**
Lack of efficient extension support	10	8.3	22	18.2	23	**19.0**	55	15.2
Distance to irrigable land to home	12	**9.9**	25	**20.7**	23	**19.0**	60	16.5
Lack of input supply and irrigation facilities	9	7.4	33	**27.3**	33	**27.3**	75	**20.7**
Total sum	**121**	**100**	**121**	**100**	**121**	**100**	**363**	**100**

Source: Own computation based on survey data, (2021)

4.4. Econometric Result

To identify factors affecting participation in irrigation and the effect of irrigation small-scale irrigation on household food security; econometric analysis was employed. Logistic regression model and Propensity score matching techniques were used.

4.4.1. Diagnosis Tests for Explanatory Variables

4.4.1.1. Multicollinearity Test

Before directly running the logit model, the existence of multicollinearity problem between explanatory variables of the study was tested by using the Variance Inflation Factor (VIF) for continuous explanatory variables. The problem of multicollinearity was not serious among variables because of VIF value less than 10 and tolerance less than 1 (see Appendix 4). Similarly, multicollinearity was not a serious problem between dummy variables as the value of contingency coefficient less than 0.5 assumes a weak association between variables (see Appendix 5). The test of both analyses indicates that there was no serious multicollinearity problem between independent variables of the study. As a result, no variables were dropped from the model. Therefore, all explanatory variables were used in the analysis procedure.

4.4.1.2. Heteroscedasticity Test

Heteroscedasticity means unequal variance of the error term. Breusch-Pagan/CookWeisburg test was carried out for heteroscedasticity before running the model. This test creates a statistic that is chi-squared distributed. The p-value is the result of the chi-squared and normally the null hypothesis is rejected for a p-value less 0.05 as it tests the null hypothesis that the error variance is all equal versus the alternative that the error variances are a multiplicative function of one or more variables. According to the result, the null hypothesis was rejected because the p-value is 0.0173 which is less than a critical value of 0.05 (see Appendix 6). Therefore, this value was suggesting the need for standard error robust. Hence, the robust standard error was conducted accordingly.

4.4.1.3. Model Specification Test

A link test was done to determine the association among the independent variable. The values of the link test; in the logit regression model looks every bit as reasonable as the original model. The link test reveals no problems with our specification having seen a dataset, as shown in (appendix 9). Moreover, the link test of the hat-square p-value (0.326), which was statically insignificant means there was not enough evidence to say that the model is miss specified. Therefore, the irrigation decision model can be explained through the included explanatory variables**.**

4.4.2. Factors that affect household participation in small scale irrigation

The goodness fit of the model for the binary logistic regression model, an intuitively appealing way to summarize the result of the fitted logistic model is via a classification table. This cross-classification is the result of cross-classification of the outcome variable with a dichotomous variable whose values are derived from the estimated logistic probabilities. Concerning the predictive efficiency, 76.42% of sampled households were correctly predicted. The sensitivity and specificity indicate that 61.16% of a participant of small scale irrigation and 85.79% of non-participant of small scale irrigation households were correctly predicted in their categories respectively.

To identify determinants factors that affect participation in small scale irrigation, a binary logit model was used to predict the probability that the sample households are participating in small scale irrigation using the hypothesized independent variables, and the binary logistic regression result revealed that among twelve hypothesized variables, eight were found to be significant while the rest four variables were not significant in influencing participation in irrigation use in the study area. These are gender of the household head (gendhh), age of the household head (hhage), educational level of the household head (educhh), access to credit services (accrsv), size of cultivated land (culsize), number of oxen (noxen), distance of households' residence from the water source (diswafal), and availability of family labor force (famlab) presented in Table 4.6

Table 4.6: Binary Logit Regression Results for Determinants of Participation in Irrigation

Variables	Coefficient	Robust Std. Err	Z-Value	(dy/dx) Marginal Effect
gendhh	.8089446	.40927	1.98*	.1629047
hhage	-.0493593	.0281522	-1.75*	-.0112242
educhh	.0931769	.0560488	1.66*	.0211882
accrsv	.6565778	.2815366	2.33**	.1433672
culsize	.5497761	.1944383	2.83***	.1250178
noxen	.4481536	.1388256	3.23***	.1019091
tlueox	-.0820133	.0839622	-0.98	-.018649
nonfami	-.0000901	.0000686	-1.31	-.0000205
diswafal	-1.74635	.2689739	-6.49***	-.3971159
soilfts	.6094716	.4306524	1.42	.1263458
exsevce	.6260217	.4827186	1.30	.1296018
famlab	.3129568	.1194872	2.62***	.0711656
_cons	-.0383652	1.669472	-0.02	-
Number of Obs	318	Sensitivity		61.16%
LRchi2(12)	93.73	Specificity		85.79%
Prob > chi2	0. 000	Correctly classified		76.42%
Pseudo-Rsquared	0.2218	Link test P-value		0.326

***, **, and * represents level of significance p<0.01, p<0.05, and p<0.1 respectively

Source: Own computation based on survey data, (2021)

Gender of the household head: The result of the econometric model indicates that the gender of the household head positively affects the probability of participation in small-scale irrigation and was significant at a 10% significance level. In table 4.6, the marginal effect of this variable shows that those male-headed households have a 16.29% more chance of participation in small-scale irrigation than those female-headed households keeping all other variables constant. This result is consistent with Bedasso et al., (2020) that women's access to irrigation is limited in Northern Ethiopia and in contrary to the study conducted by Sinyolo et al., (2014) which found that female-headed households are more likely to participate in small-scale irrigation.

Age of the household head: The sign of this variable is consistent with the prior expectation that means negatively and significantly influenced the probability of household heads to use irrigation at equal to 5% significance level. This may be because the use of irrigation is labor-intensive and exhaustive work that the older household heads cannot tolerate this challenge. In another way, the negative sign indicates that younger farmers use irrigation than older farmers. Also found that the older the household head the less inclined to adopt new irrigation technology. The marginal effect also confirms that the age of the household head increases by one year to a certain level, the probability of participation in small-scale irrigation would be decreased by 4.9%, keeping all other variables constant at their mean value. Ambe, (2018)

The educational level of the household head: The econometrics logit model result presented in Table 4.6, shows the literacy status of the household head. The result shows that education status is positively and significantly associated with household irrigation participation at a 10% significance level. Hence, the positive association designates that the coefficient of the probability of being irrigation participation increase with an increase in household head's literacy status. Therefore households who have literate heads were most likely to be participating in small-scale irrigation than their counterparts. The result of marginal effect also indicates that as the education level of sample household head increase by one school year, assuming other factors constant at their mean values, the probability of being the household to become irrigation participant would increase by 2.28%. This is because the better-educated household head can understand agricultural instructions easily, have a higher tendency to adopt improved agricultural technologies, have better access to information, and can apply technical skills communicated to them than less educated ones. This result was consistent with the finding of Tigga et al., (2019); Jambo et al., (2021).

Access to credit services: This variable was one of the variables hypothesized as one factor of the household participation decision in small-scale irrigation practice. The econometrics logit model result indicates that access to credit was positively associated with the participation of small-scale irrigation at a 5% significant level (Table 4.6). Additionally, the marginal effect shows that a change in the dummy variable access to credit from 0 to1, assuming other factors constant at their mean values, the probability of participating in small-scale irrigation also increases by 14.34%. Access to credit helps farmers to purchase inputs such as seeds, fertilizers, and agriculture tools. This is to means that households getting access to credit services were more likely to participate in small-scale irrigation than households without access to credit services. This is because of those farmers having access to credit services are more capable to purchase irrigation inputs like fertilizers, motor pumps, seeds, irrigable land, etc. This result is consistent with the results finding reported by Wassihun, (2016); Temesgen et al., (2018).

Size of cultivated land: The result reveals that farm size positively influences the probability to participate in small-scale irrigation and it was significant at a 1% significance level. Households with larger cultivated land also own more plots spatially distributed over various locations providing opportunities to exploit the agricultural potential of the area. Moreover, households with larger land holing are more likely to occupy land extended to the river-bank which creates a better opportunity to participate in irrigation. The marginal effect of this variable indicates that as the size of cultivated land increases by one hectare, the probability of participation in small-scale irrigation increases by 12.5%, keeping all other variables constant at their mean value. This result is consistent with the findings of Abdissa et al., (2017) Ambe, (2018), who also obtained that farm size influenced the household decision to participate in small-scale irrigation.

Oxen: As hypothesized, oxen-owned affected household participation decisions in small-scale irrigation positively and significantly at a 1% percent significance level. From this result, the households having more oxen are more likely to participate in irrigation farming compared to those households owning lesser numbers of oxen. In table 4.6, the marginal effect shows that other things hold constant at their mean values, as the number of oxen increases by one unit, the probability of household participation in small-scale irrigation increases by 10.19%. Oxen were forgotten by most previous researchers in irrigation, but it is one of the important factors in the participation of small-scale irrigation to rural farm households. Ox is one of the most important domestic animals used for farming purposes in rural areas. Therefore, if the numbers of oxen are high the household can farm itself its' own land and he can rent in and share in other lands for farming. Oxen were missing in most previous researchers.

Distance of households' residence from the water source: This variable is statistically significant at 1% and influences participation in small-scale irrigation negatively. In Table 4.6 in column5, the marginal effect shows that as the distance from the farmers' residence to the water source decreases by one kilometer, the probability of participation in small-scale irrigation increases by 39.71%, keeping all other variables constant at their mean value. This implies that the farther households' residence from the water source, the lesser would be farmers' probability to participate in small-scale irrigation. Households living closer to the irrigation sites are more likely to use irrigation. The reason may the advantage of performing agronomic practice, suitability to guard the plots during day and night, the lesser walking time required, etc. This result is consistent with the findings reported by Temesgen et al., (2018); Kedir and Beyene, (2019); Jambo et al., (2021).

Availability of family labor force: The model output shows that the family labor force has a positive influence on households' decision to participate in small-scale irrigation and is significant at a 5% level of significance. In table 4.6, the marginal effect of this variable reveals that as the family labor force increases by one in man equivalent, the probability of the households' participation in small-scale irrigation increases by 13.8%, keeping all other variables constant at their mean value. The positive relationship implies that like other parts of Ethiopia, labor is one of the most extensively used inputs of agricultural production in the study area. Participation in small-scale irrigation demands an additional labor force for different farming operations such as land preparation, planting, fertilizer application, and watering. This finding is in line with the previous studies was conducted by (Ambe, 2018; Bedasso et al., 2020) also reported that labor availability is a crucial factor influencing a household's decision to involve in small-scale irrigation.

4.4.3. Impact of small-scale irrigation on household food security

4.4.3.1. Generation propensity score matching

Under this subsection, the impact of small-scale irrigation on household food security was assessed using the propensity score matching method of impact evaluation since there was no baseline data. Assessment of impact evaluation using this method follows five basic steps. These steps are an estimation of the propensity score, restricting common support region, choosing a matching algorithm, checking for balance, and sensitivity analysis.

4.4.3.2. Estimation of propensity scores

The logistic regression was used to estimate propensity score matching for treatment (participant) and control (non-participant) households in the program. The results from the logit model of sample household participation in the program were used to create propensity scores for the matching algorithms. The model used twelve matching variables that have been chosen as explanatory variables. In doing so, the dependent variable was a binary variable taking a value of 1 for household participation irrigation or 0 otherwise. Results presented in appendix 10 shows the estimated model appears to perform well for the intended matching exercise. The pseudo-R^2 value is 0.2218. A low pseudo-R^2 value shows that program households do not have many distinct characteristics between explanatory covariate which easier a match between treatment and control household.

4.4.3.3. The Common Support Condition

The predicted values of propensity scores were estimated for all households in the program and outside the program, the next step would be imposing common support conditions on the propensity score distributions of households with and without the program. As shown in Table 4.9 estimated propensity scores vary between 0.0187712 and 0.9342712 (mean=0.2763218) for non-participant households vary between 0.0470136 and 0.9610066(mean=0.5501208) for participant households. Therefore, the common support region would then lie between 0.0470136 and 0.9342712. In other words, households whose estimated propensity scores are less than 0.0187712 and larger than 0.9610066 are not considered for the matching exercise. Based on the restriction of the common support, 11 observations (8 observations from non-users, and 3 observations from users) were found to be out of the common support region and excluded from the further analysis. The common support region is defined, individuals that fall outside this region have to be rejected and hence the treatment effect cannot be estimated. As the main purpose of the propensity score estimation was to balance the observed distributions of covariates across two groups, it is necessary to ascertain that there is sufficient common support region for the two groups and the differences in the covariates in the matched two groups have been eliminated.

Table 4.7: Distribution of propensity score among non-participant and participants households

Irrigation status	Observation	Mean	St.devation	Minimum	Maximum
Non-participants	197	.2763218	.1981409	.0187712	.9342712
Participants	121	.5501208	.2435435	.0470136	.9610066
Total	318	.3805031	.2538779	.0187712	.9610066

Source: Own computation based on survey data, (2021)

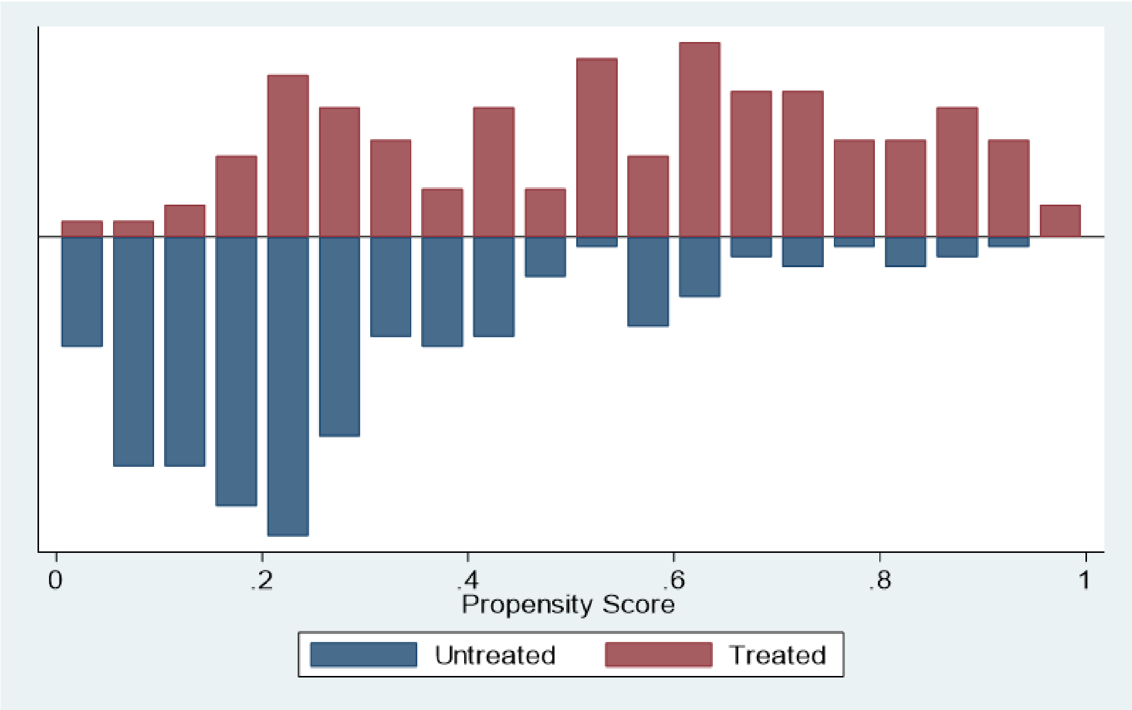


Figure 4.2.Propensity score distribution before matched sample

Fig 4.3 below shows the distribution of propensity score and common support region. The bottom halves of the histogram show the propensity score distribution of irrigation non-user households and the upper halves show the propensity score distribution of irrigation user households. The green-colored (treated on support), and the red-colored (untreated on support) indicates the observations in the irrigation user group and non-user group that have a suitable comparison respectively, whereas the orange-colored (treated off support) and the blue colored (untreated off support) indicates the observations in the irrigation user and non-user group that does not have a suitable comparison respectively.

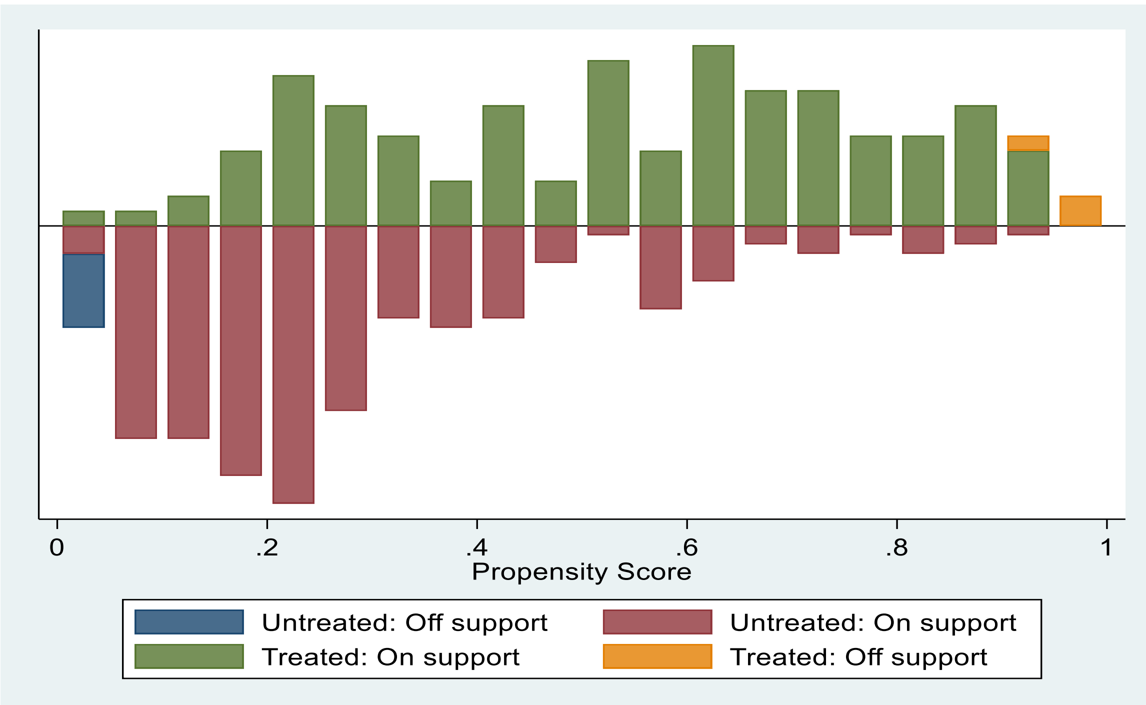


Figure 4.3 Propensity score distribution of after matched sample

4.3.3.4. Matching irrigation users with non-users household

To achieve the best matching result, one should choose the best matching method out of the different matching algorithms. Thus, the pseudo-R2, sample size after matching standardized bias, and numbers of insignificant variables after matching approaches were used as criteria to decide on the best matching algorithm. According to Caliendo and Kopeinig, (2005), one possible problem with the standardized bias approach is that we do not have a clear indication for the success of the matching procedure, even though in most empirical studies a bias reduction is below 3% or 5% is seen as sufficient. The pseudo-R2 indicates how well the regressors X explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo-R2 should be fairly low.

Therefore, from the result in Table 4.8, a kernel matching estimator with a bandwidth of 0.1 was chosen based on the criteria of mean standardized bias 3-5% after matching, small pseudo-$\mathbf{R^2}$ after matching, large matched sample size, and a large number of insignificant variables after matching. The major advantage of kernel matching is the lower variance which is achieved because more information is used Caliendo and Kopeinig,(2005).

Table 4.8: Performances criteria of matching algorisms

Matching Algorisms	**Performances criteria**			
	Balancing test	**Pseudo-R^2**	**Matched Sample Size**	**Mean SB**
Nearest Neighbor Matching				
Nearest Neighbor (1)	8	0.106	307	15.1
Nearest Neighbor (2)	9	0.064	307	13.9
Nearest Neighbor (3)	12	0.040	307	10.5
Nearest Neighbor (4)	12	0.030	307	8.3
Radius Matching				
Radius (0.01)	5	0.200	307	28.7
Radius (0.1)	5	0.200	307	28.7
Radius (0.25)	5	0.200	307	28.7
Radius (0.5)	5	0.020	307	28.7
Caliper Matching				
Caliper (0.01)	9	0.102	248	15.2
Caliper (0.1)	8	0.106	307	15.1
Caliper (0.25)	8	0.106	307	15.1
Caliper (0.5)	8	0.106	307	15.1
Kernel Matching				
kernel bandwidth (0.01)	12	0.058	248	12.5
kernel bandwidth (0.1)	**12**	**0.011**	**307**	**5.0**
kernel bandwidth (0.25)	12	0.014	307	6.6
kernel bandwidth (0.5)	11	0.059	307	15.6

4.4.3.5. Assessing the matching quality

As it is conditioned on the propensity score, rather than on covariates, we should have to check whether or not the matching procedure balances the distribution of the relevant variable in both irrigation participants and non-participants. The main idea is to compare situations before and after matching and check whether or not any difference exists after matching conditioning on the propensity score. A balancing test is a test conducted to check whether there is a significant difference in the mean values of covariates for participants and non-participants. Based on Table 4.8, kernel matching with a bandwidth of 0.1 matched a larger sample size, balanced all the covariates, and bears the minimum Pseudo- R^2 value compared to other matching methods**.**

Therefore, the kernel matching method with a bandwidth of 0.1 was tested for balancing the covariates. According to the survey result presented in Table 4.9, the t-value was showing that eight covariates were statistically significant before matching, but all the covariates become statistically insignificant after matching. Moreover, the standard bias for all the covariates before matching was larger and in the range of 4.1% to 80.3 % in absolute value, and the mean bias of the covariates before matching was 32.1% as presented in the bottom rows of Table 4.9. But, after matching the standard bias for all the covariates become smaller and ranged from 1% to 13.8% in absolute value, which is below the critical level of 20% suggested by Rosenbaum and Rubin, (1985) with the mean bias after matching of 5% as presented in Table 4.9. These values guarantee us that the matching method has high matching quality.

Table 4.9: Balancing Test for Covariates

Variable	Unmatched Matched	Mean		%reduct		Test		
		Treated	Control	%bias	Bias	T	p>t	V(T)/V(C)
Gendhh	Unmatched	.90909	.8731	11.5		0.98	0.327	-
	Matched	.90678	.9123	-1.8	84.7	-0.15	0.883	-
Hhage	Unmatched	43.901	45.249	-23.7		-1.99	0.048**	0.60*
	Matched	43.958	43.884	1.3	94.6	0.08	0.933	0.39*
Educhh	Unmatched	4.1322	3.4213	28.6		2.55	0.011**	1.67*
	Matched	4.1525	4.0278	5.0	82.5	0.37	0.713	1.40
Accrsv	Unmatched	.75207	.60914	30.9		2.64	0.009**	-
	Matched	.74576	.75055	-1.0	96.6	-0.08	0.933	-
Culsize	Unmatched	1.6147	1.3845	31.7		2.68	0.008**	0.65*
	Matched	1.5858	1.5996	-1.9	94.0	-0.14	0.889	0.52*
Noxen	Unmatched	2.0744	1.7462	31.5		2.75	0.006**	1.16
	Matched	2.0424	1.9627	7.6	75.7	0.58	0.563	1.03
Tlueox	Unmatched	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	Matched	3.1866	3.2321	-3.1	23.9	-0.25	0.802	1.24
Nonfami	Unmatched	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	Matched	1637.7	1898.4	-12.7	0.3	-0.96	0.336	0.68*
Diswafal	Unmatched	1.6868	2.134	-80.3		-6.72	0.000**	0.55*
	Matched	1.7042	1.6693	6.3	92.2	0.52	0.607	0.65*
Soilfts	Unmatched	.90083	.91371	-4.4		-0.39	0.700	-
	Matched	.90678	.91801	-3.9	12.8	-0.30	0.762	-
Exsevce	Unmatched	.91736	.8934	8.2		0.70	0.486	-
	Matched	.91525	.90614	3.1	61.9	0.24	0.807	-

Famlab	Unmatched	4.0719	3.7675	25.9		2.25	0.025*	1.06
	Matched	4.0653	3.9026	13.8	46.6	1.02	0.308	0.93

* If variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Source: Own computation based on survey data, (2021)

Similarly, the joint significance test presented in Table 4.10 revealed that the value of pseudo-R^2 was very small (0.011) and the t-test was not significant. These also give a guarantee that the matching process created a good balance between participants and non-participants based on the included covariates. Therefore, estimation of the Average Treatment Effect on the Treated (ATT) was preceded.

Table.4.10: Chi2 Test for the Joint Significance of Variables

Sample	Ps R2	LR chi2	p>chi2	Mean Bias	Med Bias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.011	3.76	0.994	5.0	3.9	25.3*	0.75	44

Source: Own computation based on survey data, (2021)

4.4.3.6. Estimation of the average treatment effect on treated (ATT)

To attain the stated objectives of the study, this section evaluates the impact of the program on the outcome variable for their significant impact on participant households, after the pre-intervention differences were controlled. The estimation result presented in Table 4.11 provides supportive evidence of a significant effect of irrigation on the outcome variable (calorie intake). A positive value of average treatment effect on the treated (ATT) (the difference between the treated and the control) indicates that the households' calorie intake per adult equivalent per day has been improved because of participation in irrigation intervention in the study area.

According to Caliendo and Kopeinig, (2008), the main goal of performing propensity score matching is to ensure that both participants and non-participants are in the same condition to estimate the average treatment effect on the treated (ATT). For this research, ATT measures the average difference of Calorie Intake per adult equivalent per day between irrigation participants and non-participants. Therefore, the Average Treatment Effect on the Treated (ATT) was estimated by taking daily calorie intake as an outcome indicator as presented in Table.4.11.

Table 4.11: Estimation of the average treatment effect on treated of the outcome variable

Outcome variable	**Sample**	**Treated**	**Control**	**Difference**	**SE**	**t-value**
Calorie Intake	Unmatched	3157.88	2255.491	902.39	162.88	5.54
	ATT	3178.81	2315.72	863.09	215.41	4.01***

******* represents a level of significance p<0.01

Source: Own computation based on survey data, (2021)

As can be seen from Table 4.11, the study provides evidence as to whether or not participation in small-scale irrigation has brought significant changes to a household's food security or calorie intake. The estimation result presented in Table 4.11 provides supportive evidence of a significant effect of the program on household intake of 863kcal per adult equivalent per day. In other words, the participation in small-scale irrigation has higher than the kilocalorie intake per adult equivalent for participant households on average by 37% due to participating in small-scale irrigation and this difference was significant at 1 percent.

4.4.3.7. Sensitivity Analysis

Deciding which variables should be included in a statistical model is one of the unsolved and probably most debatable issues in an observational study Shenyang Guo and Mark W, (2015). Relevant but omitted variables but which are relevant to the matching irrigation users with non-user households cause bias in the outcome of an intervention. The standard response to this knowledge has been to include additional control variables under the belief that the inclusion of every additional variable serves to reduce the potential threat from omitted variable bias. However, the reality is more complicated, and the control variable strategy does not protect from omitted variable bias (Rosenbaum, 2002).

To reduce the above problem, sensitivity analysis has got great attention on this day. Recently, it becomes an increasingly important topic in the applied evaluation literature Caliendo and Kopeinig, (2008). To check for unobservable biases, using the Rosenbaum Bounding approach sensitivity analysis was performed on the computed outcome variable to deviation from the conditional independence assumption Shenyang Guo and Mark W, (2015). The basic question to be answered here is whether the finding of treatment effects may be affected by unobserved factors (hidden bias) or not.

The sensitivity analysis using Rosenbaum bounding approach is also presented in appendix 17. Estimation of treatment effects with matching estimators is based on the CIA, which is a selection of observable characteristics. However, if there are unobserved variables that affect assignment into treatment and the outcome variable simultaneously, a `hidden bias' might arise. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, we address this problem with the bounding approach Caliendo and Kopeinig, (2005). As shown in appendix 17, if the critical level of gamma increases, the level of significance is not affected (p-value $2.7e^{-07}$ to 0.00). This indicates that for the outcome variable estimated, at various level of the critical value of gamma, the p- critical values is significant which further indicate that the study considered important covariates that affected both participation and household food security. Thus, it can be concluded that our impact estimate (ATT) is insensitive to unobserved selection bias and is a pure effect on household food security due to small-scale irrigation.

CHAPTER FIVE

5. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1. Summary

The study was conducted analyzing the effect of small-scale irrigation on household food security in Gombora woreda. The specific objectives of the study were measuring household food security status of irrigation users and non-users, identifying factors affecting participation in small-scale irrigation, evaluating the impact of small-scale irrigation on household food security, and assessing the major constraints encountered in irrigation use in the study area.

Both primary and secondary data were used. A multi-stage sampling technique was employed and the primary data were collected from four randomly selected kebeles from a total of 318 households (197 irrigation non-users and 121 irrigation users). Secondary data were collected from different sources. Descriptive, household food balance model and econometric analyses were performed. Propensity score matching was the method used in analyzing the impact of small-scale irrigation on household food security since there was no baseline data.

The descriptive result showed that gender of the household head, access to credit services, educational level of the household head, age of the household head, livestock holding, family labor, irrigation distance, and cultivated land size were the variables that showed significant relation with irrigation participation.

The study revealed that the main problems of irrigation farming have been challenged by some constraints among which are occurrences of pests and diseases, poor irrigation method practices, and lack of input supply and irrigation facilities are most prominent in the study area.

The binary logistic regression result showed that participation in small-scale irrigation was significantly affected by eight explanatory variables, viz., gender of the household head, educational level of the household head, age of the household head, access to credit services, family labor, cultivated land size, oxen owned, and distance from water source to irrigation site. Gender of the household head, educational level of the household head, access to credit services, family labor, cultivated land size, oxen owned, and positively affected participation in irrigation, whereas the age of the household head and distance from water source to irrigation site were the variables that negatively and significantly affected households participation in small-scale irrigation.

5.2. Conclusion

The household food balance model result revealed that on average of availability of food for food-secure households was 3623.305kcal/day/adult equivalent while it was 1279.597kcal/day/ adult equivalent for food-insecure households. The result shows that there was a shortage of food energy for a considerable portion of the community in the study area. Besides, the survey result showed that the overall average food energy was 2598.854 kcal, which was higher than the national minimum recommended value of 2100kcal due to households is used small-scale irrigation.

Participation in small-scale irrigation was significantly affected by the gender of the household head, age of the household head, educational level of household head, family labor, oxen ownership, cultivated land size, access to credit services, and distance of irrigation source.

To analyze the effect of small-scale irrigation on household food security, the propensity score was estimated by logistic regression and the common support region was restricted. Based on this common support region, 118 irrigation users were matched with 189 irrigation non-users using kernel matching bandwidth 0.1 by discarding 11 observations that are out of the common support region. Matching qualities like pseudo-R^2, matched sample size, and the number of balanced covariates were checked, and accordingly, the pseudo-R^2 value was 0.011, the matched sample size was 307 and the numbers of matched covariates were 12. Moreover, the standard error was bootstrapped to capture all sources of errors, and sensitivity analysis was done and the estimated Average Treatment Effect on the Treated was insensitive, showing its robustness.

Generally, the impact estimation result revealed that methods of measuring household food security individuals' daily calories revealed significant mean differences for irrigation users and non-users. On average, a family member irrigation user household intakes more calories of 863kcal than a family member non-user, which is indicated that a significant difference.

5.3. Recommendation

Based on the empirical findings of this study, the following recommendations were forwarded.

- The results of this study showed that households using small-scale irrigation were more food secure than those households not using small-scale irrigation in daily calorie intake methods of measuring households' food security. Therefore, government policies and strategies focusing on promoting small-scale irrigation should be implemented to take out the lives of millions of small-holders from the state of food insecurity and poverty, especially in erratic rainfall and drought-prone areas of the country.
- Distance from the irrigation scheme affects the use of irrigation negatively. This implies that the closer the household to the scheme, the higher is the probability of participation decision and the better household food secured. Thus, the construction of irrigation schemes should consider the distance between the water source and households' residence for proper utilization of the schemes.
- The government or other concerned body should have to create awareness and providing credit service for buying oxen or giving oxen in credit for the households with no ox is important to boost irrigation and agriculture.
- The household head's education level was found to be a significant determinant of the participation in small-scale irrigation. Therefore, the farmers should be educated by a means that fits with their living conditions, such as adult education.
- The size of cultivated land positively and significantly influenced the participation decision and household sustenance securities are directly related to the size of cultivated land. However, land in the study area is scarce to expand because of the increasing population. Therefore, provision of extension on land-use techniques could encourage the farm households to properly use their land and meet the food demand of their family members through participation in irrigation utilization.
- Crop diseases and pests are common constraints to irrigation farming and according to the users of the irrigation pesticides and other anti-diseases are very limited in supply and some of them are not favorable in their usage and are even supplied late. Therefore, government and other concerned body should do their best on it, which means if possible for the common diseases should supply protective anti pests before.

5.4. Further study

The single difference method of project impact evaluation based on cross-section data adopted in this study can be strengthened by using panel data. It is, therefore, recommended that data be collected for several seasons and more robust methods such as difference-in-difference or endogenous switching methods that use panel data be used to analyze the effect of small-scale irrigation on household food security. There is a greater need for panel datasets that observe small-scale irrigators over time to better understand the dynamics of irrigation.

6. REFERENCE

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7. APPENDICES

Appendix 1: Conversion factor for adult and man equivalent

Age group in Year	Adult Equivalent(AE)		Man Equivalent(ME)	
	Male	**Female**	**Male**	**Female**
<10	0.6	0.6	0	0
10-13	0.9	0.8	0.2	0.2
14-16	1	0.75	0.5	0.4
17-50	1	0.75	1	0.8
>50	1	0.75	0.7	0.5

Source: Storck et al., (1991)

Appendix 2: Conversion factor for livestock units

Animals	Livestock unit	Animals	Livestock unit
Cow and Oxen	1	Donkey (young)	0.35
Horse and mule	1.1	Sheep and goat(adult)	0.13
Weaned calf	0.75	Sheep and goat(young)	0.06
Calf	0.25	Chicken	0.013
Donkey (adult)	0.7	Camel	1.25

Source: Storck et al., (1991)

Appendix 3: Calorie value of food items consumed by sampled household

Item	Unit	Kcal per kg
Teff	Kilogram	3589
Sorghum	Kilogram	3805
Maize	Kilogram	3751
Wheat	Kilogram	3623
Peas	Kilogram	3553
Beans	Kilogram	3450
Chickpeas	Kilogram	3450
Barley	Kilogram	3723
Potato	Kilogram	1037
Onion	Kilogram	713

Source: EHNRI, 2000

Appendix 4: Multicolinearity problem test for continuous explanatory variables

Variable	VIF	1/VIF
HHAGE	1.06	0.93357
CULSIZE	1.05	0.952394
EDUCHH	1.04	0.957347
NOXEN	1.04	0.959651
DISWAFAL	1.03	0.973322
TLUEOX	1.02	0.977754
NONFAMI	1.02	0.980742
FAMLAB	1.02	0.981359
Mean VIF	**1.04**	

Source: Own computation based on survey data, (2021)

Appendix 5: Multicollinearity problem test for discrete explanatory variables

Variable	Number of Observation	χ^2_ Value	Contingency Coefficient(CC)
Gender of HH Head	318	0.9674	0.055
Access to credit	318	6.8589	0.145
Contact to extension	318	0.4889	0.039
Soil fertility	318	0.1500	0.022

Source: Own computation based on survey data, (2021)

Appendix 6: Heteroscedaciticity problem test

```
. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
       Ho: Constant variance
       Variables: fitted values of hhprtirr

       chi2(1)      =     5.66
       Prob > chi2  =   0.0173
```

Appendix 7: Logistic regression for factors affecting participation in irrigation

```
. logit hhprtirr gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab, robust

Iteration 0:   log pseudolikelihood = -211.25055
Iteration 1:   log pseudolikelihood =  -165.1365
Iteration 2:   log pseudolikelihood = -164.38723
Iteration 3:   log pseudolikelihood = -164.38499
Iteration 4:   log pseudolikelihood = -164.38499

Logistic regression                             Number of obs     =        318
                                                Wald chi2(12)     =      60.23
                                                Prob > chi2       =     0.0000
Log pseudolikelihood = -164.38499               Pseudo R2         =     0.2218
```

hhprtirr	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
gendhh	.8089446	.4093627	1.98	0.048	.0066084	1.611281
hhage	-.0493593	.0281522	-1.75	0.080	-.1045365	.005818
educhh	.0931769	.0560488	1.66	0.096	-.0166768	.2030306
accrsv	.6565778	.2815366	2.33	0.020	.1047762	1.208379
culsize	.5497761	.1944383	2.83	0.005	.168684	.9308683
noxen	.4481536	.1388256	3.23	0.001	.1760603	.7202469
tlueox	-.0820133	.0839622	-0.98	0.329	-.2465762	.0825497
nonfami	-.0000901	.0000686	-1.31	0.189	-.0002246	.0000444
diswafal	-1.74635	.2689739	-6.49	0.000	-2.273529	-1.219171
soilfts	.6094716	.4306524	1.42	0.157	-.2345917	1.453535
exsevce	.6260217	.4827186	1.30	0.195	-.3200895	1.572133
famlab	.3129568	.1194872	2.62	0.009	.0787662	.5471475
_cons	-.0383652	1.669472	-0.02	0.982	-3.31047	3.23374

Appendix 8: Marginal effect after Logistic regression for participation in irrigation

Marginal effects after logit

y = Pr(hhprtirr) (predict)

= .34965906

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
gendhh*	.1629047	.07749	2.10	0.036	.011019	.31479	.886792
hhage	-.0112242	.00573	-1.96	0.050	-.022463	.000014	44.7358
educhh	.0211882	.01282	1.65	0.098	-.003937	.046314	3.69182
accrsv*	.1433672	.06147	2.33	0.020	.022886	.263848	.663522
culsize	.1250178	.0439	2.85	0.004	.03897	.211066	1.47209
noxen	.1019091	.03188	3.20	0.001	.039424	.164394	1.87107
tlueox	-.0186496	.02132	-0.87	0.382	-.060438	.023139	3.20879
nonfami	-.0000205	.00002	-1.31	0.190	-.000051	.00001	1779.72
diswafal	-.3971159	.06069	-6.54	0.000	-.516065	-.278167	1.96384
soilfts*	.1263458	.08731	1.45	0.148	-.04477	.297462	.908805
exsevce*	.1296018	.08865	1.46	0.144	-.044157	.30336	.902516
famlab	.0711656	.02666	2.67	0.008	.018903	.123428	3.88333

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Appendix 9: Link test after logistic regression to test model specification

```
. linktest

Iteration 0:   log likelihood = -211.25055
Iteration 1:   log likelihood = -165.21879
Iteration 2:   log likelihood = -164.00199
Iteration 3:   log likelihood = -163.90698
Iteration 4:   log likelihood = -163.90665
Iteration 5:   log likelihood = -163.90665

Logistic regression                     Number of obs   =        318
                                        LR chi2(2)      =      94.69
                                        Prob > chi2     =     0.0000
Log likelihood = -163.90665             Pseudo R2       =     0.2241
```

hhprtirr	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_hat	.9649684	.1261777	7.65	0.000	.7176648	1.212272
_hatsq	-.0828263	.084318	-0.98	0.326	-.2480866	.0824339
_cons	.0963879	.1758268	0.55	0.584	-.2482262	.4410021

```
. estat classification

Logistic model for hhprtirr

              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |        74            28  |        102
     -     |        47           169  |        216
-----------+--------------------------+-----------
   Total   |       121           197  |        318

Classified + if predicted Pr(D) >= .5
True D defined as hhprtirr != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   61.16%
Specificity                     Pr( -|~D)   85.79%
Positive predictive value       Pr( D| +)   72.55%
Negative predictive value       Pr(~D| -)   78.24%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   14.21%
False - rate for true D         Pr( -| D)   38.84%
False + rate for classified +   Pr(~D| +)   27.45%
False - rate for classified -   Pr( D| -)   21.76%
--------------------------------------------------
Correctly classified                        76.42%
--------------------------------------------------
```

Appendix 10: Estimation of propensity score

```
. psmatch2 hhprtirr gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab, logit

Logistic regression                               Number of obs   =        318
                                                  LR chi2(12)     =      93.73
                                                  Prob > chi2     =     0.0000
Log likelihood = -164.38499                       Pseudo R2       =     0.2218
```

hhprtirr	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
gendhh	.8089446	.4474972	1.81	0.071	-.0681338	1.686023
hhage	-.0493593	.0252056	-1.96	0.050	-.0987614	.0000428
educhh	.0931769	.056395	1.65	0.098	-.0173554	.2037091
accrsv	.6565778	.2951677	2.22	0.026	.0780597	1.235096
culsize	.5497761	.1924461	2.86	0.004	.1725887	.9269636
noxen	.4481536	.1404361	3.19	0.001	.1729039	.7234033
tlueox	-.0820133	.0937471	-0.87	0.382	-.2657543	.1017278
nonfami	-.0000901	.0000688	-1.31	0.190	-.0002249	.0000446
diswafal	-1.74635	.2691133	-6.49	0.000	-2.273803	-1.218898
soilfts	.6094716	.4710383	1.29	0.196	-.3137466	1.53269
exsevce	.6260217	.4802005	1.30	0.192	-.315154	1.567197
famlab	.3129568	.1169564	2.68	0.007	.0837266	.5421871
_cons	-.0383652	1.622187	-0.02	0.981	-3.217793	3.141063

Appendix 11: Summary propensity score for the common support condition

```
. sum _pscore if hhprtirr==1
```

Variable	Obs	Mean	Std. Dev.	Min	Max
_pscore	121	.5501208	.2435435	.0470136	.9610066

```
. sum _pscore if hhprtirr==0
```

Variable	Obs	Mean	Std. Dev.	Min	Max
_pscore	197	.2763218	.1981409	.0187712	.9342712

```
. sum _pscore
```

Variable	Obs	Mean	Std. Dev.	Min	Max
_pscore	318	.3805031	.2538779	.0187712	.9610066

Appendix 12: Kernel matching algorithms

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), kernel outcome( netkilocal ) bwidth(0.01) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	41	156	197
Treated	29	92	121
Total	70	248	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.49784	.49784	-0.0	100.0	-0.00	1.000	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.92391	.88969	11.0	4.9	0.80	0.427	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.913	43.783	2.3	90.3	0.14	0.891	0.44*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1413	3.622	20.9	26.9	1.41	0.160	1.25
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.71739	.64931	14.7	52.4	0.99	0.324	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5068	1.669	-22.4	29.5	-1.50	0.136	0.54*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0217	1.8002	21.2	32.5	1.44	0.152	1.30
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1183	3.3975	-18.9	-367.1	-1.38	0.169	0.96
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1770.1	1939.9	-8.3	35.1	-0.55	0.586	0.68
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7652	1.6773	15.8	80.3	1.12	0.265	0.63*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90217	.95541	-18.3	-313.3	-1.40	0.162	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91304	.9191	-2.1	74.7	-0.15	0.883	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0217	3.9414	6.8	73.6	0.44	0.661	0.83

* if variance ratio outside [0.70; 1.43] for U and [0.66; 1.51] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.058	14.75	0.323	12.5	14.7	57.7*	0.66	33

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), kernel outcome(netkilocal) bwidth(0.1) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53122	3.9	96.8	0.28	0.781	0.99
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.9123	-1.8	84.7	-0.15	0.883	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	43.884	1.3	94.6	0.08	0.933	0.39*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0278	5.0	82.5	0.37	0.713	1.40
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.75055	-1.0	96.6	-0.08	0.933	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.5996	-1.9	94.0	-0.14	0.889	0.52*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.9627	7.6	75.7	0.58	0.563	1.03
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2321	-3.1	23.9	-0.25	0.802	1.24
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1898.4	-12.7	0.3	-0.96	0.336	0.68*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6693	6.3	92.2	0.52	0.607	0.65*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.91801	-3.9	12.8	-0.30	0.762	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.90614	3.1	61.9	0.24	0.807	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.9026	13.8	46.6	1.02	0.308	0.93

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.011	3.76	0.994	5.0	3.9	25.3*	0.75	44

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), kernel outcome(netkilocal) bwidth(0.25) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.49766	19.0	84.6	1.36	0.175	0.99
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.90796	-0.4	96.7	-0.03	0.975	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	44.067	-1.9	91.9	-0.13	0.899	0.39*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.9736	7.2	74.8	0.53	0.597	1.40
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.72787	3.9	87.5	0.31	0.756	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.5453	5.6	82.4	0.42	0.678	0.53*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.9386	10.0	68.4	0.76	0.449	1.05
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2122	-1.7	57.3	-0.14	0.889	1.22
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1898.5	-12.8	0.2	-0.96	0.336	0.68*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.7243	-3.6	95.5	-0.29	0.771	0.61*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.9128	-2.1	53.3	-0.16	0.872	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.90326	4.1	49.9	0.32	0.750	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.8971	14.3	44.8	1.06	0.290	0.95

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.014	4.70	0.981	6.6	4.1	28.2*	1.09	44

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), kernel outcome( netkilocal ) bwidth(0.5) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.40723	59.7	51.6	4.40	0.000	1.12
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89532	3.7	68.2	0.29	0.769	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	44.626	-11.7	50.4	-0.86	0.392	0.52*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.7726	15.3	46.6	1.14	0.256	1.50*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.67687	14.9	51.8	1.17	0.245	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.462	17.1	46.2	1.29	0.197	0.57*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.8806	15.5	50.7	1.19	0.234	1.10
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.218	-2.1	47.5	-0.17	0.867	1.08
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1841.8	-10.0	21.9	-0.76	0.449	0.69*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.8725	-30.2	62.4	-2.43	0.016	0.60*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.90671	0.0	99.5	0.00	0.999	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.90129	4.8	41.7	0.37	0.712	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.8497	18.3	29.2	1.37	0.172	0.98

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.059	19.21	0.117	15.6	14.9	58.3*	1.26	56

Appendix 13: Nearest Neighbor matching

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab),  outcome( netkilocal ) neighbor(1) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53973	0.1	100.0	0.00	0.997	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89831	2.7	76.5	0.22	0.827	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	41.559	42.1	-77.9	2.20	0.029	0.21*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0424	4.4	84.5	0.32	0.750	1.26
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.72881	3.7	88.1	0.29	0.769	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.7405	-21.3	32.8	-1.55	0.123	0.50*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7627	26.8	14.8	2.21	0.028	1.52*
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.4052	-14.8	-265.6	-1.25	0.211	1.49*
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	2002.5	-17.8	-39.6	-1.25	0.214	0.53*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6805	4.3	94.7	0.35	0.724	0.67*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.98305	-26.2	-492.2	-2.59	0.010	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.9322	-5.8	29.2	-0.49	0.626	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7542	26.4	-2.2	1.94	0.054	0.90

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.106	34.59	0.001	15.1	14.8	78.7*	1.12	67

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab),  outcome( netkilocal ) neighbor(2) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53901	0.4	99.7	0.03	0.978	1.01
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.87712	9.5	17.6	0.73	0.465	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	43.076	15.5	34.6	0.94	0.349	0.31*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.9492	8.2	71.4	0.60	0.550	1.37
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.68644	12.8	58.5	1.01	0.314	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.7669	-25.0	21.3	-1.92	0.057	0.59*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7881	24.4	22.5	1.91	0.057	1.19
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.4224	-16.0	-294.5	-1.26	0.208	1.09
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	2079.7	-21.6	-69.1	-1.57	0.119	0.59*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6398	11.6	85.6	0.94	0.350	0.62*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.9661	-20.4	-360.6	-1.87	0.062	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.88983	8.7	-6.1	0.66	0.512	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.9864	6.7	74.1	0.48	0.634	0.81

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.064	20.85	0.076	13.9	12.8	60.8*	0.77	44

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), outcome(netkilocal) neighbor(3) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53718	1.2	99.0	0.09	0.931	1.02
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89548	3.6	68.6	0.29	0.772	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	43.201	13.3	43.8	0.88	0.382	0.39*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0113	5.7	80.1	0.42	0.675	1.43
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.67797	14.7	52.6	1.15	0.252	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.709	-17.0	46.5	-1.28	0.202	0.56*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.8672	16.8	46.6	1.29	0.199	1.08
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2563	-4.7	-16.5	-0.37	0.714	1.01
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1900.6	-12.9	-0.5	-0.96	0.339	0.65*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6571	8.5	89.5	0.69	0.490	0.63*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.95763	-17.5	-294.8	-1.55	0.121	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.89266	7.7	5.7	0.59	0.558	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.9153	12.7	50.7	0.92	0.359	0.84

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.040	13.07	0.442	10.5	12.7	47.7*	0.80	44

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab),  outcome( netkilocal ) neighbor(4) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53575	1.8	98.5	0.13	0.894	1.03
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.90042	2.0	82.3	0.16	0.869	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	43.339	10.9	54.1	0.70	0.483	0.37*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0064	5.9	79.4	0.44	0.662	1.48*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.7161	6.4	79.2	0.51	0.609	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.6653	-11.0	65.5	-0.83	0.410	0.56*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.875	16.0	49.0	1.22	0.224	1.04
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2774	-6.2	-51.9	-0.48	0.630	1.05
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1828	-9.3	27.2	-0.70	0.487	0.66*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6733	5.6	93.1	0.46	0.646	0.67*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.95975	-18.2	-311.3	-1.63	0.104	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.90678	2.9	64.6	0.23	0.820	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.9216	12.2	52.8	0.89	0.375	0.88

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.030	9.67	0.721	8.3	6.4	40.8*	0.98	56

Appendix 14: Caliper matching algorithms

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab),  outcome( netkilocal ) caliper(0.01) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	41	156	197
Treated	29	92	121
Total	70	248	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.49784	.49831	-0.2	99.8	-0.01	0.990	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.92391	.93478	-3.5	69.8	-0.29	0.775	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.913	43.217	12.2	48.4	0.74	0.457	0.47*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1413	3.5761	22.7	20.5	1.53	0.128	1.22
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.71739	.65217	14.1	54.4	0.95	0.344	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5068	1.6929	-25.7	19.1	-1.72	0.087	0.54*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0217	1.7826	22.9	27.1	1.60	0.112	1.48
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1183	3.5045	-26.2	-546.2	-2.02	0.045	1.20
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1770.1	1882.6	-5.5	57.0	-0.36	0.718	0.68
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7652	1.6913	13.3	83.5	0.96	0.336	0.68
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90217	.97826	-26.1	-490.8	-2.19	0.030	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91304	.92391	-3.7	54.6	-0.27	0.789	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0217	3.7685	21.5	16.8	1.41	0.160	0.89

* if variance ratio outside [0.70; 1.43] for U and [0.66; 1.51] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.102	26.14	0.016	15.2	14.1	77.5*	0.84	22

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab),  outcome( netkilocal ) caliper(0.1) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53973	0.1	100.0	0.00	0.997	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89831	2.7	76.5	0.22	0.827	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	41.559	42.1	-77.9	2.20	0.029	0.21*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0424	4.4	84.5	0.32	0.750	1.26
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.72881	3.7	88.1	0.29	0.769	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.7405	-21.3	32.8	-1.55	0.123	0.50*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7627	26.8	14.8	2.21	0.028	1.52*
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.4052	-14.8	-265.6	-1.25	0.211	1.49*
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	2002.5	-17.8	-39.6	-1.25	0.214	0.53*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6805	4.3	94.7	0.35	0.724	0.67*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.98305	-26.2	-492.2	-2.59	0.010	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.9322	-5.8	29.2	-0.49	0.626	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7542	26.4	-2.2	1.94	0.054	0.90

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.106	34.59	0.001	15.1	14.8	78.7*	1.12	67

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), outcome(netkilocal) caliper(0.25) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53973	0.1	100.0	0.00	0.997	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89831	2.7	76.5	0.22	0.827	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	41.559	42.1	-77.9	2.20	0.029	0.21*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0424	4.4	84.5	0.32	0.750	1.26
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.72881	3.7	88.1	0.29	0.769	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.7405	-21.3	32.8	-1.55	0.123	0.50*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7627	26.8	14.8	2.21	0.028	1.52*
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.4052	-14.8	-265.6	-1.25	0.211	1.49*
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	2002.5	-17.8	-39.6	-1.25	0.214	0.53*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6805	4.3	94.7	0.35	0.724	0.67*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.98305	-26.2	-492.2	-2.59	0.010	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.9322	-5.8	29.2	-0.49	0.626	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7542	26.4	-2.2	1.94	0.054	0.90

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.106	34.59	0.001	15.1	14.8	78.7*	1.12	67

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), outcome(netkilocal) caliper(0.5) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.53973	0.1	100.0	0.00	0.997	1.00
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.89831	2.7	76.5	0.22	0.827	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	41.559	42.1	-77.9	2.20	0.029	0.21*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	4.0424	4.4	84.5	0.32	0.750	1.26
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.72881	3.7	88.1	0.29	0.769	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.7405	-21.3	32.8	-1.55	0.123	0.50*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7627	26.8	14.8	2.21	0.028	1.52*
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.4052	-14.8	-265.6	-1.25	0.211	1.49*
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	2002.5	-17.8	-39.6	-1.25	0.214	0.53*
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	1.6805	4.3	94.7	0.35	0.724	0.67*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.98305	-26.2	-492.2	-2.59	0.010	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.9322	-5.8	29.2	-0.49	0.626	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7542	26.4	-2.2	1.94	0.054	0.90

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.106	34.59	0.001	15.1	14.8	78.7*	1.12	67

Appendix 15: Radius matching algorithims

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), radius bw(0.01) outcome( netkilocal ) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.28672	114.0	7.5	10.05	0.000	1.48*
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.87302	10.8	6.2	0.90	0.370	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	45.243	-22.6	4.6	-1.84	0.067	0.59*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.5026	26.1	8.6	2.27	0.024	1.71*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.60317	30.8	0.2	2.57	0.011	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.3955	26.2	17.3	2.19	0.029	0.61*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7672	26.4	16.2	2.27	0.024	1.14
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2432	-3.8	5.3	-0.32	0.747	0.95
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1883.6	-12.0	5.9	-1.00	0.318	0.72
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	2.0921	-69.7	13.3	-5.94	0.000	0.58*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.91005	-1.1	74.6	-0.10	0.924	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.89947	5.4	34.1	0.46	0.649	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7836	23.9	7.5	2.01	0.045	1.05

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.200	80.63	0.000	28.7	23.9	116.2*	1.46	56

. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), radius bw(0.1) outcome(netkilocal) common logit ate

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.28672	114.0	7.5	10.05	0.000	1.48*
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.87302	10.8	6.2	0.90	0.370	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	45.243	-22.6	4.6	-1.84	0.067	0.59*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.5026	26.1	8.6	2.27	0.024	1.71*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.60317	30.8	0.2	2.57	0.011	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.3955	26.2	17.3	2.19	0.029	0.61*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7672	26.4	16.2	2.27	0.024	1.14
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2432	-3.8	5.3	-0.32	0.747	0.95
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1883.6	-12.0	5.9	-1.00	0.318	0.72
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	2.0921	-69.7	13.3	-5.94	0.000	0.58*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.91005	-1.1	74.6	-0.10	0.924	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.89947	5.4	34.1	0.46	0.649	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7836	23.9	7.5	2.01	0.045	1.05

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.200	80.63	0.000	28.7	23.9	116.2*	1.46	56

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), radius bw(0.25) outcome( netkilocal ) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.28672	114.0	7.5	10.05	0.000	1.48*
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.87302	10.8	6.2	0.90	0.370	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	45.243	-22.6	4.6	-1.84	0.067	0.59*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.5026	26.1	8.6	2.27	0.024	1.71*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.60317	30.8	0.2	2.57	0.011	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.3955	26.2	17.3	2.19	0.029	0.61*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7672	26.4	16.2	2.27	0.024	1.14
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2432	-3.8	5.3	-0.32	0.747	0.95
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1883.6	-12.0	5.9	-1.00	0.318	0.72
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	2.0921	-69.7	13.3	-5.94	0.000	0.58*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.91005	-1.1	74.6	-0.10	0.924	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.89947	5.4	34.1	0.46	0.649	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7836	23.9	7.5	2.01	0.045	1.05

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.200	80.63	0.000	28.7	23.9	116.2*	1.46	56

```
. psmatch2 hhprtirr (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), radius bw(0.5) outcome( netkilocal ) common logit ate
```

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	8	189	197
Treated	3	118	121
Total	11	307	318

```
. pstest _pscore (gendhh hhage educhh accrsv culsize noxen tlueox nonfami diswafal soilfts exsevce famlab), both sum
```

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
_pscore	U	.55012	.27632	123.3		10.95	0.000	1.51*
	M	.53985	.28672	114.0	7.5	10.05	0.000	1.48*
gendhh	U	.90909	.8731	11.5		0.98	0.327	.
	M	.90678	.87302	10.8	6.2	0.90	0.370	.
hhage	U	43.901	45.249	-23.7		-1.99	0.048	0.60*
	M	43.958	45.243	-22.6	4.6	-1.84	0.067	0.59*
educhh	U	4.1322	3.4213	28.6		2.55	0.011	1.67*
	M	4.1525	3.5026	26.1	8.6	2.27	0.024	1.71*
accrsv	U	.75207	.60914	30.9		2.64	0.009	.
	M	.74576	.60317	30.8	0.2	2.57	0.011	.
culsize	U	1.6147	1.3845	31.7		2.68	0.008	0.65*
	M	1.5858	1.3955	26.2	17.3	2.19	0.029	0.61*
noxen	U	2.0744	1.7462	31.5		2.75	0.006	1.16
	M	2.0424	1.7672	26.4	16.2	2.27	0.024	1.14
tlueox	U	3.1718	3.2315	-4.1		-0.35	0.727	0.94
	M	3.1866	3.2432	-3.8	5.3	-0.32	0.747	0.95
nonfami	U	1617.8	1879.2	-12.8		-1.08	0.279	0.71
	M	1637.7	1883.6	-12.0	5.9	-1.00	0.318	0.72
diswafal	U	1.6868	2.134	-80.3		-6.72	0.000	0.55*
	M	1.7042	2.0921	-69.7	13.3	-5.94	0.000	0.58*
soilfts	U	.90083	.91371	-4.4		-0.39	0.700	.
	M	.90678	.91005	-1.1	74.6	-0.10	0.924	.
exsevce	U	.91736	.8934	8.2		0.70	0.486	.
	M	.91525	.89947	5.4	34.1	0.46	0.649	.
famlab	U	4.0719	3.7675	25.9		2.25	0.025	1.06
	M	4.0653	3.7836	23.9	7.5	2.01	0.045	1.05

* if variance ratio outside [0.70; 1.43] for U and [0.69; 1.44] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.222	93.91	0.000	32.1	25.9	122.9*	1.36	56
Matched	0.200	80.63	0.000	28.7	23.9	116.2*	1.46	56

Appendix 16: Result of ATT using kernel bandwidth (0.1) Matching

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
netkilocal	Unmatched	3157.88326	2255.491	902.392264	162.806575	5.54
	ATT	3178.81464	2315.7218	863.092839	215.414595	4.01
	ATU	2261.55741	3203.58497	942.027563	.	.
	ATE			911.687832	.	.

Note: S.E. does not take into account that the propensity score is estimated.

Appendix 17: Rosenbaum Sensitivity Analysis Daily Calorie Intake per Adult Equivalent

```
. rbounds _netkilocal , gamma(1(0.25)9)

Rosenbaum bounds for _netkilocal (N = 307 matched pairs)
```

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	2890.61	2890.61	2804.06	2950.63
1.25	0	0	2816.12	2942.76	2733.65	3001.47
1.5	0	0	2757.7	2982.93	2692.48	3039.13
1.75	0	0	2717.57	3017.14	2653.45	3074.21
2	0	0	2688.69	3041.67	2616.09	3111.69
2.25	0	0	2660.46	3066.52	2584.56	3159.26
2.5	0	0	2633.56	3093.91	2553.65	3201.79
2.75	0	0	2608.77	3121.78	2514.65	3243.73
3	0	0	2587.57	3156.06	2476.57	3284.21
3.25	0	0	2565.4	3185.97	2438.02	3311.15
3.5	2.2e-16	0	2544.58	3213.85	2416.03	3330.9
3.75	2.2e-15	0	2517.47	3241.59	2399.89	3344.72
4	1.6e-14	0	2490.79	3269.53	2382.45	3356.86
4.25	8.8e-14	0	2466.85	3291.61	2362.04	3368.89
4.5	4.1e-13	0	2441.74	3309.33	2348.33	3380.53
4.75	1.6e-12	0	2424.86	3321.62	2334.34	3390.7
5	5.5e-12	0	2412.68	3333.44	2321.39	3401.12
5.25	1.7e-11	0	2403.21	3341.72	2311.18	3411.79
5.5	4.7e-11	0	2393.21	3349.33	2304.04	3421.68
5.75	1.2e-10	0	2382.15	3357.03	2297.44	3430.74
6	2.8e-10	0	2368.35	3364.42	2292.04	3440.59
6.25	6.2e-10	0	2357.78	3371.45	2286.48	3450.25
6.5	1.3e-09	0	2349.96	3377.92	2281.48	3457.8
6.75	2.5e-09	0	2341.78	3385.25	2276.18	3465.81
7	4.7e-09	0	2334.34	3390.7	2270.45	3475.41
7.25	8.5e-09	0	2326.28	3396.81	2264.86	3484.93
7.5	1.5e-08	0	2319.84	3402.67	2258.72	3493.62
7.75	2.4e-08	0	2313.82	3408.81	2253.91	3503.2
8	4.0e-08	0	2309.2	3414.47	2248.65	3513.72
8.25	6.2e-08	0	2305.1	3420.16	2244.14	3524.79
8.5	9.5e-08	0	2301.22	3425.24	2239.32	3533.76
8.75	1.4e-07	0	2297.82	3430.13	2235.3	3544.48
9	2.1e-07	0	2294.65	3435.47	2231.09	3554.83

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

Appendix 18: Questionnaire for Respondents

Dear Respondent

This questionnaire is prepared to undertake a study on the effect of small-scale irrigation on the household food security case of Gombora woreda. The purpose of the questionnaire is to gather information on irrigating and non-irrigating households. Dear respondents, the result of this study will help different stockholders and policymakers to take appropriate measures on irrigation development in the future in your area. Your responses are confidential. Therefore, you are kindly requested to provide genuine responses. Thank you for your time and cooperation

Participant status: 1. Participate in irrigation

0. Non participate in irrigation

I. Demographic characteristic

1. Household code____________, Kebele _________
2. Gender

    1= Male

    0= female
3. Age ________________
4. Marital status

    1=married

    2=unmarried

    3=divorce

    4=widowed
5. Educational level;

    if literate, write class year________________and

    illiterate write 0____________________
6. Total household Size;__________________
7. Could you list out the age category of your household members?

No.	Age category (years)	Sex		Total
		M	F	

1	Individuals who are less 15			
2	Individuals who are 15-64			
3	Individuals who are over 64			

Part II: **Measures of Food production and/or Agricultural production**

8. How much of food grain was AVILABLE for your family consumption purpose during the past one year (2012E.C) production time (in Quintal)?

	Name of crop	**Total grain produced**	**Total grain bought**	**Total grain obtained from food aid**	**Total grain utilized for seed**	**Total grain sold at market**	**Post- harvest**	**Total grain given to other**	**Net grain Available**
Irrigation	Potato								
	Tomato								
	Onion								
	Carrot								
	Cabbage								
Rain-fed	Wheat								
	Teff								
	Sorghum								
	Beans								
	Maize								
	Peas								

Part III: Determinant factor that affect Participation in Small-Scale Irrigation

Land size

9. Could you tell the total land size you have owned (hectare)?

Land category	Hectare
1.Cultivated rainfed agriculture	
2.Cultivated land (irrigable land)	
Total	

10. How do you think your land soil fertility status in 2012E.C?

1. Fertile 0. infertile

Livestock

11. Do you have livestock? 1) Yes 2) No

12. If yes, Q11 indicate the number of livestock you have last year:-

Types of livestock	Number	
Cattle		
1.Ox		
2.Cows		
3.Culves		
4.Heifers		
5.Bulls		
Pack animal		

6.Donkey		
7.Mule		
8.Horse		
Small ruminant		
9.Chichen		
10.Sheep		
11.Goat		
Other		

Participation in non-farm activity

13. Do you or any member of the family have a non-farm job? 1=yes 0=no

14. If yes, Q13 please indicate the work and income from it in the following table

No.	Activities	Income earned (ETBirr)
1	Charcoal sale	
2	Hire out labor	
3	Firewood sale	
4	Remittance	
	Total	

Agricultural Extension, Credit, Marketing and other institutional support services

15. Did you use improved seed varieties in past production time? 1) Yes 2)No

16. If your answer is yes for Q15, did you face a problem in using the improved seeds? 1) yes 2) No

17. If you faced a problem in using improved seeds, what are those? ____
18. Did you use inorganic fertilizer in past production time? 1) Yes 2)No
19. Did you use chemicals to kill pests if you had a problem? 1) Yes 2)No
20. Had you got extension support by development agents during 2019/20? 1) Yes 2) No
21. If yes for the above question, how many times have they visited your farm?_(no of contacts)
22. Is there Farmers training center (FTC) in your locality? 1) yes 2) No
23. Where do you sell your products produced by irrigation? 1) Local market 2) on-farm 3) regional market 4) federal market
24. How much is the distance between the sources of water to your irrigated land? ____ km
25. How far is the market you mentioned from your farmland? _________kms.
26. Have you used credit in the last production season? 1) yes 0) no
27. If yes, what is the source of credit? Please could you mention the source of the credit in the following table?

No	Source of credit	Purpose	Amount

Part IV:-factors constraining irrigation use

For Only Irrigations User

28. What are the major problems/factors constraining irrigation use in your area? Choice out of the following problems only **three** based on your priority rank them.

Major problems	First	Second	Third
Poor irrigation method practice			
Presence of pests and diseases			
Distance from water source to farmland			
Lack of efficient extension support			
Lack of input supply and irrigation facilities			

Thank you

Appendix 19: Data gathering completed letter from Gombora woreda agriculture and natural resource development office

በደ/ብ/ብ/ሕ/ክ./መ/ በሀዲያ ዞን
ጎምቦራ ወረዳ የእርሻና ተፈጥሮ
ሀብት ልማት ጽ/ቤት ሀብት
DAbuuphphi Giir-Giich
Minaadaphphi Kulullees
Adillanonne Hadiyyi Zoonanne
Gombo'l Woraxxi Abullane
Umo'l Amaxxi Kitaphphi Mine

ቁጥር: [illegible]/1939/2013
ቀን: 23/9/2013

ለጅማ ዩኒቨርሲቲ ግብርና ሀብት ትምህርት ክፍል

ጅማ

ጉዳዩ:- መረጃ መሰብሰቡን ስለመግለጽ ይሆናል፤

ከዩኒቨርሲቲያችሁ በቁጥር Ref.No.: 83/2013 በቀን 24/07/2013 በተፃፈልን ደብዳቤ መሠረት ተማሪ አብርሃም አባይነህ በጎምቦራ ወረዳ ከሉት ከተመረጡት ከአረት ቀበሌያት(1ኛ ከኦርዴቦብቾ 2ኛ ከሰጠራ 3ኛ ከሀብቾ እና 4ኛ ከወገኖ) ለምርምር ጽሑፍ የሚሆን መረጃ ለመሰብሰብ መሥሪያ ቤታችንን ትብብር አድርጉ ብሎ በጠየቀን መሰረት አስፈለግዉን ትብብር አድርገናል፡፡

በመሆኑም ከጎምቦራ ወረዳ እርሻና ተፈጥሮ ሀብት ልማት ጽ/ቤት እና ከተመረጡት ከአረት ቀበሌያት ለምርምር ጽሑፍ ይደግፋል ተብሎ የታሰቡ መጠይቆችን በመባተን መረጃ መሰብሰቡን እንገልፃለን፡፡

ከሰላምታ ጋር!

...chew Ersumo kencho
Deputy Dep't Head &
Farm Dev't Division Head