IMPACT OF SMALL-SCALE IRRIGATION ON SMALLHOLDER FARMERS'INCOME: THE CASE OF SHEBE SOMBO DISTRICT, JIMMA ZONE, ETHIOPIA

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ABDULSEMED ABANEGA

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Abdulsemed Abanega

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Jimma University

College of Agriculture and Veterinary Medicine

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Name of Student: Abdulsemed Abanega ID No: **RM 8053/11**

Program of Study: Agribusiness and Value Chain Management

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, I hereby kindly request the Department to allow me to present the findings of my work and submit the thesis.

Name: **Abdulsemed Abanega** Signature: _________

We, have evaluated the content of this thesis and found to be satisfactory executed according to the approved proposal, written according to the standard and format of the University and is ready to be submitted. Hence, we recommend the thesis to be submitted.

Major Advisor: Tesfaye Eba (PhD) _______________ _____/______/_______

Name Signature Date

Co- Advisor: Yadeta Bekele (MSc) _____________ ______/______/_______

Name Signature Date

Internal Examiner: Ermias Melaku (MSc) _____________ ______/______/_______

Name Signature Date

Decision/suggestion of Department Graduate Council (DGC)

____

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______________________ ____________________ _____/____/_____

Chairperson, DGC **Signature** **Date**

_____________________ ____________________ _____/____/_____

Chairperson, CGS **Signature** **Date**

DEDICATION

I dedicate this thesis Manuscript to my mother who sacrificed much to bring me up to this level, my beloved son, Sa'ad Abdulsemed and my wife Fatiha Ahmed.

STATEMENT OF AUTHOR

First, I declare that this thesis is a result of my honest work and that I have duly acknowledged all sources of materials used for writing it. This thesis has been submitted in partial fulfillment of the requirements of M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and deposited at the University Library and is made available to users under rules of the Library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Name: Abdulsemed Abanega Abdurahman

Signature: ______________

Date: June 2020

Place: Jimma University

BIOGRAPHICAL SKETCH

The author, Abdulsemed Abanega Abdurahman, was born in Boba Roge Kebele, Seka Cokorsa District, Jimma Zone of Oromia Regional State in Ethiopia in 1989. He attended elementary and secondary school education at Seka and Jimma secondary Schools, respectively. In 2012, he joined Mizan-Tepi University and graduated with the degree of Bachelor of Science in Agricultural economics in June 2014.

After graduation, in 2015, the author joined Shabe Sombo irrigation Authority Office as planer expert until he joined the School of Graduate Studies of Jimma University in 2018 to follow a study leading to the Degree of Master of Science in Agribusiness and value chain management.

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LIST OF ACRONYMSAND ABBREVIATION

ATA	Agricultural Transformation Agency
ATT	Average Treatment effect on the Treated
ATE	Average Treatment Effect
CSA	Central Statistical Authority
DOoARD	District Office of Agriculture and Rural Development
E ATA	Ethiopian Agricultural Transformation Agency
GDP	Growth Domestic product
FAO	Food and Agricultural Organization
IDP	Irrigation Development Plan
masl.	Meter above sea levels
MOFED	Ministry of Finance and Economic Development
NGO	Non-Government Organization
MoA	Ministry of Agriculture
PS	Propensity Score
PSM	Propensity Score Matching
SMIS	Small-scale & Micro Irrigation Support Project
SNNP	Southern Nation, Nationalities and People
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SSI	Small-scale irrigation
TLU	Tropical Livestock Unit
WSDP	Water Sector Development Programs

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IMPACT OF SMALL-SCALE IRRIGATION ON SMALLHOLDER FARMERS'INCOME: THE CAE OF SHEBE SOMBO DISTRICT, JIMMA ZONE, ETHIOPIA

ABSTRACT

Even if irrigation plays a significant role in increasing smallholder farmers' income, a detailed comparative analysis studies are scarce on the impact of small-scale irrigation on household income in the study area. This study was conducted to identify factors that affect smallholder farmer's participation in small-scale irrigation and to estimate the impact of participation in small-scale irrigation on smallholder farmers' income in the district. In this study, a two-*stage sampling technique was used to select sample households. In the first stage, two Kebeles were selected purposively based on their irrigation potential. In the second stage, by stratifying the sampling frame into two groups (participant and non-participant), 186 household heads were selected and interviewed. Data for the study were collected from both primary and secondary sources. Primary data was collected using structured questionnaire and conducting focus group discussions and key informant interview. Various documents were reviewed to collect the secondary data. Descriptive and inferential methods of data analysis were used to analyze the data. The logit model was employed to identify factors that determine small-scale irrigation participation of smallholders' farmer. Propensity score matching was used to estimate the impact of small-scale irrigation on their income. The logit result shows that education level of the household head, total landholding size, extension contact, distance from market, total livestock owned, distance of plot of land from water source, access to input and use of credit significantly affect participation in small-scale irrigation. The propensity score matching result shows that there is a significant difference on the income of smallholder farmers' between participants and non-participants due to participation in small-scale irrigation farming. Therefore, to improve small-scale irrigation participation, the Government, especially Agriculture and rural development Office of the district and other stakeholders should attempt to hamper factors that hinder participation in small-scale irrigation and improve factors that initiate participation in small-scale irrigation identified in the study area.*

Keywords: Impact, Logit model, Propensity Score Matching, Small-scale irrigation

1. INTRODUCTION

1.1. Background of the Study

Agriculture remains an important economic sector in Africa and more than half of the total population is still engaged in agricultural production (World Bank, 2013). The rural poor in Sub-Saharan Africa (SSA) earn their livelihoods mostly from rain fed agriculture. Their production is typically limited to rainy season and crops grown are mainly primary cereal crops meant to sustain their livelihoods (Burney and Naylor, 2012; Nelson et al., 2018). Small-scale irrigation is critically important as an innovative practice in smallholder agriculture in Africa (Kamwamba et al., 2016). This is because small-scale irrigation is an important step towards the intensification of farming systems and in helping farmers ensure against drought risk and transform their farming activities (Fan et al., 2013).

Ethiopia is predominantly an agrarian country with the vast majority of its population directly or indirectly involved in agriculture and produces about one-third of GDP and employs 70 percent of the workforce (EATA, 2014). In Ethiopia, agricultural practice has been traditionally dominated for centuries by small-scale farmers and its performance has long been adversely affected by shortage of rain (Abebe et al., 2011; Temesgen et al., 2018). Because of high dependency on rain-fed agriculture, other topographic and low adaptive capacity along with other related factors, Ethiopia ranks the ninth most susceptible country in the world to natural disasters and weather related shocks (Tongul and Hobson, 2013). Ethiopia has abundant water resources, but its agricultural system does not yet fully benefit from the technologies of water management and irrigation while irrigation has key role to stabilize agricultural production and mitigate the negative impacts of variable or insufficient rainfall (Awulachew et al., 2010; Getaneh, 2011). Evidence shows that, Ethiopia is alone believed to have the potential of 5.1 million hectares of land that can be developed for irrigation through the river and spring diversion, pump, gravity, pressure, underground water, water harvesting and other mechanisms (MoFED, 2010).

According to Nahusenay and Madhu (2015), those farmers who are producing more through small-scale irrigation are increasing their income from the sale of agricultural products and this will lead them to increase their revenue and thereby improve their livelihood. Irrigation plays the key role in the performance of agriculture, which increases income from agriculture sector and reduce the risk of crop failure because of erratic rainfall. There are four interrelated mechanisms by which irrigated agriculture can improve household income and food security,: increasing farm production and productivity that helps very poor households meet the basic needs, protecting against risks of crop loss due to erratic, unreliable or insufficient rainwater supplies, promoting greater use of yield enhancing farm inputs and creation of additional employment (Agidew, 2017).

Agricultural intensification is assumed to be a necessary pre-condition for the development of the agricultural sector in Ethiopia. To this end, various government and non-governmental organizations (NGOs), among others, initiated small-scale irrigation schemes throughout the country (Kinfe et al., 2012).The importance of small scale irrigation for improving farmers' income and reducing rural poverty has been emphasized in various literatures and small-scale irrigation schemes play a huge role to increase income of the society (Ayana, 2016). Furthermore, a study taken by Banchaymolu(2019), shows that, small scale irrigation strategy is important to reducing risks associated with both rainfall variability, production of different crops twice or three times within a year, increasing income of rural farm-households and also reduce the poverty status of farm household.

Evidences also shows that, the expansion of small-scale irrigation can be an important strategy to increase income, build-up assets, increase total expenditure, and spend more income on improved agricultural technologies (Woldegebrial et al., 2015). Irrigation in Ethiopia contributes to increase farmers‟ income, household resilience and safeguarding livelihoods against shocks and stresses by producing higher value crops for sale at market and to harvest more than once per year. In turn, this provided them to build up their assets, buy more food and non-food household items, educate their children and reinvest in further increasing their production by buying farm inputs or livestock. However, the benefits are very unevenly distributed among households (Eshetu et al., 2010).

Shabe Sombo district have consisting of high irrigation potential i.e. rivers like Anja, Bore, Gurati, Kishe, Gulufa, Duko, etc. However, the potential available for irrigated farming is not exhaustively used and there was no scientific evidence why the farmers in the district are not using this potential to increase their production and improve their income and hence their standard of living. For that reason, this study was mainly concern with identifying factors that affects the farmers' participation decision and the impact of small-scale irrigation participation on farmers' income in the study area (DOoARD, 2019).

1.2. Statement of the Problem

Small-scale farmers in the developing world face multiple challenges that limit their opportunities to achieve higher agricultural productivity and improve their living conditions. One promising channel to help farmers attain more desirable agricultural outcome is to increase their access to water and an important input for agricultural activities. Several studies have noted the positive and significant benefits of irrigation infrastructure on agriculture (Garbero and Songsermsawas, 2018). Small-scale irrigation schemes exposed to organizational and management problems, creating differences and confusion amongst institutions and irrigation project supervisors, regarding their duties and responsibilities (Chazovachii, 2016).

The main source of livelihood in Ethiopian economy is mainly rain-fed agriculture and it depends on erratic and often insufficient rainfall despite its high water potential. As a result, there are frequent failures of agricultural production and this forced many of the societies to lead their live dependent on assistance from different organizations for food (Abebe et al., 2011; Abebaw et al., 2015). While the country has high potential to irrigate its agriculture, about 97 percent of Ethiopia's food crops are produced by rain-fed agriculture, whereas only three (3) percent is from irrigated agriculture (FAO, 2015). There is a huge gap between the potential and the level of irrigation applied in the country due to technical, physical and economic challenge but the determinants of participation in irrigation are not exhaustively identified in specific areas of the country (ATA, 2016). Oromia regional state has a number of small-scale irrigation schemes that have been constructed by the federal government, the regional governments and international NGO's aimed at providing assured irrigation water supply to users (Mengesha, 2008;"cited in,"; Abdissa et al., 2017). Similarly, in the study area various irrigation schemes were constructed by the government aimed to improve the poor living condition and low food production of the residents of the area.

Even though, various studies suggests that small-scale irrigation has an important influence on income and rural poverty alleviation, little scientific knowledge exists on the magnitude of the impacts of irrigation on household income (Ayana , 2016). In line with this, the study has high potential of water resource and farmers in the area have long history of small-scale irrigation practices, a well-documented comparative analysis studies are scarce on factors that affect smallholder households' participation in small-scale irrigation. In addition, there was a knowledge gap regarding with the contribution of small-scale irrigation to smallholders' household income in the study area.

Therefore, this study was initiated to analyze and contribute to the knowledge gap on impact of small-scale irrigation on income of smallholder farmers' by identifying factors that affects small-scale irrigation participation and examining the effect of small-scale irrigation participation on income of smallholders' farmer in the study area.

1.3. Research Questions

This study was tried to answer the following questions.

1. What factors affects small-scale irrigation participation of farmers in the study area?
2. What is the impact of small-scale irrigation participation on smallholder farmers' Income?

1.4. Objectives of the Study

1.4.1. General objective

The main objective of the study was to investigate the impact of small-scale irrigation on smallholder farmer's income.

1.4.2. The specific objectives

1. To analyze factors that affect smallholder farmers' participation in small-scale irrigation.
2. To estimate the impact of small-scale irrigation participation on smallholder farmers' income.

1.5. Significance of the study

This study has contributed to irrigation literature by providing a clear information on the factors affecting irrigation participation and impact of small-scale irrigation on smallholder farmers' income in the study area and provides recommendation for the problems. Also the results of this study can be useful for the government or policy makers, stakeholders and contribute to empirical review with existing studies.

1.6. Scope and limitations of the Study

This study was limited to one administration District and two kebeles. The data base of this study was a cross sectional survey. As Ethiopia has wide range of diverse agro ecologies, institutional capacities, organizations and environmental conditions, the result of the study may have limitations to make generalizations and make them applicable to a country level. Thus, it may be useful for areas with similar context as the study area. Besides, the accuracy of the results depends on authenticity and willingness of farmers to share actual information during the course of data collection. So far, maximum efforts have been made to minimize the limitations associated with the impact of small-scale irrigation on smallholder farmer's income, and hence the information herein is valuable.

1.7. Organization of the Thesis

The thesis was organized into five chapters. Chapter one deals with the introduction of the study while chapter two deals with the review of theoretical, empirical literatures, methodological framework and shows the conceptual framework of the study. Chapter three outlines the methodology employed to achieve the objectives of the study. In particular, it describes the study area, sampling techniques adopted for the data collection, method of data analysis and definitions of important variable. Chapter four provides the descriptive statistics from the survey and discusses the econometric results. Chapter five provides a summary and the conclusions of the study as well as some recommendation.

2. LITERATURE REVIEW

This chapter focuses on review of literature on impact of small-scale irrigation on farmers' income. In this part, Theoretical Frame work, Empirical literature reviews and Conceptual framework were summarized. The chapter also reviews different impact evaluation methods that used in estimating the impact of small-scale irrigation on farmers' income.

2.1. Theoretical Framework

2.1.1. Technology Adoption theories

Technology adoption is one of the mature areas of research in information systems. Research in this domain has evolved over time by conceptualizing new factors, which can better explain the phenomena of technology adoption resulting in development of several theories. This process of evolution has been primarily driven by rapidly changing technology scenario and has led to new factors which are grounded in theory from other disciplines (Rajesh and Rajhans, 2014). Several studies have revealed that technology adoption is not related to the aspects of technology alone but has evolved as a much more complex process involving dimensions of user attitude and personality (Venkatesh et al., 2014)

The diffusion of innovation theory states four elements that influence the spread of a new idea: the innovation, communication channels, time and social system. The process of diffusion consists of five stages, namely, knowledge, persuasion, decision, implementation, and confirmation (Roger, 2003). According to theory of reasoned action, behavioral intention of a person depends on his attitude and subjective norms. Moreover, intention of a person likely to convert to action if there is the intention to behave in a specific manner is strong enough (Fishbein and Ajzen, 1975) .

The social cognitive theory is another theory that explains self-efficacy, which is defined as "the judgment of one's ability to use a technology to accomplish a particular job or task". According to this theory, behavior of the user is influenced by expectations of outcome related to personal as well as performance-related gains (Compeau and Higgins, 1995).

2.1.2. Intensification theories

The intensification of crop production in the developing world began in earnest with the Green Revolution. This revolution was successful in promoting widespread use of new, input responsive seeds together with irrigation, fertilizer and pesticides to increase cereal crop yields and improve food security (Suhardiman et al., 2016). Even if smallholder is the key actor to achieve food security in all countries and the main adopting body of different sustainable intensification practices, sustainable development is not necessarily the first consideration of smallholder production. Since small farmers seek direct agricultural benefits, any path to sustainable intensification will necessarily protect other ecosystem services while improving agricultural productivity (Hualin et al., 2019).

The agricultural policies of East African countries indicated that the imperfect infrastructure such as road networks limited agricultural participants' implementation of sustainable crop intensification (Yami and Van, 2017). Sustainable intensification depends on how farmers live with natural, ecological, social, economic and political environments and rely on them to achieve sustainable living (Reidsma and Marie, 2017). The main factors affecting the sustainable intensification of agriculture are socio-economic factors, farmers' own characteristics and natural factors. The realization path is to enhance the effectiveness of external inputs of agricultural systems and optimize the practice and technology combination within the crop production system. Although agricultural sustainable intensification can be achieved through the widely recognized and promoted technologies such as no-tillage, conservation tillage, irrigation and water harvesting, improved varieties, soil and water conservation (Hualin et al., 2019).

2.1.3. Irrigation development in the world

Many agricultural production areas worldwide are characterized by high variability of water supply conditions, or simply lack of water, creating a dependence on irrigation since Neolithic times (Andreas et al., 2020) . According to Zewdie et al.(2007), irrigation has been practiced in Egypt, China, India and other parts of Asia for a long period of time. India and Far East have grown rice, using irrigation nearly for 5000 years. The Nile valley in Egypt, the plain of Euphrates and Tigris in Iraq were under irrigation for 4000 years. Irrigation is the foundation of civilization in numerous regions. Egyptians have depended on Nile's flooding for irrigation continuously for a long period of time on a large scale. The land between Euphrates and Tigris, Mesopotamia, was the breadbasket for the Sumerian Empire. The civilization developed from centrally controlled irrigation system (Schilfgaarde, 1994).

2.1.4. The Importance of Small-Scale Irrigation

Agricultural mechanization is not only enables efficient utilization of various inputs such as seeds, fertilizers, plant protection chemicals and water for irrigation but also it helps in poverty alleviation by making farming an attractive enterprise (MoA, 2015). Irrigation expansion has been regarded as a promising approach to ensure food and livelihood security in the face of climate change and population growth (Giordano et al., 2012). Previous investments in irrigation by donors and governments have focused on developing large-scale irrigation schemes, but evidence suggests that the greatest gains in terms of profitability and sustainability will come from investments in small-scale irrigation (Xie et al., 2014).

Small-scale irrigation is one of the most useful irrigation systems designed to increase production and productivity and reduces risk related with rainfall variability and increasing income of rural farm households indeed. In fact, planners, researchers, development practitioners and donors emphasized the importance of small sale irrigation in their policy recommendations and actual measures (Tsegazeab and Surajit, 2016). In addition, Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty and hence food security. It is useful to transform the rain-fed agricultural system, which depends on rainfall into the combined rain-fed and irrigation agricultural system. This is believed to be the most prominent way of sustainable development in the country. However, the development of irrigation practices in Ethiopia has to be investigated so as to seriously know the history of irrigation emergence and its subsequent developments (Gebremedhin, 2015).

According to Aam (2013), small-scale irrigation has immense potential to improve agricultural productivity and incomes of poor rural households. The basic problem of water distribution in the world is the temporal and spatial differences that exist in the supply and demand of water. A crop requires certain amount of water at certain fixed intervals throughout its period of growth. Irrigation is required at dry and last rainy period's. Because at dry period irrigation give important role in order to produce food crops and cash crops, also at last rainy period as Ethiopian situation especially country that rainy season as observed rainfall starts late and ends early, so in order to supplement the crop irrigation provides a greatest role in order to produce more yield.

2.1.5. Management of Irrigation Systems

Ethiopia is an economy with little water resources infrastructure and relatively weak management institutions and capacity. It also suffers from extreme variability, seasonality and water resources development and management is a core issue for development in Ethiopia. Ethiopia, which experiences extreme hydrological variability and is highly dependent on rain fed agriculture, lacks the minimum infrastructure, institutions and capacity to achieve water security. So Efforts to strengthen capacity are ongoing and should be seen as a continued priority (SMIS, 2015).

Irrigation is widely criticized as a profligate and wasteful user of water, especially in water short areas. Besides attention to infrastructure and irrigation canals and networks, successful modernization needs to ensure improved managerial skills and technical support for effective management and sustainable operation. These is a serious limitation towards achieving high productivity and profitability in modern systems, particularly in the dry areas with limited water resources that demands need for tight water management. Enhanced managerial capabilities need to go hand in hand with technology upgrades. Emphasis is needed on on–farm management of irrigation water, which includes irrigation scheduling and allocation strategies among crops and between growing seasons in intensified systems (Farahani et al., 2014).

Improving water situation of a country is of paramount importance if economic growth in a country is to be sustained. Therefore, improved water resources control is expected to play a fundamental and multifaceted role in the process of economic transformation of Ethiopia. However, the huge water potential in the country for irrigated agriculture lays largely unexploited due to lack of investments in irrigation infrastructures. This could be realized by rehabilitating, improving and upgrading the existing irrigation systems, and establishing new smallholder irrigation systems as well as household irrigation systems from surface and ground water sources (MoA, 2015).

2.1.6. Irrigation development and participation Condition in Ethiopia

Ethiopia has a long history of traditional irrigation systems and simple river diversion still is the dominant irrigation system in Ethiopia. According to Gebremedhin and Peden (2002), the country's irrigation potential ranges from 1.0 to 3.5 million hectares but the recent studies indicate that the irrigation potential of the country is higher. Although, Awulachew *et al.* (2010), estimates the irrigation potential of Ethiopia may be as large as 4.3 million hectares. Traditional irrigation schemes cover more than 138,000 hectares whereas modern small-scale irrigation covers about 48,000 hectares. The total current irrigation covers only about 6% of the estimated potential land area. The study taken by Gebremedhin and Asfaw (2015), shows that irrigation was practiced during ancient times in Ethiopia even if its exact date of emergence is unknown. Ancient use of irrigation water was through use of surface irrigation methods and spate irrigation types. Modern irrigation was started at the Awash River basin with bilateral cooperation of Ethiopia and Dutch company.

According to (Woldegebrial et al., 2017), the policies and strategies of Ethiopia strongly supports the irrigation developments especially the small-scale irrigation through the Water Sector Development Programs (WSDP) and Ethiopian Irrigation Development Plan (IDP). This irrigation development is mainly expressed in the development of small-scale irrigation schemes by governments, donors and NGOs. Irrigation is believed as a key for food security and poverty reduction in Ethiopia. As a result, developments in the Ethiopian irrigation system have shown great advancements to assure Ethiopian livelihoods especially in the rural areas. However, the contribution of irrigation to the national economy as compared to its potentials is insignificant.

The national effort in promoting agriculture development emphasizes irrigation as an integral part. For example, the current national development plan Growth and Transformation Plan (GTP) presents as "Expansion of small-scale irrigation will be given priority while due attention will be given to medium and large scale irrigation to the extent possible"(MoFED, 2010). Although SMIS (2015), reported Water resources development and management is a core issue for development in Ethiopia. In addition Ethiopia, which experiences extreme hydrological variability and is highly dependent on rain fed agriculture, lacks the minimum infrastructure, institutions and capacity to achieve water security. Without serious investment in water security, Ethiopia will be held hostage by its hydrology and be unable to break out of its cycles of famine and food aid.

Ethiopia is a rich country in water resource and most of the time it is termed as a water tower of east Africa because of its abundant water resource availability (Adugna, 2014). Also the Country has a huge potential of water resource which accounts 122 billion meter cube annual surface runoff and 2.9 billion meter cube groundwater, though it is characterized by uneven spatial and temporal distributions (Tesfa, 2015). But the Country is using a very little of its abundant water resource potential for irrigated agriculture (ATA, 2016). According to Awulachew et al.(2010), with this high potential, if it is successfully operated, irrigation in Ethiopia could play a significant role in the agricultural transformation of the country, contributing up to ETB 140 billion to the economy and potentially moving up to 6 million households into food security.

2.2. Impact Evaluation Methods

Impact evaluations are empirical studies that quantify the causal link between interventions or estimate the effects attributable to a specific intervention and the statistical significance of those effects. In addition, outcomes of interest and the difference between the observed outcomes and the counterfactual outcomes is the measure of impact. To know the effect of a program on a participating individual, we must compare the observed outcome with the outcome that would have resulted had that individual not participated in the program (Bryson et al., 2002).

Estimating the impact of a program requires separating its effect from intervening factors, which may be correlated with the outcomes but not caused by the project. This task of "netting out" the effect of the program from other factors facilitated if control groups are introduced. "Control Groups" consist of comparator group of individuals or households who did not receive the intervention, but have similar characteristics as those receiving the intervention, called the "treatment groups". Identifying these groups correctly is a key to identifying what would have occurred in the absence of the intervention. In theory, evaluators could follow three main methods in establishing control and treatment groups.

2.2.1. Randomization/ Experimental Design

The treatment and control samples are randomly drawn from the same population. In other words, in a randomized experiment, individuals are randomly placed into two groups, namely, those that receive the program or intervention and those that do not. This allows the researcher to determine program impact by comparing means of outcome variable for the two groups. The main advantage of a randomized experiment is its ability to avoid problem of selection bias, which arises when participation in the program by individuals is related to their unobservable or unmeasured characteristics (like motivation and confidence).

According to Shahidur et al.(2010), randomization could be conducted purely randomly (where treated and control units have the same expected outcome in absence of the program) this method requires ensuring external and internal validity of the targeting design. Despite the clarity of a randomized approach, a number of factors still need to be addressed in practice. They include resolving ethical issues in excluding areas that share similar characteristics with the targeted sample, accounting for spillovers to non-targeted areas as well as for selective attrition and ensuring heterogeneity in participation and ultimate outcomes even if, the program is randomized.

2.2.2. Non-Experimental Design

There are two broad categories of non-experimental approach, before and after estimator and cross-sectional estimator. The essential idea of before and after estimator of an impact evaluation approach is to compare the outcome of interest variable for a group of individuals after participating in a program with outcome of the same variable for the same group and to view the difference between the two outcomes as the estimate of average treatment effect on the treated. Cross-section estimators use non-participants to derive the counterfactual for participants in which case it becomes quasi-experimental method (Bryson et al., 2002).

2.2.2.1. Quasi-experimental design

Quasi-experimental design involves matching program participants with a comparable group of individuals who did not participate in the program. This simulates randomization but need not take place prior to the intervention. A quasi-experimental method is the only alternative when neither a baseline survey nor randomizations are feasible options. Quasi-experimental method consists of constructed (matched) control where individuals to whom the intervention is applied are matched with an “equivalent “group from whom the intervention is withheld. This method uses as there is no base line data and as the program placement is not random (Jalan, 2003).

According toVivien and Zeiser (2008) the most frequently used quasi-experimental design methods available for evaluating development programs include: propensity score matching, Difference in Difference, Regression discontinuity design and Instrumental variables which are explained in the following section.

2.2.2.2. Propensity Score Matching (PSM)

Propensity score matching (PSM) is one of quasi-experimental design methods, matched comparison techniques are generally considered a second-best alternative to experimental design (Becker, 2000) . Although, it constructs a statistical comparison group that is based on a model of the probability of participating in the treatment, using observed characteristics unaffected by the program. Participants are then matched based on this probability, or propensity score, to nonparticipants. The average treatment effect of the program is then calculated as the mean difference in outcomes across these two groups and on its own, PSM is useful when only observed characteristics are believed to affect program participation. The validity of PSM depends on two conditions: (a) conditional independence (namely, that unobserved factors do not affect participation) and (b) sizable common support or overlap in propensity scores across the participant and nonparticipant samples (Shahidur et al., 2010).

Automatically, PSM tries to create the observational equivalent of an Experiment in which everyone has the same probability of participation. The difference is that in PSM it is the conditional probability (P(X)) that is intended to be uniform between participants and matched comparators, while randomization assures that the participant and comparison groups are identical in terms of the distribution of all characteristics whether observed or not (Ravallion, 2005). Once the propensity scores are estimated, these methods can be used to estimate the treatment effect after adjusting for differences between the treatment groups. Both stratification and matching are used to adjust for the covariate before calculating the treatment effect. These methods allow us to estimate the treatment effects after adjusting for differences between the treatment and control groups but are regarded as impractical in situations when there are a large number of covariates or strata. In contrast, propensity scores provide a scalar summary of all the covariate information and there is no limit on the number of covariates for adjustment (Thavaneswaran and Lix, 2008).

2.2.2.3. Difference-In-Differences (DID)

In this method, one can compare a treatment and comparison group (first difference) before and after a 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 actually allowed to participate in the project. The identified participants who do not actually participate in the project form the counterfactual (Becker, 2000).Double-difference (DD) methods, compared with propensity score matching (PSM), assume that unobserved heterogeneity in participation is present but that such factors are time invariant. With data on project and control observations before and after the program intervention, therefore, this fixed component can be differenced out (Shahidur et al., 2010).

2.2.2.4. Regression discontinuity design

This method can be used when program participation is determined by an explicitly specified exogenous rule. The method stems from the intuition that individuals around the cut-off point (above and below) for eligibility are similar and uses individuals just on the other side of the cut-off point as the counterfactual. In other words, RD compares outcomes of a group of individuals just above the cut-off point for eligibility with a group of individuals just below it. So a difference in mean outcomes of treated and control groups restricted to the vicinity of the cutoff point (that is, local to the discontinuity) gives the impact of intervention. The major technical problem of the RD method is that it assesses the marginal impact of the program only around the cut-off point for eligibility, and nothing can be said of individuals far away from it. In addition, for the RD estimate to be valid threshold has to be applied in practice and individuals should not be able to manipulate the selection score to become eligible (Shahidur et al., 2010).

2.2.2.5. Instrumental variables or statistical control

In this case, one uses one or more variables, which matter to participation, but not to outcomes given participation. This identifies the exogenous variation in outcomes attributable to the program recognizing that its placement is not random but purposive. The "instrumental variables" are first used to predict program participation, and then one sees how the outcome indicator varies with the predicted values (Bakker, 1999).

2.3. Empirical Review

2.3.1. Factors affecting smallholder farmers' participation in small-scale irrigation

There are different studies that have been conducted by different scholars on the factors affecting small-scale irrigation participation by smallholder farmers' in different countries of the world. The researchers get different factors that affect participation in small-scale irrigation by smallholder households using different models and hypothesizing different regressors that influence small-scale irrigation participation.

According to Banchaymolu (2019), the main constraints for irrigation non-user households is living far distance from rivers. These factors were negatively and significantly affected the use of small-scale irrigation water. Livestock holding size also affects small-scale irrigation participation of households positively and significantly (Seid, 2016). Although the study taken by Temesgen (2017), revealed that education level, market distance, farm distance from irrigation water source and access to credit were significantly affect small-scale irrigation participation. From these variables, education level of the household and access to credit has positive significant effect while market distance, farm distance from irrigation water source has negative effects. The same study taken by Agidew(2017), shows that sex of household head, household size, education level and number of contact of household with agricultural development agents had significant positive effect while farm distance from the river had significant negative effect on the participation in small-scale irrigation adoption of farmers.

According to Woldegebrial et al.(2017), the farmers with higher family size were found participating in small-scale irrigation practice more than those with lower family size and positively significant. Age has also a negative impact on the adoption of small-scale irrigation farming, which suggests that the odds of adoption are higher among younger farmers than older farmers and an increase in household members with off-farm employment increases the chances of adoption because of its supportive role (Nelson et al., 2018). The study taken by Ayana (2016), indicated that owning land, is key factors that influence irrigation participation. Moreover, irrigation participation, land size and livestock are the main factors that affect households' income.

According to Tsegazeab (2015),as distance in kilometer of the access to irrigation increases the probability of irrigation participation decreases. The same study taken by Temesgen (2017),indicated that as a distance of walking hour on foot from irrigation water source increases the probability of irrigation adoption decreases. Also the study pointed out by Abraham et al.(2015), sex of household, access to extension and access to credit and household head social participation have positive significant difference between irrigation users and non-user. The other study taken by Tsegazeab and Surajit (2016), indicates that sex of the household head, age, education, plot size, total livestock unit, extension service and access to credit are statistically significant and economically meaning full variables, that affects the probability of small-scale irrigation participation.

2.3.2. Impact of small-scale irrigation on smallholder farmers' income

Several studies have noted the positive and significant benefits of irrigation infrastructure on agriculture. Irrigated agriculture plays a central and dynamic role in the improvement of rural household incomes (Reinders, 2011). Although irrigation leads to increased agricultural income and production diversity and increased income leads to improved diets and access to irrigation has the potential to improve both household income and the diversity of crops that farmers produce. Increasing farmers' income, in turn leads to higher dietary diversity while increases in production diversity do not contribute to increases in dietary diversity over and above the effect of income. Thus, irrigation is likely to influence nutrition through higher incomes rather than directly through production (Passarelli et al., 2018).

According to Garbero and Songsermsawas (2018), small-scale farmers in the developing world face multiple challenges that limit their opportunities to achieve higher agricultural productivity and improve their living conditions by increasing their income. The study result by Muez (2014), indicates that small-scale irrigation development has a positive impact on livelihood of rural farmers' and a much higher proportion of those who are poor are non-irrigating rather than irrigating households and suggested that small-scale irrigation has an important influence on rural farmers' income. Also, another study done by Tsegazeab (2015), micro irrigation is one of the most useful irrigation systems designed to increase production and productivity and reduces risk related with rainfall variability and increases income of rural farm households.

The main income sources of rural household are cropping, livestock and off-farm activities and the irrigating households have significantly larger mean annual income than non-irrigating households(Getaneh, 2011; Temesgen et al., 2018). The same study taken by Seid (2016), estimated that the results of average treatment effect on the treated of the outcome variable household income by using propensity score matching (PSM) techniques revealed that small-scale irrigation had a positive and significant impact on household income. Although the study taken by Ayana (2016), indicated that irrigation access enable households to grow cash crops, vegetables and fruits. As a result, irrigation user had far higher annual income compared to non-user and indicated that mean annual income of the irrigators were twice more than that of non-irrigators.

According toAbraham et al.(2015), small-scale irrigation is unquestionably boosts the income of rural farm households. Although the same study taken by Kinfe et al.(2012); Agidew (2017), revealed that the small-scale irrigation user household obtained larger mean annual gross farm income than small-scale irrigation non-user households. Access to small-scale irrigation can significantly improve income level of beneficiary households (Eshetu and Young-Bohk, 2017). Therefore, all of the above empirical studies taken by different author in different area by different method of analysis like PSM and Heckman two-step model revealed that small-scale irrigation participation of farmers have positive significant impact on their annual income.

2.4. Conceptual framework

Numerous factors are affect participation in small-scale irrigation of smallholder farmers'. These factors, which affect small-scale irrigation participation was characterized into demographic, socio-economic and institutional are those variables either negatively or positively related to small-scale irrigation participation of smallholders' farmers'. Based on literature review and empirical studies, a conceptual framework has been formulated by taking into consideration demographic, socio-economic and institutional could affect smallholders' participation in small-scale-irrigation water use in the study area. The conceptual framework in Figure 1 illustrates the interrelationships in the study, the key variables involved and how they are interrelated.

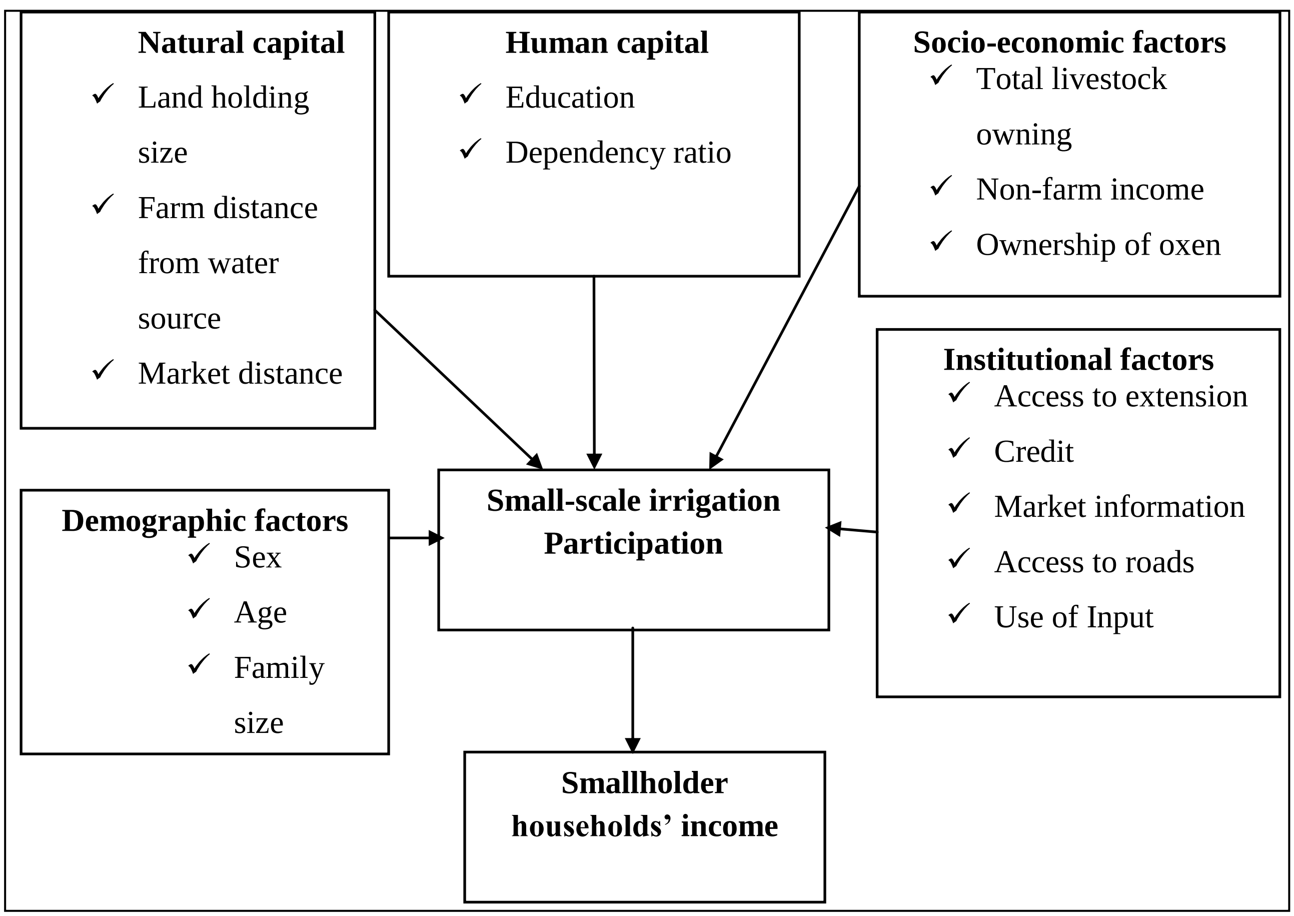

Figure 1: Conceptual framework

Source: Own design based on literature review

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

The study was conducted in Shabe Sombo District of Jimma zone of Oromia regional state and southwest of Ethiopia. It is about 402Km far from the capital city of Ethiopia to south west, and 50Km south of Jimma. It has 20 rural and 3 urban kebeles. The District is bordered SNNP at South, Gera District at East, Seka District at North and West and located at longitude between $36^{0}15'$E and$36^{0}45'$ E N and latitudes $7^{0}30'$ N and $7^{0}45'$N longitude and altitude between 1,300 and 3,000 masl. The minimum and maximum daily temperatures of the area are 20°C and 28°C, respectively. When we see the land coverage of the study area, the District have the total land size of 119,100 hectares, from this about 40014(33.59%) hectare is cultivated land, 490(0.41%) hectare is grazing land, 51,000(42.82%) hectare is forest land, 8696(7.3%) is settlement land, 2798(2.35%) is wet land and 16102(13.52%) hectare land is covered by others (Ahmed, 2018). The district has many rivers such as Anja, Bore, Gulufa, kishe and other many water sources flowing throughout the year and can serve for irrigation during the dry season. Although, in the District there are different types of small-scale irrigation found, like Modern micro dam, Motor pump, Traditional water diversion and Hand pump (DOoARD, 2019).

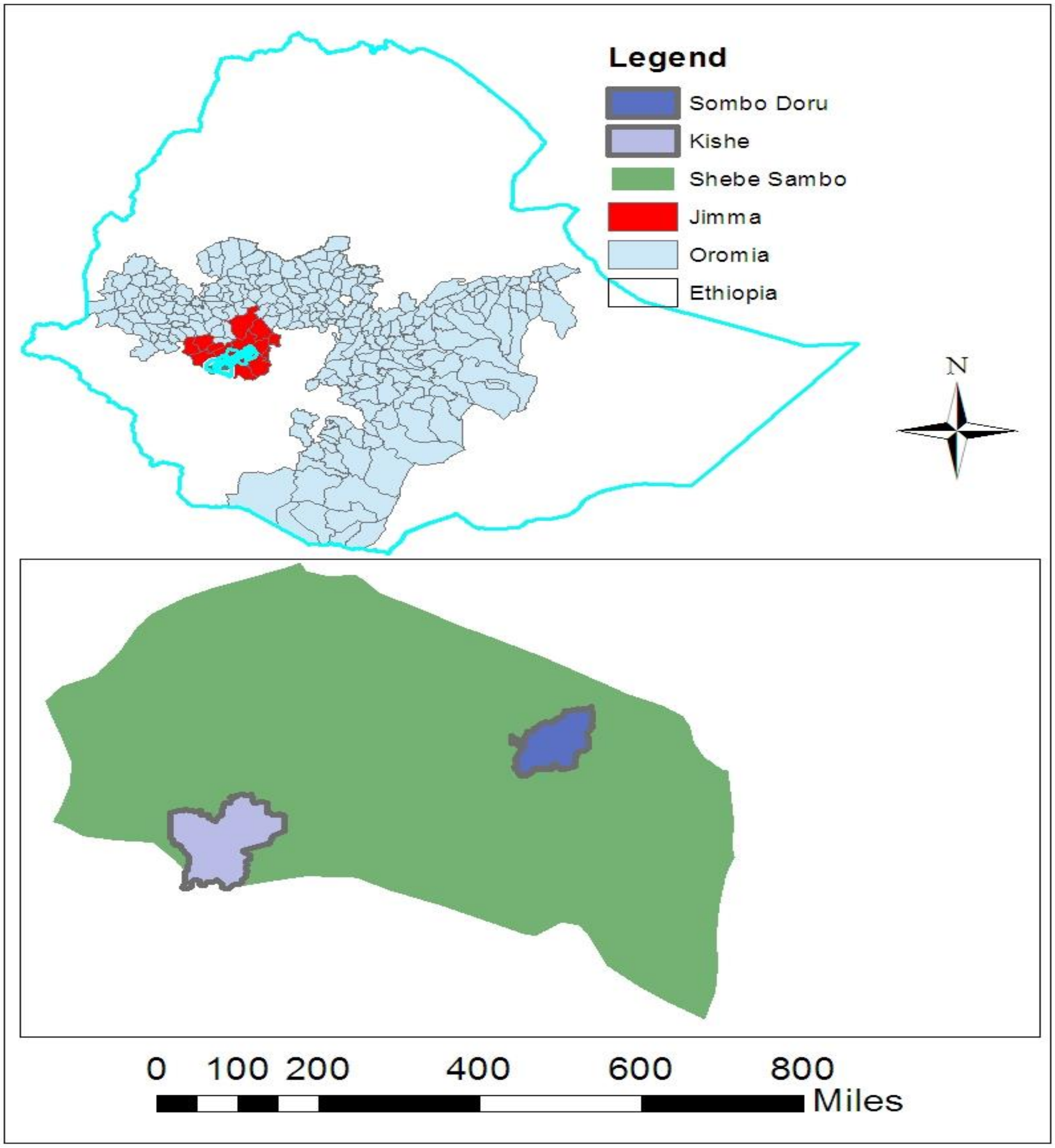

Figure 2: Location Map of Shabe Sombo District, Oromia, Ethiopia

Source: Own design with the help of GIS expert Ahmed Mohamed

3.2. Data types, Source and method of collection

In this study, both quantitative and qualitative types of data were collected from primary and secondary data sources. Primary data were obtained from irrigation users and non-users households. Important variables on economic, social and institutional aspect of the society in the sampled two kebeles were collected. Secondary data were collected from documents and publications of different organizations and relevant local offices as well as journal documents.

During primary data collection, a structured interview questionnaire was administered to 186 sampled households of participant and non-participant households in the selected kebeles and the survey was conducted from December 2019 to January 2020. In this process, training was given to enumerators about the questionnaire and follow up was made to manage the process of data collection and to make it smooth. The survey questionnaire was pre-tested before full-size data collection in order to clarify issues in the questionnaire if any. For explanation on weather the questionnaire is structured or semi-structure, evidence shows that structured questionnaire is the questions as well as their order is already scheduled while semi-structured questionnaire include a number of planned questions, but the interviewer has more freedom to modify the wording and order of questions (Karim, 2013).

Besides, personal observations, focus group discussion and key informant interview were employed to supplement the survey data. Focus Group Discussion (FDG) were made with local community who participate in small-scale irrigation as model farmers, two FGD (each containing 8 members) from two selected kebeles. The key informant interview was made with experts working in District Agriculture and rural development office working on different agriculture improvement technologies and community leader were made to broaden the qualitative database of the study and to enrich the interpretations of the result of quantitative result.

3.3. Sample Size determination and Sampling Procedure

3.3.1 Sample size determination

Sample size was determined following a simplified formula provided by (Yamane, 1967). Accordingly, the requires sample size of estimated result was at 95% confidence level with level of precision equal to 7% were used due to shortage of resource to obtain a sample size required which represent a true population.

$n = \frac{N}{1+Ne^2}$ Where n = is the sample size

N= number of the two kebeles household

e = is the error term which will be 7% (0.07).

The total sample size will be n=2231/ (1+2231*0.0049) =2231/12=186

Table 1: Sample size by kebeles

Sample Kebele	Total Household	Participant		Non-participant		Total sample household(n)
		Total (N)	sampled household(n)	Total (N)	sampled household(n)	
Kishe	1315	645	53	670	55	108
Sombo-daru	916	446	38	470	40	78
Total	2231	1091	91	1140	95	186

Source: Own computation based on DOoARD data (2019).

3.3.2 .Sampling procedures

A two-stage sampling procedure was used to select the representative households from the study area. In the first stage, with the consultation of District Agricultural Office experts, two Kebeles were selected out of 20 rural kebeles purposively, based on irrigation potential and current practice of this technology. In addition to their potential, all types of small-scale irrigation found in these two kebeles (including modern micro-dam, which found only in these two kebeles) from the study area. In the second stage, by stratifying the sampling frame obtained from the kebeles Office into two groups and using proportional probability to the size of identified groups, 91 households from irrigation participants and 95 from non-participant group were selected randomly through simple random sampling and a total of 186 household heads were interviewed.

3.4. Methods of Data Analysis

Both descriptive statistics and inferential statistics were used to analyze the data collected from sampled households. The analytical tools used in this study were discussed in the following sub-section.

3.4.1. Descriptive statistics and inferential analysis

The descriptive statistics are frequencies, means, percent, standard deviation, maximum and minimum were used for describing data. Chi-square and t-test were used as inferential statistical tools to compare treatment and control groups in terms of the different explanatory variable.

3.4.2. Model Specification

The logit models was used to analyze factors affecting smallholder farmers' participation in small-scale irrigation and the propensity score matching was used to examine the relationship between the variables (dependent and independent variables).The specification of these two models was discussed as follow.

3.4.2.1. Participation models specification

The dependent variable in this study is the participation decision of the farmers in small-scale irrigation. Since one of the dependent variables of this study, household's participation decision in small-scale irrigation is dichotomous (binary), it takes a value of 1 if the household has participated in small-scale irrigation technologies in 2011 E.C. production year and 0 otherwise. The scope of this study is only the participation decision of the farmers and it is possible to use either binary logit or binary probit model. As indicated in Gujirati (2004), logit or probit models are widely applied to analysis of determinant studies for a limited dependent variable and their result is similar. The logit and probit models are comparable, the main difference being that the logistic function has slightly flatter tails that is, the normal curve under logit function approaches the axes more quickly than in the case of probit function. Contrary to this Caliendo and Kopeinig(2005), suggests that although both model results with similar outputs, the logit model is easier in estimation. They usually generate predicted probabilities that are almost identical, though the logit model is preferred over the probit model.

According to Gujirati(2004), Participation decision equation is specified as follows:

$$P_i = \frac{e^{-zi}}{1+e^{-zi}} \text{ --1}$$

Where, $Zi= \beta_o + \beta_i x_i + U_i$

P_i = probability of participation

β_o=intercept

$\beta_{i\,=}$ regression coefficient to be estimated

x_i= pre-intervention characteristics

U_i= disturbance term

The problem of non-linearity can be solved by creating odds ratio:

$$1-P_i = 1 - \frac{1}{1+e^{-zi}} = \frac{e^{-zi}}{1+e^{-zi}} \text{-----} 2$$

$$\frac{P_i}{1-P_i} = e^{zi} \text{-----} 3$$

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = zi = \beta_o + \beta_1 x1 + \beta_2 x_2 + \beta_i x_i + U_i \text{-----} 4$$

Note that L is the log of the odds ratio and is linear in parameters. The odds ratio can be interpreted as the probability of something happening to the probability that it would not happen. In this case, the odds ratio of participating in small-scale irrigation is the probability of participant to non-participant. Where, $1-P_i$ is the probability of non-participation and β_i=regression coefficient.

3.4.2.2. Matching Methods of propensity Score Estimation

The use of matching methods in evaluating program/treatment effects has grown in popularity across a wide range of disciplines (Caliendo and Kopeinig., 2005). The fundamental notion behind matching is to construct a comparable sub group of individuals who are similar to the treatment individuals/groups in all relevant pre-treatment characteristics X from a sample of untreated ones. Then, having created this comparable group and performed matching under some identifying assumptions, any observed difference in outcome between the two groups can be attributed to the program/treatment. However, matching on all observed characteristics X is problematic referred to as the 'curse of dimensionality' the technique mostly relies on the use of balancing scores, the commonest of them being propensity scores, i.e., the probability of participating in a treatment/program conditional on observable characteristics X. Matching techniques based on this score are referred to as propensity score matching (Rosenbaum and Rubin, 1985).

Propensity score matching consist of the following steps most commonly: estimating the propensity score for each unit in the sample; selecting a matching algorithm that is used to match beneficiaries with non-beneficiaries in order to construct a comparison group; checking for balance in the characteristics of the treatment and comparison groups; and estimating the program effect and interpreting the results (Caliendo and Kopeinig, 2005). The interest of the impact part of this study will be to determine the average treatment effect on the treated (ATT) of irrigation participants. But the estimation of this effect is impossible based on the before and after because of absence of baseline data and it needs substituting the counterfactual mean of treated, by the mean outcome of untreated (Caliendo and Kopeinig, 2005). It accounts for sample selection bias due to observable differences between treatment and comparison groups. It controls for self-selection 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.

The PSM method takes care of the bias, so that estimated irrigation impact is largely consistent. The method identifies and matches households within the irrigating farmers that are similar in observable characteristics Xi, to those of the non-irrigating farmers. This is done by deriving propensity scores from a binary logit estimation of irrigation participation model explained above.

To develop the PSM framework, let Y_i be the outcome variable of household i, such that Y_{1i} and Y_{0i} denote household outcomes with and without access to irrigation respectively. A dummy variable Ii denotes irrigation access by household i, where $I_i = 1$ if the household has access to irrigation and, $I_0 = 0$, otherwise. The impact of irrigation on household i's income is given by;

$$Y_I = Y_{1i} - Y_{0i} ------------------------------ 6$$

Where $\Delta_i Y_i$ denotes the change in the outcome variable of household i, resulting from participation to small-scale irrigation. A household cannot be both ways, therefore, at any time, either Y_{1i} (irrigating household) or Y_{0i} (non-irrigating household) is observed for that household. Two means are common in the impact analysis framework, the average treatment effect and the average treatment effect on the treated (ATT).

According to the guide line steps in propensity score matching prepared by (Nelson et al., 2018) the following steps was followed. To estimates the effect of Average Treatment Effect of small scale irrigation on the outcomes of the whole population without regards to small-scale irrigation will obtained by averaging the impact across all the individuals in the population.

$$\text{ATE} = \text{E}(\text{Y}_1 - \text{Y}_0) ------------------------------ (7)$$

Where $\text{E}(\text{Y}_1 - \text{Y}_0)$ represents the average (or expected value).

On the other hand, the average treatment effect on the treated (ATT), this measures the impact of the program on those individuals who participated:

$$ATT = E(Y_1 - Y_0|D = 1 ------------------------------ (8)$$

Also using the fact that the average of a difference is the difference of the averages, the ATT can be rewritten as:

$$ATT = E(Y_1|D = 1) - E(Y_0|D = 1) ------------------------ (9)$$

This answers the question, how much did households participating in the program benefit compared to what they would have experienced without participating in the program. Data on $E(Y_1|D = 1)$are available from the program participants. An evaluator's classic problem is to find $E(Y_0|D = 1)$. So the difference between $E(Y_1|D = 1) - E(Y_0|D = 1)$cannot be observed for the same household. Due to this problem, one has to choose a proper substitute for it in order to estimate ATT. The possible solution for this is to use the mean outcome of the comparison individuals, $E(Y_0|D = 0)$as a substitute to the counterfactual mean for those being treated, $E(Y_0|D = 1)$after correcting the difference between treated and untreated households arising from selection effect. In non-experimental studies, one has to introduce some identifying assumptions to solve the selection problem. The following are two assumptions to solve the selection problem.

1. **Conditional Independence Assumption (CIA)**

Conditional independence states that given a set of observable covariates X that are not affected by treatment potential outcomes Y are independent of treatment assignment T. This assumption is also called unconfoundedness, and it implies that uptake of the program is based entirely on observed characteristics. That means, if outcomes without the intervention are independent of participation given X, then they are also independent of participation given(X). This reduces a multidimensional matching problem to a single dimensional problem. Due to this, differences between the two groups are reduced to only the attribute of treatment assignment, and unbiased impact estimate can be produced (Rosenbaum and Rubin, 1983).

Conditional Independence Assumption is given as

$$Y_o \perp {}^{Ti}/_{Xi} ------------------------------------ 10$$

Where$\perp$ indicates independence X_i -is a set of observable characteristics, Y_o-nonparticipants.

Given a set of observable covariates (X) which are not affected by treatment (in our case, participating in small-scale irrigation), potential outcomes (annual income) are independent of treatment assignment (independent of how the small-scale irrigation participation decision is made by the household). This assumption implies that the selection is exclusively based on observable characteristics (X) and variables that influence treatment assignment (small-scale irrigation participation decision is made by the household) and potential outcomes (annual income) are simultaneously observed.

Hence, after adjusting for observable differences, the mean of the potential outcome is the same for D = 1 and D = 0 and $E(Y_0|D = 1, X) = E(Y_0|D = 0, X)$

2. **Region of Common Support condition**

Imposing a common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group. The common support region is the area, which contains the minimum and maximum propensity scores of treatment and control group households, respectively. It requires deleting of all observations whose propensity scores is smaller than the minimum and larger than the maximum of treatment and control, respectively (Caliendo and Kopeinig., 2005).

According to Assumption of Common Support Condition: for each value of X, there is a positive probability of being both treated and untreated:

$$0 < P(D = 1|X) < 1 ------------------ (11)$$

This equation implies that the probability of receiving treatment for each value of X lies between 0 and 1. By the rules of probability, this means that the probability of not receiving treatment lies between the same values. Then, a simple way of interpreting this formula is the following: the proportion of treated and untreated individuals must be greater than zero for every possible value of X. The second requirement is also known as overlap condition, because it ensures that there is sufficient overlap in the characteristics of the treated and untreated units to find adequate matches or a common support (Nelson et al., 2018).

Matching Algorism

There are different matching algorithms that can be used to determine the treatment effect on the treated in PSM. But the most common matching algorithms used in PSM include: nearest neighbor matching, radius(caliper) matching and kernel matching (Caliendo and Kopeinig., 2005).These matching methods use different means of matching the treated to the control group to determine the average effect of a given program intervention.

Nearest Neighbor matching: it is the most straightforward matching estimator among the abovementioned techniques is the nearest neighbor matching. The basic notion behind this estimator is that an individual from a treatment group is matched to an individual with the closest propensity score in the comparison group. A problem with nearest neighbor matching is that the difference in the propensity scores of a treatment and its closest comparison neighbor may still be very high, which may result in poor matches (Caliendo and Kopeinig., 2005).

Caliper Matching: It involves matching treated and untreated individuals, which are close to each other within a given propensity score range (given by caliper). A potential downside of caliper matching is the difficulty to know a priori the tolerance level that is reasonable (Smith, 2005). It use a tolerance level on the maximum propensity score distance (caliper) to avoid the risk of bad matches with the Nearest Neighbor within the caliper. The radius matching is to use not only the closest Nearest Neighbor within each caliper, but all the individuals in control group within the caliper (Vivien and Zeiser, 2008)

Kernel Matching: this is another matching estimator that uses a weighted average of all depending on the choice of the kernel function individuals in the comparison group to construct the counterfactual outcome. Hence, a key benefit of these methods is the use of more information, which leads to lower variance. However, a drawback of these methods is that possibly observations are used that are bad matches. This is why it is important to properly set the common support condition in kernel matching and local linear matching (Caliendo and Kopeinig., 2005).

3.4.2.3. Matching Quality Analysis (Balance Checking)

After having performed matching, it is a recommended practice to check whether balancing of the relevant covariates in the two groups is achieved through the matching procedure. The main idea behind analysis of matching quality is the comparison of situations before and after matching and checking if there remains any difference between the two groups after conditioning on the propensity score (Caliendo and Kopeinig, 2008). The success of propensity score estimation is therefore evaluated by the resultant balance rather than by the fit of the models used to create the estimated propensity scores (Lee, 2006). A number of techniques are available to check balancing, including mean comparisons between treatment and comparison groups (before and after matching) and overall measures of covariate imbalance.

T-test: A similar approach uses 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 in both groups and hence no significant differences should be found.

Joint significance and Pseudo-*R*2: Additionally, (Sianesi, 2004) suggests to re-estimate the propensity score on the matched sample, that is only on participants and matched non-participants and compare the pseudo-*R*2's before and after matching. The pseudo-*R*2 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-*R*2 should be low.

3.4.2.3. Sensitivity analysis

According to Caliendo and Kopeinig (2008), the last step of matching analysis is to test the sensitivity of the results with respect to variable, which affect assignment into treatment, and the outcome variable leading to a ‘hidden biases. They also pointed out that matching estimators are not robust against this bias and that researchers become increasingly aware that it is important to test the sensitivity of their results. The estimation of treatment effects with matching estimators is based on the unconfoundedness or selection on observables assumption. However, if there are unobserved variables which affect assignment into treatment and the outcome variable simultaneously, a ‘hidden bias’ might arise (Rosenbaum, 2002). The same study taken by Caliendo (2007), indicated that, matching method is based on the conditional independence and states that the researcher should observe all variables simultaneously influencing the participation decision and outcome variables. Hence, checking the sensitivity of the estimated results with respect to deviations from this identifying assumption becomes an increasingly important topic in the applied evaluation literature. If there are unobserved variables that affect assignment into treatment and the outcome variable simultaneously, a hidden bias might arise to which matching estimators are not robust.

3.5. Definition of Variables and Hypothesis

Dependent Variables

The first dependent variable was participation in small-scale irrigation taking value of 1 if the farmer participated and 0 if not participated in small-scale irrigation. The main intension here is to identify the factors affecting the participation of the farmers in small-scale irrigation. Each variable was defined with their hypothesis based on economic theory and results of previous empirical studies.

Outcome Variables

Net annual income: - Increasing net annual income of the smallholder farmers is the final planned outcome of the irrigation participation program. Thus, it is reasonable to evaluate the change in the net annual income across the farmers group. Here, we considered only income from irrigation product. We have computed net annual income for each household for production year of 2011 E.C., using information on the price and quantity of the harvested irrigation produce as reported by the household.

We have used net annual economic income, which consider all explicit and implicit costs of production. Explicit costs include all costs of production, which involved out of pocket money payment for specific households during the year. Such costs include costs for chemical fertilizers, hired labour cost, costs of improved seeds, costs of herbicides and pesticides used for production, land rental cost, motor pump rental costs and transportation cost. Implicit costs include opportunity cost of unpaid labour and other materials used for farm activities. Such costs include family labour, own oxen labor, estimated value of compost and estimated value of traditional seeds used. Here, we use average village price to calculate explicit cost and economic cost of farm household. Finally, the log form of the economic income was used as dependent variable in estimating program impacts.

Independent (Explanatory) Variables

The explanatory variables found most commonly affecting irrigation participation were defined and hypothesized below based on different sources. Because there is no underlying principle for what variables should be included in the model (Anderson *et al*., 2011). Therefore, the study was based on different empirical studies conducted previously to know which independent variables influence smallholder farmer's participation in small-scale irrigation.

Sex of Household head (hhsex): This variable is dummy variable taking value of 1 if the sex of the household head is male or 0 if the sex of the household head is female. Female headed households are less likely to participate in irrigation adoption as compared to their counter parts of male headed households (Tsegazeab, 2015;Nelson et al., 2018).So that, this study was hypothesized male headed households were more likely to participate in small scale irrigation than female headed households.

Age of household head (Age): Age is a continuous variable measured in years and one of the factors that determine decision making of a person. The different studies indicate that age of household head is found negatively affected the participation in irrigation practice of smallholder household (Nelson et al., 2018; Gebrehaweria et al., 2014). From this, we can conclude that as age of the household increase the probability to accept new technology decreases. On the other hand, as age increase farming experience also increase and indicate that farmers with longer farming experience are ready to accept changes and adopt new ideas and techniques (Muez, 2014).Therefore, this variable was hypothesized as influencing the small-scale irrigation participation of the farmers both positively and negatively.

Family size (hhsiz): Family size is a contentious variable measured in numbers of persons included in the household. Evidences show that the farmers with higher family size were found participating in small-scale irrigation practice more than those with lower family size and positively significant (Woldegebrial et al., 2017;Nelson et al., 2018). This means that the higher the family sizes of the household, the higher the probability of participation in small-scale irrigation practice because, the higher family sizes of the household the higher availability work force in farming activities. Therefore, variable was hypothesized as influencing small-scale irrigation participation of households positively.

Dependency ratio of the household (Depratio): The dependency ratio is equal to the number of individuals aged below 15 and/or above 64 divided by the number of individuals aged 15 to 64, expressed as a percentage (John, 2002). Dependency ratio is important because it shows the ratio of economically inactive compared to economically active. Members of holdings with high dependency ratios might not be able to participate in programs and projects due to time, labor and/or financial constraints. Therefore, this variable was hypothesized as factor affecting small-scale irrigation participation of households negatively.

Educational level of the Household (hheducl): This is a continuous variable measured in formal schooling years completed by the household head. That is the number of years of schooling attained by the sampled households' heads up to the time of the survey. Different researchers found this variable as the literate household most probably participate in small-scale irrigation practice than illiterate counterparts (Woldegebrial et al., 2017;Eshetu and Young-Bohk, 2017). This indicate that the more an educated household the more probability of participating in new technologies in general and in small-scale irrigation in particular. Therefore, this variable was hypothesized as factor affecting small-scale irrigation participation of households positively.

Contact with Agricultural Development Agent (CWADA): This is continuous variable measured in frequency of extension service given by DA on the issue of how to use irrigation technologies to produce their product. The study conducted by Tsegazeab (2015);Nelson et al.(2018), also indicate that households who get more extension service are more likely to adopt irrigation than households with no extension services of their counterparts. This indicates that, as being more an extension contact of the household the more probability of participating in small-scale irrigation. Hence, this variable was hypothesized as factor affecting small-scale irrigation participation of households positively.

Distance from market (dfmark): This is a continuous variable measured in kilometer. As the farmer is nearer to a market, the higher will be the chance of participating in small-scale irrigation and selling farm produce for income. The different study results, indicate that the farther the distance of the market from the farmer's residence area, the lower the probability of the farmers participation in small-scale irrigation practice and have negatively significant (Woldegebrial et al., 2017).This is due to access to market, to buy input and to sell output. Therefore, this variable was hypothesized as influencing the participation decision of the farmers in irrigation negatively.

Input use (Input): This variable is dummy variable taking value of 1 if the household have use input for irrigation product especially horticultural improved seed, fertilizer and agricultural chemicals and 0 other wise. Households who use one or more of these farm production inputs will usually have higher crop yields and hence higher income (Getaneh, 2011). Hence, this variable was hypothesized to enhance participation in small-scale irrigation of farmers positively.

Total land holding size (Landsize): This variable is continuous variable measured in hectare of land holding size of the households. This variable is found positively and significantly affected the participation decision of the smallholders farmers because, land is the major productive asset for farmers (Getaneh, 2011).From this we can conclude that the higher land holding size of the household, the more probability to divide their land for different types of agricultural production. Therefore, this variable was hypothesized to influence the small-scale irrigation participation positively.

Total livestock owned (Tlu): This is a continuous variable measured in Tropical Livestock Unit (TLU). The higher the total livestock owned by the households the higher the probability of participation in small-scale irrigation practice and it affects small-scale irrigation participation of households positively (Eshetu and Young-Bohk, 2017; Nelson et al., 2018). This shows that, livestock is an important source of income, draught power for crop cultivation and can be serve as an alternative for oxen ownership, which is important for farm activity. Therefore, this variable was hypothesized to enhance participation in small-scale irrigation of farmers positively.

Distance plot of land from water source (dplofws): This variable is continuous variable measured in terms of walking hour on foot. It is found by different scholars as it hinders participation in irrigation practice and significant negatively (Woldegebrial et al., 2017). The same study taken by (Temesgen, 2017), indicated that as a distance of walking hour on foot from irrigation water source increases the probability of irrigation adoption decreases. From this, we can conclude that as the farm place far from irrigation water source it need high cost and high labor force to use irrigation water. Therefore, this variable was hypothesized to influence participation in small-scale irrigation negatively.

Access to road: This variable is dummy variable taking value of 1 if the household have an access to use road to their farm get or 0 if the respondent does not have an access to road and take the production to the market by using labor force. Access to road to the farm get affects farm technology participation positively because it reduces perishability of products and reduces labor cost (Dereje et al., 2011). This indicates that as the farmer get access to road they can easily transport input and output of agricultural product. Therefore, this variable was hypothesized to affect participation decision in small-scale irrigation positively.

Credit access (Credit): This variable is dummy variable taking on 1 if the farmer has access to credit or 0 if the farmer did not used credit. Access to credit by different researchers was found affecting the irrigation practice decision of the farmers positively (Nelson et al., 2018). This indicates that as the farmer get credit they can easily buy and use input of agricultural product. Therefore, this variable was hypothesized to affect participation decision in small-scale irrigation positively.

Access to non-farm income (Acnfinc): This variable is dummy variable taking on 1 if the household head has involved non-farm activity or 0 otherwise. The evidences shows that the farmers having access to non-farm activity were found participating in irrigation practice than those not having access to non-farm activity (Temesgen, 2017). On the other hand, households engaged in non-farm activities are less likely to participate in small-scale irrigation farming (Abraham et al., 2015). Therefore, based on these reasons the variable was hypothesized to influence participation in small-scale irrigation both positively and negatively.

Market information (mketinf): This variable is dummy variable taking value of 1 if the respondent have an information on the market concerning the demand and price issue of the product, or 0 if the respondent does not have an access to market information and undertake every production without market information. This variable is found positively and significantly affected the participation decision of the farmers (Abebaw et al., 2015). This may be rendered that the information on the market, such as input and output price enables the farmers to be benefited from the production under irrigated farming. Therefore, this variable was hypothesized to influence the irrigation participation positively.

Ownership of oxen (Oxen): This variable is quantitative measured in number of the oxen owned by a household. As the sources indicate in the literature review part of this document, the farmers with higher number of oxen were found to participate in irrigation practice and with higher intensity of participation than those with lower number of oxen (Gebrehaweria *et al.,* 2014) Oxen can be used as draft power for land preparation. The farmers with no oxen or lower number of oxen may face difficulty in land preparation and may be in low probability for participating in irrigation practice. Hence, the variable was hypothesized as affecting small-scale irrigation participation decision of the farmers positively.

Table 2: Summary of the definition and hypothesis of explanatory variables

Variables code	Variable description	Hypothesized sign
Hhsex	Household's sex, Dummy (1=male,0= female)	(+)
Age	Household's age, Continuous (years)	(+/-)
Hheducl	Household's education level, Continuous (class year)	(+)
Hhsiz	Household size(Number of family members)	(+)
Depratio	Dependency ratio is continuous variable(ratio of inactive to active family members)	(-)
Dfmark	Distance from market, Continuous(km)	(-)
Landsize	Household's total Land size, Continuous (hectare)	(+)
credit	Access to credit, Dummy (1 if used, 0 if not)	(+)
Dplofws	Distance plot of land from water source, Continuous (hrs)	(-)
Tlu	Total livestock holding, Continuous (TLU)	(+)
CWADA	Contact with Agricultural Development Agent, Continuous (Frequency of contact)	(+)
Acnfinc	Access to non-farm income, Dummy (Access=1, 0 otherwise)	(+/-)
Mketinf	Market information, Dummy (Access=1, 0 otherwise)	(+)
Oxen	Ownership of oxen, Continuous (number of oxen)	(+)
Input	Input use, Dummy (1 if used, 0 if not)	(+)
Accesroad	Access to road, Dummy (Access=1, 0 otherwise)	(+)

4. Results and Discussions

The result and discussion part of this thesis deals with the findings from descriptive statistics and inferential analysis obtained from the survey data and secondary data from both qualitative and quantitative analysis. It includes descriptive analysis categorical, contentious variable, logistic regression analysis and impact assessment.

4.1. Descriptive Analysis

The descriptive analyses tools used are mean, percentage, mean difference and standard deviation. The descriptive statistics was used to observe the distribution of independent variables. The t-statistics and chi-square (χ 2) tests were used to test statistical significances of the variable. After estimating the mean values, the significance of mean difference test was undertaken by two-group (irrigation participants and non-participants) mean comparison test for the continuous variables. The distribution of the categorical variables difference of the proportion across participants and non-participants was tested by using chi-square test.

Table 3: Summary of descriptive statistics result of the dummy variables

Variables	Total Observation (N=186)		Participants (N=91)		Non participants (N=95)		
	Frequency	(%)	Frequency	(%)	Frequency	%	χ2
Sex							
Male=1	169	90.9	87	51.5	82	48.5	4.83**
Female=0	17	9.1	4	23.3	13	76.5	
Market information							
yes=1	156	83.9	83	52	73	48	7.1 ***
N=0	30	16.1	8	27	22	73	
Credit							
yes=1	22	12	15	68.2	7	31.8	
N=0	164	88	76	46.3	88	53.7	3.7*
Non-farm Income							
yes=1	18	9.7	7	38.9	11	61.1	
N=0	168	90.3	84	50	84	50	0.8032
Access to road							
yes=1	128	68.8	70	54.7	58	45.3	
N=0	58	31.2	21	36.2	37	63.8	5.45**
Access to input							
yes=1	138	74.2	75	54.4	63	45.6	6.29**
N=0	48	25.8	16	33.3	32	66.7	

Source: Own survey data, 2020

Sex of household head: regarding the sex of household head, out of the total sampled households, 90.9% (169 households) were male-headed and 9.1% (17 households) were female-headed. While 51.5% of the male in the sample adopts the technology, only 23.5% of the females in the samples actually adopted the technology and this difference is statistically significant. Conversely, while 48.5% and 76.5% of the males and female respondents are non-adopters respectively. This is in line with (Dereje and Desale, 2016)

Market information: Market information access on input and output price was also analyzed across participants and non-participants in small-scale irrigation participation. For the total observation, 16.1% of households do not have any information on input and output prices. Whereas, 52% of the sample household who have information on input and output prices adopts the technology, only 27% of the sample household have no information on input and output prices actually adopted the technology and this difference is statistically significant. Conversely, while 48% and 73% of the household have information on input and output prices, and have no information on input and output prices respondents are non-adopters respectively. This is in line with (Temesgen, 2017)

Credit: This variable was an important institutional service to finance poor farmers for input purchase and ultimately to adopt new technology. For the total sampled households, about 88% did not use credit. Whereas, 68.2% of the sample households use credit, 46% of the sample household who did not use credit actually adopted the technology and this difference is statistically significant. Conversely, while 31.8% and 53.7% of the household use credit, and did not use credit are non-adopters respectively. This is in line with (Dereje et al., 2011)

Access to non-farm income: The proportion of households that does not have access to non-farm activity was about 90.3% for the total sampled households. Whereas, 38.9% of the sample households have access to non-farm income, 50% of the sample household who have no access to non- farm income actually adopted the technology and this difference is statistically non-significant. Conversely, while 61.1% and 50% of the household access to non-farm income and not access to non-farm income are non-adopters respectively. This is in line with (Abraham et al., 2015).

Access to road: access to road for taking agricultural product to the market was analyzed across participants and non-participants in small-scale irrigation participation. For the total observation, 31.2% of households do not have access road to take their product farm get to the market, Whereas, 54.7% of the sample households have access to road, 36.2 % of the sample household who did not access to road actually adopted the technology and this difference is statistically significant. Conversely, while 45.3% and 63.8% of the household access to road, and did not access to road are non-adopters respectively. This is in line with (Dereje et al., 2011)

Access to input (Input): access to input technology was analyzed across participants and non-participants household in small-scale irrigation. For the total observation, 25.8% of households do not have access to input technologies, Whereas, 54.4% of the sample households have access to input, 33.3 % of the sample household who did no access to input actually adopted the technology and this difference is statistically significant. Conversely, while 45.6% and 66.7% of the household access to input, and did no access to input are non-adopters respectively. This is in line with (Ziba, 2015)

Table 4: summary of descriptive statistics result of continuous variables

Variable	Sample household N=186				Participant N=91		Non-participants N=95		Mean difference	T-test
	Mean	STD	Min	Max	Mean	STD	Mean	STD		
Age	44.17	9.79	25	74	45.27	9.77	43.12	9.74	2.16	1.51
Dependency ratio	.299	.27	0	1	.298	.261	.30	.28	-.0026	-0.07
Household size	5.04	1.53	3	9	5.23	1.64	4.85	1.39	.378	1.99**
Education level	2.21	1.97	0	12	2.49	2.24	1.94	1.64	.557	1.94*
Land size	1.65	.61	0.15	3	1.82	.596	1.48	.577	.332	3.85***
Extension contact	4.4	1.998	0	9	4.76	2	4.05	1.94	.70	2.44**
Distance from market	6.71	1.67	4.5	13	6.35	1.47	7.05	1.78	-.695	-2.89***
Total livestock holding	3.09	1.43	0	8.8	3.63	1.5	2.57	1.150	1.056	5.4***
Number of Oxen	1.15	.885	0	4	1.4	.95	.94	.77	.43	3.37***
Distance of land from water	.072	.057	0.01	0.25	.054	.042	.09	.065	-.036	-4.5***
Income	33,806	18,529	3750	118,760	40,936	18,328.4	26,976	16,052.5	13960.45	5.53***

***and** Significant at 1% and 5% Significant level.

Source: Own computation from survey data, 2020

Age of household head was one of the variables used in the analysis of the characteristics of the farm household in the study area related with irrigation participation. The mean age of the total sample households in the study area was 44.17 with minimum and maximum age of 25 and 74 years old, respectively. While the mean age of participants was 45.27 and that of non-participants was 43.12 years, respectively. The descriptive analysis revealed that there was no significant difference in age of household heads between irrigation participants and non-participants.

Dependency ratio: The mean dependency ratio of the total sample households in the study area was about 0.299, with minimum and maximum family size of 0 and 1 respectively. While the mean dependency ratio of participants was, 0.298 and that of non-participants were 0.30 respectively. The descriptive analysis revealed that there was no significant difference in the dependency ratio of households between participants and non-participants.

Family size: The mean family size of the total sample households in the study area was about 5.04, with minimum and maximum family size of 3 and 9 respectively. While the mean family size of participants was, 5.23 and that of non-participants were 4.85 respectively. The descriptive analysis revealed that there was significant difference in the family size of households between participants and non-participants in irrigation and significant at 5% significance level. This is in line with (Bekele and Maryam, 2011)

Education level: The mean years of education of the total households in the study, area was 2.21 with minimum and maximum land size of 0 and 12 in terms of years of schooling, respectively. Whereas, the mean education level of participants and non-participants was 2.24 and 1.94 years of schooling, respectively. There was significant difference in the education level between participants and non-participant's household heads at 10% level of significance. The result indicates that, the education level of the non-participants was lower as compared to participants. This is in line with (Sandile, 2016)

Total land holding size: This variable was used in the analysis of the characteristics of the farm household in the study area. The result of the descriptive analysis shows that the mean land size calculated for the total sample households in the study area was 1.65 he, with minimum and maximum land size of 0.15 and 3 he, respectively. Although, the mean land size of the household for participants was found to be 1.82 he, and the mean land size of the non-participants was 1.48 hectare. The descriptive analysis revealed that there was significant difference in the total land holding size of households between participants and non-participants in irrigation at 1% level of significance. This implies that the participants have higher land holding size on average when compared to that of non-participants. This is in line with (Ziba, 2015)

Contact with Agricultural Development Agent: The mean number of contact with DA of the total households in the study area was 4.4 with minimum and maximum land size of 0 and 9 in the production years of 2011 E.C, respectively While that of participants and non-participants had a mean DA contact of 4.76 and 4.05, respectively. The descriptive statistics shows that there was significant difference in the contact with DA between participants and non-participants household heads at 5% level of significance. The result indicates that, the number of contact with DA of the non-participants was lower as compared to participants. This is in line with (Bekele and Maryam, 2011)

Distance from market: This variable was analyzed across the farm households as their characteristics in the study area related with irrigation participation. From the descriptive analysis, the mean walking distance of the market for the total sample households in the study area was 6.71km, with minimum and maximum market distance of 4.5km and 13km, respectively. However, the mean walking market distance of the participants was 6.35km, where as that of the non-participants was 7.05km. The descriptive analysis revealed that there was significant difference in the distance of the market from household residence between participants and non-participants in irrigation at 1% significance level. The result indicates that the market distance for the non-participants is higher as compared to that of participants. This is in line with (Abraham et al., 2015).

Total livestock holding: It was one of the socio-economic factors of the farm household analyzed in the study area. The mean total livestock holding of the total sample households is 3.09 TLU. However, the mean livestock holding of the participants was 3.63 TLU, while that of the non-participants was 2.57 TLU. There was significant difference at 1% level of significance in the livestock holding of households between participants and non-participants.

The result implies that the livestock holding by participants was higher as compared to non-participants. This is in line with (Muez, 2014).

Number of oxen owned: The number of oxen owned by total households in the study area was 1.15 on average and the minimum and maximum number of oxen was 0 and 4, respectively. The mean number of oxen owned for the participants were 1.40, where as that of the non- participants was 0.94. The descriptive analysis revealed that there was highly significant difference (at 1%) on the number of oxen owned by households between participants and non-participants in small-scale irrigation participation. This implies that the number of oxen of the participants was higher as compared to non-participants. This is in line with (Abraham et al., 2015).

Distance of plot of land from water source: Regarding the Distance of plot of land from water source, the mean distance of water source from the plot of land in the study area for all sample households was .072hrs with the minimum and maximum number of distance was 0.01 and 0.25hrs, respectively. The mean distance for the participants were 0.054hrs, whereas that of the non- participants was 0.090hrs.The descriptive analysis revealed that this variable was significant at 1% level of significance and has a negative relationship with household participation decision in small-scale irrigation. This is in line with (Temesgen, 2017)

Total annual income of the household: This was analyzed as characterizing the total annual net income of households in the study area including the income that come from small-scale irrigation. The mean annual income of the sample households in the study area was Birr 33,806, with minimum and maximum annual income of Birr 3750 and 118,760, respectively. However, the mean annual income of the participants was Birr 40,936, while the mean annual income of the non-participants was Birr 26,976 and the mean difference between irrigation participant and non-participant was birr 13960.45. The descriptive analysis revealed that there was significant difference in the annual income of households between participants and non-participants of small-scale irrigation it was significant at 1% significance level. This implies that income of the participants was higher as compared to non-participants. The result is in line with (Seid, 2016).

4.1.1. Types of Irrigation Used

From the total participant households, about (38.46%) use the traditional river diversion. Motor pump was the other irrigation type used by the farmers in the study area. There was about 31.87% of participants use motor pump irrigation. The lower number of the farmers use modern micro dam 29.67% that was two micro dam built by the Oromia regional government (constructed on Gulufa and kishe rivers found in Sombo daru and kishe kebeles, respectively) and the farmers around this project use this modern micro dam irrigation.

Table 5: Distribution of sample households by the type of irrigation used for participants

Types of irrigation uses	Frequency	%
Modern micro dam	27	29.67
Traditional river diversion	35	38.46
Motor pump	29	31.87
Total	91	100.00

Source: Own computation from survey data, 2020

4.2. Econometric Result

In this part, econometric data analysis is applied to estimate the impact of small-scale irrigation participation on smallholder farmers' income in the production year of 2018/19 G.C by using the logit and PSM model. Initially, the logistic regression model was used to identify the potential factors that affect households participation in small-scale technologies. Then after, the PSM model was used to estimate the impact of small-scale irrigation participation of smallholder's farmer by using the different ATT estimation algorithms. Finally, the sensitivity analysis has been implemented to test the robustness of estimated ATTs.

4.2.1. Factors affecting small-scale irrigation participation

Before going to conduct logistic estimation, we have to assess the significance of variables in the model by conducting likelihood ratio test. The classification table tells us how good the fitted model is for prediction purposes. The following table (Table: 6) shows the classification for fitted model.

Table 6: Classification table of the model

Logistic model for Irpartn			
	-------- True --------		
Classified	D	~D	Total
+	73	24	97
-	18	71	89
Total	91	95	186
Classified + if predicted Pr(D) >= .5			
True D defined as Irpartn != 0			
Sensitivity		Pr(+| D)	80.22%
Specificity		Pr(-|~D)	74.74%
Positive predictive value		Pr(D| +)	75.26%
Negative predictive value		Pr(~D| -)	79.78%
False + rate for true ~D		Pr(+|~D)	25.26%
False - rate for true D		Pr(-| D)	19.78%
False + rate for classified +		Pr(~D| +)	24.74%
False - rate for classified -		Pr(D| -)	20.22%
Correctly classified			77.42

Source: Own computation from survey data, 2020

As we can see from the above table, of the 186 samples included in the analysis, 77.42 percent of them (or 73 + 71 = 144/1186=77.42%) are correctly classified on the basis of their personal (and household) characteristics. Thus, the overall rate of correct classification is estimated to be 77.42, with 80.2% (73/91=80.2%) of the participants correctly classified (specificity) and 74.74% (71/95= 74.74%) of the non-participants correctly classified (sensitivity). As expected, classification is sensitive to the relative sizes of each component group, and always favors classification into the larger group.

Then after, the logit estimate of the household probability of participation in small-scale irrigation is conducted and presented below in (Table: 7), and the pseudo R squared is found about 0.3407. The results indicated that program participation is significantly influenced by eight explanatory variables from total sixteen explanatory variables expected to affect the participation of the smallholder farmers to the program and interpreted. Similarly, this logit estimation used for propensity score estimation.

Table 7: Estimation result of Logit model for small scale irrigation participation

Variable	Coef.	Std.Err.	Z	P>|z|	Odds Ratio
Sex	.8183341	.817719	1.00	0.317	2.266721
Age	.0155084	.02139	0.73	0.468	1.015629
Dependency ratio	-.046138	.790413	-0.06	0.953	.9549097
Household size	.1590324	.131740	1.21	0.227	1.172376
Education level	.2505129	.110937	2.26	0.024	1.284684**
Access to road	.7489542	.458838	1.63	0.103	2.114787
Land size	.6957894	.38441	1.81	0.070	2.005291*
Extension contact	.2321431	.106131	2.19	0.029	1.2613**
Distance from market	-.376971	.13157	-2.87	0.004	.6859355***
Use of input	1.156958	.477438	2.42	0.015	3.180245**
Market information	.771227	.558490	1.38	0.167	2.162418
Total livestock holding	.522812	.201092	2.60	0.009	1.686764***
Ownership of oxen	.225023	.289787	0.78	0.437	.7984975
Distance of land from water	-15.1742	4.47615	-3.39	0.001	0. 257***
Credit	1.352695	.64606	2.09	0.036	3.867835**
Access to non-farm income	-.365405	.674899	-0.54	0.588	.6939151
_cons	-4.98361	1.87032	-2.66	0.008	.0068493
Number of observation	186				
LR chi2(16)	87.81				
Prob > chi2	0.0000				
Pseudo R2	0.3407				
Log likelihood	-84.9785				

***, ** and * Means significant at 1%, 5% and 10% probability levels.

Source: Own computation from survey data, 2020

Education level of the household: As hypothesized, education level of the household head found positively affects small-scale irrigation participation decision at 5% significance level.

It is recognizable that in the farming community, the higher the academic qualification of the household member is highly flexible to receipts in technology adoption in farming activities. As a result, they will be the first parts of community that receive the technology and initiated to be taken as the role model for the community in which they live in. The odd ratio indicated that as the household education level increase by one grade the probability to participate in small-scale irrigation increases by1.285 times than non-educated household. In addition, the result obtained from the key informant interview revealed that in the study area the educated farmers were easily understood the operation and accept improved technologies in general and small-scale irrigation technologies in particular. It increases their access to use of irrigation water through lifting with irrigation technologies from the sources by using different mechanism like motor pump and it help to follow market demand easily through different media. This is in line with (Agidew, 2017; Woldegebrial et al., 2017).

Total land holding size: The size of the total landholding has a significant positive influence to the participation of small-scale irrigation at 10% significant level. The odd ratio result indicated that keeping other variables constant, an increase in the land holding size by one hectare increases the participation of small-scale irrigation by 2 times. Therefore, the more the farmers having land size could able higher probability to participate than the one who has less land. This is in line with (Tsegazeab, 2015; Seid, 2016; Banchaymolu, 2019) that indicate households with more farm holding size had more participate in small-scale irrigation.

Contact with Agricultural Development Agent: The number of contact with agricultural development agents per year had significant positive effects on the small-scale irrigation participation at 5% significance level in the study area. Frequency of extension (DA) contact is influential and essential to achieve better adoption of improved agricultural innovations like small-scale irrigation practice, which expected to enhance household decision to adopt small-scale irrigation practice. The odd ratio result shows that as contact with DA increases by one the probability of participation in small-scale irrigation increases by 1.26 times(holding other variables constant). This indicates that those farmers who have access to extension service are more likely to adopt small-scale irrigation than who have not access to extension services.

The result obtained from the key informant interview revealed that, as farmers' contact increase with DA, they gained advice from agricultural development agents and initiated to improve their knowledge and skills on farming practices. So that they used their improved knowledge and skill, they utilize improved irrigation technology. This is in line with finding of (Bekele and Maryam, 2014; Abraham et al., 2015; Tsegazeab, 2015) that suggest extension services is one of the important factors for technology adoption in general and small-scale irrigation in particular.

Distance from market: This variable was found negatively and significantly affected participation decision of the farmers in small-scale irrigation at 1% significance level in the study area. The odds ratio shows that, an increase a one Km from the market to the residence decreases .686 times the probability of participation of households in small-scale irrigation, keeping other variables constant. Although the result from focus group discussion indicates that, as the farmer far from the market center, they face the problem of taking their product to the market easily and incur more costs than the farmer nearest to the market center incurs. Because most of product produced by irrigation are perishable product and this may have leaded them less participate in small-scale irrigation farming as compared to the farmers nearest to the market. Therefore, the distance from the market to the household house is one of the factors affecting the participation of small-scale irrigation negatively in the study area. This finding was is in line with (Abraham et al., 2015;Tsegazeab, 2015; Woldegebrial et al., 2017) that revealed that, households with nearest to market are more likely to participate in irrigation than with too far apart household.

Access to input: Access to input influences household decision to participate in the small-scale irrigation positively and significant at 5% significance level. Access to input for irrigation technology is one of an institutional variable that used in the production process to increase farm product and productivity of smallholder household. The odds ratio 3.18 from table 7 tells us, the odd of participating in small-scale irrigation for farmers who access to input 3.18 times higher than farmers who are not access to input, keeping other variables constant. Therefore, Access to input of the household is an important variable for the participation of small-scale irrigation. This is in line with (Getaneh, 2011).

Total livestock owning: Livestock holding unit is also the other important factor found to have positive significant effects on the household decision to participate in the small-scale irrigation of smallholder farmers and significant at 1% significance level. Livestock are considered as an asset that could be used either in the production process or be exchanged for cash for the purchase of inputs during cash shortages necessary. The odds ratio 1.69 from table 7 tells us, an increase a one-unit livestock in TLU increases 1.69 times the participation of households in small-scale irrigation, keeping other variables constant. The result from focus group discussion shows that livestock provide manures for their farmland, means of transportation of their produce to market. In addition, farmers having large livestock holding have more draught power for agricultural practices. Therefore, livestock holding of the household is an important variable for the participation of small-scale irrigation. This is in line with (Tsegazeab, 2015; Ayana, 2016) that revealed livestock holding size of the household necessary for the participation of small-scale irrigation.

Distance of plot of land from water: Farm distance from the water source had significant negative effect on the use of irrigation water at 1% significance level. The odds ratio shows that, an increase a one walking hour on foot, from the water source to the plot of land decreases 0. 257 times the probability of participation of smallholder households in small-scale irrigation, keeping other variables constant. This indicated that those households whose farmland is located far from the water source had less chance to use small-scale irrigation water and vice versa. The key informant interview revealed that as the farm distance increase from water source the flexibility of the farmer to take the advice to adopt small-scale irrigation technology decreases. Hence, when the farm distance far from main irrigation water source, it needs high financial cost and take time to bring water towards individual plot of land to use small-scale irrigation water. This finding is in-line with the findings reported by (Temesgen, 2017; Banchaymolu, 2019).

Credit: Use of credit was one of the variables hypothesized as one determinant of the farmers participation decision in small-scale irrigation practice. This variable was also found significantly influencing the participation decision of the farmers in small-scale irrigated farming as it was hypothesized. It was found significantly and positively related with the participation decision of the farmers in small-scale irrigated farming at 5% level of significance. The odds ratio shows that, the odd of participating in small-scale irrigation for credit user 3.87 times higher than non-users, keeping other variables constant. This is in line with (Temesgen, 2017).

4.2.2 Impact Assessment

To estimate the effect of small-scale irrigation on smallholder household income further analysis was done by using econometric model called Propensity score matching(PSM) method of impact evaluation mainly because of the absence of baseline data. Based on Caliendo and Kopeinig (2005), the following steps were followed during implementation of Propensity score matching: estimation of the propensity scores using binary model, checking on common support condition, choosing a matching algorism, testing the matching quality, estimating the program effect and interpreting the results. Also at the end, analysis of sensitivity of the result is made to check whether the result is sensitive to hidden bias or not.

4.2.2.1. Common support condition

The estimation of small-scale irrigation participation, propensity scores for all participant and non-participant households would be accomplished from the propensity of participation. After estimating the values of propensity score for participant and non-participant by using logit model, the next step in propensity score-matching technique is the common support condition. The basic criterion for determining common support region is to discard all observations whose propensity score is smaller than the minimum propensity scores of treated and larger than the maximum of the control group (Caliendo and Kopeinig, 2008). Since, the region of common support needs to be defined where distributions of the propensity score for treatment and comparison group overlap (Shahidur et al., 2010).

Table 8: Distribution of estimated propensity scores distribution for sample households

Group	Observation	Mean	STD	Min	Max
Total households	186	.4892473	.3171442	.0000953	.9808401
Treatment households	91	.6935521	.2365663	.0621805	.9808401
Control households	95	.2935448	.2554475	.0000953	.9445853

Source: Own computation from survey data, 2020

As shown in Table 8, the estimated propensity scores vary between .0621805 and .9808401with mean of .6935521 for treatment households and between .0000953 and .9445853 with mean of .2935448 for control households. The common support region would then lie between .0621805 and .9445853. In other words, households whose estimated propensity scores are less than .0621805 and greater than .9445853 are not considered for the matching implementation. Because of this restriction, 34 households (12 from treated and 22 from control households) were discarded from the analysis.

4.2.2.2. Choice of matching algorithm

Alternative matching estimators were tried in matching the treatment and control households in the common support region. According to Dehejia and Wahba (2002), the final choice of a matching estimator was guided by different criteria such as equal means test referred to as the balancing test, pseudo-R^2 and Number of matched sample size. Particularly, a matching estimator, which balances all explanatory variables stand with a low R^2 value and results in large matched sample size, is preferable. After looking into the results all matching estimators used, it has been found that kernel matching with a bandwidth of 0.1 is the best estimator for the data at hand. As such, in what follows estimation results and discussion are direct outcomes of the kernel matching algorithm based on a bandwidth of 0.1. Kernel matching uses several comparison group members, pairing a treatment case with the weighted average score of all control cases within a certain distance (Christina, 2005).Kernel matching has an advantage of lower variance because more information is used (Caliendo and Kopeinig., 2005).

Table 9: Performance of different matching estimator

	Performance criteria		
Matching estimator	pseoudo-R^2	Balancing test*	matched sample size
NN			
NN(1)	0.089	15	152
NN(2)	0.089	15	152
NN(3)	0.043	16	152
NN(4)	0.045	15	152
NN(5)	0.043	15	152
Radius caliper			
0.1	0.089	15	152
0.25	0.089	15	152
0.50	0.089	15	152
Kernel			
band width 0.1	**0.034**	**16**	**152**
band width 0.25	0.037	16	152
band width 0.5	0.062	15	152

* Number of covariates with no statistically significant mean differences between matched groups of program and non-program households.

Source: Own estimation result, 2020

4.2.2.3. Testing the balance of propensity score and covariates

In propensity score matching analysis, assessing the quality of matching is to perform tests that check whether the propensity score adequately balances characteristics between the treatment and comparison group units (Heinrich et al., 2010). After choosing the best performing matching algorithm that is kernel matching as shown in table 9 above, we have to proceed to check the balancing of propensity score and covariate using different procedures by applying the selected matching algorithm. The balancing powers of the estimations are determined by considering different test methods such as the reduction in the mean standardized bias between the matched and unmatched households, equality of means using t-test and chi-square test for joint significance for the variables used.

The mean standardized bias before and after matching are shown in the fifth columns of Table 9, while column six reports the total bias reduction obtained by the matching procedure. In the present matching models, the standardized difference in bias before matching is in the range of 1% and 78.8% in absolute value. After matching, the remaining standardized difference of bias for almost all covariates lies between 0.3% and 18.8% in absolute value, which is below the critical level of 20% suggested by (Rosenbaum and Rubin, 1985;cited in;Lee, 2006). In all cases, it is evident that sample differences in the unmatched data significantly exceed those in the samples of matched cases. The process of matching thus creates a high degree of covariate balance between the treatment and control samples that are ready to use in the estimation procedure. Likewise, t-values in Tables 10 show that before matching from 16 chosen variable 13 of chosen variables showed statistically significant differences while after matching all of the covariates are balanced.

Table 10: Propensity score and covariate balance

Variable	Sample	Mean		%bias	%reduct bias	T-test	
		Treated	Control			T	p>|t|
_pscore	Unmatched	.69355	.29354	162.5		11.07	0.000
	Matched	.65273	.64828	1.8	98.9	0.12	0.903
Sex	Unmatched	.95604	.86316	32.7		2.21**	0.028
	Matched	.96203	.96296	-0.3	99.0	-0.03	0.976
Age	Unmatched	45.275	43.116	22.1		1.51	0.133
	Matched	45.266	45.693	-4.4	80.2	-0.28	0.778
Dependency ratio	Unmatched	.29769	.30032	-1.0		-0.07	0.948
	Matched	.29152	.27907	4.6	-374	0.27	0.787
Household size	Unmatched	5.2308	4.8526	24.9		1.70*	0.091
	Matched	5.1899	5.0115	11.7	52.8	0.75	0.455
Education level	Unmatched	2.4945	1.9368	28.4		1.94*	0.054
	Matched	2.1899	1.8215	18.8	33.9	1.34	0.183
Access to road	Unmatched	.76923	.61053	34.6		2.36**	0.019
	Matched	.73418	.7886	-11.9	65.7	-0.80	0.426
land size	Unmatched	1.817	1.4855	56.5		3.85***	0.000
	Matched	1.7943	1.7551	6.7	88.2	0.43	0.665
Extension contact	Unmatched	4.7582	4.0526	35.8		2.44**	0.016
	Matched	4.6329	4.7303	-4.9	86.2	-0.30	0.762
Distance from market	Unmatched	6.3533	7.0486	-42.6		-2.9***	0.004
	Matched	6.3987	6.4595	-3.7	91.3	-0.26	0.793
Input	Unmatched	.82418	.66316	37.3		2.54**	0.012
	Matched	.81013	.83951	-6.8	81.7	-0.48	0.630
Market information	Unmatched	.91209	.76842	39.8		2.70***	0.008
	Matched	.89873	.90314	-1.2	96.9	-0.09	0.927
Tlu	Unmatched	3.6296	2.5734	78.8		5.38***	0.000
	Matched	3.4004	3.2277	12.9	83.7	0.92	0.358
Ownership of oxen	Unmatched	1.3626	.93684	49.3		3.37***	0.001
	Matched	1.2658	1.1673	11.4	76.9	0.72	0.473
Distance of land from water	Unmatched	.05385	.09	-66.3		-4.5***	0.000
	Matched	.05494	.05408	1.6	97.6	0.13	0.897
Credit	Unmatched	.16484	.07368	28.3		1.93*	0.055
	Matched	.1519	.218	-12.5	27.5	-1.07	0.288
Non-farm income	Unmatched	.07692	.11579	-13.1		-0.89	0.373
	Matched	.08861	.06022	9.6	27.0	0.68	0.500

***, ** and * means significant at less than 1%, 5% and 10% probability levels, respectively.

Source: Own estimation result, 2020

The low pseudo-R^2 and the insignificant likelihood ratio tests support the hypothesis that both groups have the same distribution in covariates X after matching. As shown in table 11, the results clearly show that the matching procedure is able to balance the characteristics in the treated and the matched comparison groups. Therefore, we used these results to evaluate the effect of irrigation intervention among groups of households having similar observed characteristics. This allowed us to compare observed outcomes for participants with those of a comparison groups sharing a common support. For detail of Chi-square test for joint significance for the three different matching algorithms, (See Appendix 4).

Table 11: Chi-square test for the joint significance of variables

Sample	Ps R2	LR chi2	p>chi2
Unmatched	0.341	87.96	0.000
Matched	0.034	7.50	0.976

Source: Own estimation using kernel band width 0.1matching from survey data, 2020

All of the above tests suggest that the matching algorithm we have chosen is relatively best with the data we have at hand. Thus, we can proceed to estimate ATT for households.

4.2.2.4. Estimation of the Effect of Treatment

Following the steps of estimation of propensity scores, the implementation of a matching algorithm and the achievement of balance, the intervention's impact may be estimated by averaging the differences in outcome between each treated unit from the constructed comparison group. The difference in averages of the subjects who participated in the intervention and those who did not participated can be interpreted as the impact of the program. The impact evaluation of average treatment effect on the treated of participation in small-scale irrigation for this study was conducted using kernel matching at bandwidth of 0.1.

Table 12: ATT for total net income from irrigation and other sources of income

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Total net annual	Unmatched	40936.077	26975.63	13960.44	2523.41	5.53
Income	ATT	39010.04	32311.13	6698.91	3603.69	1.86**

* indicates significant at 5% significant level

Source: Own estimation using kernel band width 0.1matching from survey data, 2020

As indicated in table 12 the average income of households of small-scale irrigation participant was 39010.04 ETB and 32311.13 ETB for non-participant. This showed there was a 6698.91 ETB income difference between treated and controlled group because of small-scale irrigation participation and it is significant at 5% significance level. Therefore, the estimated average treatment effect (ATT) of sample households showed that small-scale irrigation participation has positive significant effect on smallholder farmers' annual income of treated groups. The result is in line with (Abraham et al., 2015;Seid, 2016;Temesgen et al., 2018) that conducted in different area of Ethiopia.

4.2.2.5. Sensitivity Analysis

The sensitivity test is the final step used to investigate whether the causal effect estimated from the PSM is vulnerable to the influence of unobserved covariates. As it is not possible to estimate the magnitude of the selection bias with non-experimental data, the problem can be addressed through using sensitivity test. Rosenbaum bounding approach was used to check the sensitivity of the estimated ATT. The results showed that the impact of technology intervention is not changing through participates and non-participants' households if it is allowed to differ odds of being treated between the gamma values of 1 and 3, by adding 0.25 on 1 and continuing up to 3. That means for the outcome variable estimated, at various level of critical value of gamma, the p-critical values are significant which further indicate that consideration of important covariates that affected both participation and outcome variables. We couldn't get the critical value of gamma where the estimated ATT is questioned even if we have set gamma largely up to 3, which is larger value compared to the value putted in different literatures which is usually 2 (100%). Therefore, result of the impact estimates (ATT) is insensitive to unobserved selection bias (See appendix table 5) for detail.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusion

5.1. Summary of the major findings

This study was initiated to analyze what factors influence participation of small-scale irrigation and its impact on smallholder households' income in Shabe Sombo district. Based on this the study identified factors that affect small-scale irrigation participation by smallholder households in the study area and analyzed the impact of small-scale irrigation participation on smallholders' household income. The study used logit model to analyze the factors affecting small-scale irrigation participation and propensity score matching used to estimate the impact of small-scale irrigation on smallholders' household income in the study area. The samples of 186 farm households selected by two-stage sampling technique were used in the analysis.

After identifying the best fitting model, the study identified the factors that jointly affected small-scale irrigation farming by smallholders' household. For the participation decision of the household in small-scale irrigation and estimation propensity score, the logit model was used by including 16 explanatory variables hypothesized based on previous empirical studies conducted by different scholars and economic theories. Out of these explanatory variables, 8 of them were found to be significant factors that affect participation decision of the household in small-scale irrigation. These variables were education level of the household head, total landholding size, access to extension, access to input, distance from market, Total livestock owned, distance of plot of land from water source and use of credit. From these variables, education level of the household head, total landholding size, access to extension, Total livestock owned, access to input and use of credit were positively and significantly affected participation decision of the household in small-scale irrigation. Whereas, distance from market and distance of plot of land from water source were negatively and significantly affected the participation decision in small-scale irrigation.

Finally, propensity score matching using kernel matching algorithm of bandwidth 0.1 was used to analyze the impact of small-scale irrigation participation on household income and its result revealed that, small-scale irrigation have positive significance effects on smallholder household income. Therefore, to improve small-scale irrigation participation, the Government, especially Agriculture and rural development office of the district and other stakeholders should attempt to hamper factors that hinder participation in small-scale irrigation and enhance factors that initiate participation in small-scale irrigation identified in the study area.

5.2. Conclusion

Based on the finding, the researcher generalize that, educated households are more likely to adopt new technologies than non-educated households. This is indicated by the fact that they are more likely to participate in intensive farming using irrigation as the education changed their attitude. In the same way, households who have good contacts with the development agents are more likely to shift from survival farming to commercialization. This is evidenced by the fact that they are more likely to participate in intensive farming using irrigation as the development agents changed their mindset. Although, household who have more land holding size are more likely to adopt new technologies than household that have less land holding size. This is indicated by the fact that they are more likely to participate in intensive farming using irrigation as the land holding size help them to divide their land for different types of production and adoption of different technologies.

Households who get access to input are more likely to shift from subsistence farming to commercialization than household who could not get access to input. This is evidenced by the fact that they are more likely to participate in intensive farming using irrigation as the access to input help them to adopt new farm technologies. Although, households who own more livestock holding are more likely to shift from subsistence farming to commercialization than household who own less livestock holding. This is evidenced by the fact that they are more likely to participate in intensive farming using irrigation as the livestock holding help them in land preparation and buying input during cash shortage. In the same way households who uses more credit have are more likely to shift from subsistence farming to commercialization than household who did not use credit. This is evidenced by the fact that they are more likely to participate in intensive farming using irrigation as the credit use help them to buy more input like fertilize, improved seed and chemical used for farming.

Households whose house found far from market are less likely to shift from survival farming to commercialization than household nearest to market. This is indicated by the fact that they are less likely to participate in intensive farming using irrigation as they are found at far distance from market. In the same way, household whose farmland is found far distance from water source are less likely to shift from subsistence farming to commercialization than household whose farmland is nearest to the water source. This is indicated by the fact that they are less likely to participate in intensive farming using irrigation as the distance of plot of land increases from water source. Although, small-scale irrigation participant households get more net annual income than non-participant households. This is evidenced by the fact that small-scale irrigation participant earns 6698.91 ETB more net annual income than non-participant earn.

5.3. Recommendations

Based on the study result he following recommendations are recommended for future research, policy and development intervention activities to promote adoption of small-scale irrigation and to improve smallholder farmers' income:

- Educational level of the households was significant factor that affect participation of small-scale irrigation participation. The more educated households are better in adopting small-scale irrigation than uneducated ones. Therefore, the governments should give special attention on both formal and informal education to educate farmers specially; adult education should be encouraged for household head.
- Access to extension service has positive effect on decisions of small-scale irrigation practice and for the success of the agricultural extension services; an appropriate and effective frequency of extension contacts can inspire farmers to adopt small-scale irrigation. Therefore, the researcher suggests that the development agents shall increase the frequency of extension contacts by identifying farmers' situation and problems that encourages the adoption of small-scale irrigation of smallholder farmers'.

- Distance from market to the residents is also one of factors that affect small-scale irrigation participation of the households. Therefore, the District Market Development

Office should create Local market linkage between producers and small traders as well as linkage to other markets to the farm-gate as much as possible to reduce the obstacle coming because of market distance.

- Livestock holding was also one of the factors that have effects on small-scale irrigation participation and it is essential for all agricultural activities in general and for small-scale irrigation practice in particular. Therefore, in addition to farming activities households should increase the habit of their livestock raring by improving the gene type of the livestock, feeding habit, shelters etc., to increase their livestock holding that help them in participation of new technologies in general and small-scale irrigation in particular.
- The distance of plot of land from irrigation water source was one of the most important factors that affect participation in small-scale irrigation in the study area. Therefore, to minimize this problem, government, NGO and other stakeholders should emphasis on construction of modern irrigation canals for farmers whose farmland is far from the water source as much as possible. Since it minimizes the distance from water source and their land site and creates an opportunity to shift non-users to use irrigation water in the study area. In addition, the District Agricultural Office should encourage ground water development and water harvesting to use by smallholder farmers in irrigating their farmland by giving awareness on this mechanisms through development agents.
- The government should facilitate credit system and utilization means more in the study area to enable the farmers to use the credit in small-scale irrigation because this variable was one of the significant variables found affecting irrigation practice in the study area.

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LIST OF APPENDIX

Appendix 1. List of Table

Appendix Table 1: Conversion factors used to compute tropical livestock units

Animal category	LU
Calf	0.25
Weaned calf	0.34
Heifer	0.75
Cow and ox	1.00
Horse	1.10
Donkey (adult)	0.70
Donkey (young)	0.35
Camel	1.25
Sheep and goat (adult)	0.13
Sheep and goat (young)	0.06
Chicken	0.013

Source:(Storck et al., 1991;cited in;Mulugeta A., 2009)

Appendix Table 2: Multicollinearity test for continuous explanatory variables

Variable	VIF	1/VIF
Total livestock holding	1.70	0.589729
Owner ship of Oxen	1.65	0.605094
Land size	1.18	0.844648
Household size	1.09	0.919397
Age	1.09	0.920471
Extension contact	1.08	0.927596
Dependency ratio	1.08	0.927691
Education level of household	1.07	0.933458
Distance of plot of land from water	1.06	0.939386
Distance from mark	1.06	0.945137
Mean VIF	1.21	

Source: Own computation from survey data, (2020)

Appendix Table 3: Contingency Coefficients for Discrete Explanatory Variables

	Sex	Credit	Access to nonfarm	Market information	Access to road	Input
Sex	1.0000					
Credit	0.0584	1.0000				
Access to nonfarm income	0.1038	-0.1199	1.0000			
Market information	0.0638	0.0701	-0.1037	1.0000		
Access to road	-0.0121	-0.0769	-0.0545	0.1466	1.0000	
Input	0.0688	0.0258	-0.0979	0.0754	-0.1052	1.0000

Source: Own computation from survey data, (2020)

Appendix Table 4: Joint significance test (likelihood ratio test)

Matching algorithms	Sample	Pseudo R^2	LRchi^2	P>chi^2
	Unmatched	0.341	87.96	0.000
NN(1)	Matched	0.089	19.53	0.299
	Unmatched	0.341	87.96	0.000
NN(2)	Matched	0.066	14.43	0.636
	Unmatched	0.341	87.96	0.000
NN(3)	Matched	0.043	9.32	0.930
	Unmatched	0.341	87.96	0.000
NN(4)	Matched	0.045	9.86	0.910
	Unmatched	0.341	87.96	0.000
NN(5)	Matched	0.043	9.51	0.923
	Unmatched	0.341	87.96	0.000
Caliper(0.1)	Matched	0.089	19.53	0.299
	Unmatched	0.341	87.96	0.000
Caliper(0.25)	Matched	0.089	19.53	0.299
	Unmatched	0.341	87.96	0.000
Caliper(0.5)	Matched	0.089	19.53	0.299
	Unmatched	0.341	87.96	0.000
Kernel(0.1)	**Matched**	**0.034**	**7.5**	**0.976**
	Unmatched	0.341	87.96	0.000
Kernel(0.25)	Matched	0.037	8.07	0.965
	Unmatched	0.341	87.96	0.000
Kernel(0.5)	Matched	0.062	13.56	0.698

Source: Own computation from survey data, (2020)

Appendix Table 5: Sensitivity analysis result

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	32707.5	32707.5	30060	35220
1.25	0	0	30944	34370	28360	37200
1.5	0	0	29520	35825	26930	38805
1.75	0	0	28400	37136.3	25655	40230
2	0	0	27385	38280	24675	41380
2.25	1.6e-15	0	26510	39252.5	23867.5	42450
2.5	3.7e-14	0	25700	40160	23160	43475
2.75	5.0e-13	0	25060	40935	22470	44380
3	4.3e-12	0	24520	41607.5	21860	45085

* 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)

Source: Own computation from survey data, (2020)

Appendix Table 6: ATE (Treatment-effects estimation)

	AI Robust					
Household income	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
ATET						
Irpartn (Participants vs Non participants)	4774.538	2411.926	1.98	0.048	47.25096	9501.826

Source: Own computation from survey data, (2020)

Appendix 3: Questionnaire

Research questionnaires on the impact of small-scale irrigation on smallholder farmer's income in Shabe Sombo district

The purpose of the questionnaire is to gather information on irrigating and non-irrigating farmers' socio-economic, agricultural and non-agricultural activities, access for services and other important information. Dear respondents, you are kindly requested to provide genuine responses. Thank you for your time and cooperation!

Questionnaire No _______________ District_________________________
Kebele_______________________ Name of Interviewer__________________
Date of Enumeration ___________ Mob. No________________________

I. Demographic characteristics of Households

1. Name of Respondent ____________________________phone____________________
2. Sex: 1) Male 0) Female
3. Age(in year): ______________________
4. Level of Education: 0) Illiterate 1) Literate; if literate the formal education in grade: ____
5. Marital status - 1) Single 2) Married 3) Divorced 4) Separated 5) Widow
6. How many family members live in your household including you? _____________
7. Please could you list all of your families' members?

No	Name of hh members	Sex	Age	Relation to HHH	Education level	Occupation
1						
2						
3						
4						
5						
6						
7						
8						
9						

8. Do you have irrigation farming experience? 1) Yes 0) No
9. If yes, for how many years you have practiced irrigation farming? ____________
10. Which small-scale irrigation type do you use? 1) modern micro dam 2) traditional river diversion 3) motor pump 4) others specify (if any) __________________

II. Socio-economic of households

11. Do you have farmland (owned)? ________(hectares) 1) Yes   0) No
12. If **yes**, could you please mention in detail!

No	**Purpose of use**	**Area in hectare**
1	Crop land	
3	Grazing land	
4	Coffee and forest land	
5	Fallow land	
6	Other land (specify)	
7	Total land size you have	

13. What is the approximate distance of main water source from your center of plot of land? _____in hrs.
14. Do you produce livestock? 1) Yes 0) No
15. If yes, indicate number and types of livestock you owned currently in the following table:

Type of livestock	Number owned at present	If you want to sell one today, how much would you receive per unit? **(birr)**	Total value(ETB)
Young bull			
Oxen			
Cows			
Heifer			
Calves			
Sheep			
Goat			
Horses			
Mules			
Donkeys			
Poultry			
Others (specify)			

III. Institutional support condition of Household

16. Do you have access to extension services? 1) Yes   0) No
17. If yes, where do get extension services? a) Development agent b) farmers group   c) FTC d) radio e) NGO f) district agricultural office
18. Have you ever been visited by agricultural development agents? 1) Yes   0) No

19. If yes, how many times did they contact you? a) twice a week b) once a week c) monthly d) seasonally
20. Did you get market information about prices and conditions of agricultural inputs and out puts? 1) Yes 0) No
21. If yes, what is the source information? 1) Radio 2) intermediaries 3) from friends 4) Others________
22. What is the distance of your home from the market ___________________ (in Km)?
23. What means of transport do you use to transport your product to the market? 1) Animal labor 2) Human labor 3) vehicles 4) Others (specify)_________________________
24. Do you have access to road? 1) Yes 0) No
25. Do you have access to input for irrigation produce? 1) Yes 0) No
26. Had you receive any credit in the past one year? 1) Yes 0) No
27. What are the Sources of credit? 1) Service cooperative 2) Microfinance institution 3) Commercial banks 4) Friends e) Other(specify) ___________________

IV. Income sources of Household

4.1. Income from rain fed and irrigated product

28. Please indicate the amount of crop production you got from irrigation and rain fed agriculture for the year 2011 E.C. in the following table

Type of Agricultural activity	Type of crop	Area(hek.)	Total output	Unit(code)	Amount consumed at home	Unit (code)	Total (Qt) given to others	Unit (code)	Total (Qt) sold	Unit (code)	Price per unit	Total Revenue in birr
Irrigation	Onion											
	Tomato											
	Potato											
	Cabbage											
	Maize											
	Peppers											
	Sugar cane											
	Rice											
	Carrot											

	Lettuce											
	Banana											
	Papaya											
	Coffee											
	Chat											
	Others											
Rain-fed	Maize											
	Teff											
	Sorghum											
	Wheat											
	Barley											
	Oats											
	Bean											
	Potato											
	Pea											
	Tomato											
	Cabbage											
	Coffee											
	Chat											
	Bananas											
	Papaya											
	Avocado											
	Others											

29. Have you rented out land in the past 12 months (2011 E.C)? 1) Yes 0) No
30. If "**yes**", How much rent did you receive in the past 12 months? **(In birr) _________**
31. Have you rented in land in the past 12 months (2011 E.C)? 1) Yes 0) No
32. If **"yes"**, How much rent did you pay in the past 12 months? **(In birr) ____________**
33. During the last 12 months (2011 E.C), did you use the following inputs / did you have the following costs for inputs on your fields:

No	**Cost incurred on;**	Did you incur cost on factors? 1) Yes 0) No	Total Amount used				Total payment in cash (Birr)?		Total value of payments in kinds (Birr)?	
			Rain fed	Unit (code)	Irrigation	Unit (code)	Rain fed	irrigation	Rain fed	irrigation
1	Fertilizer									
2	Ploughing									

3	Seeds & planting material									
4	Rent in oxen									
5	Pesticides(herbicide, fungicide)									
6	Hired labor									
7	Unpaid labor									
8	Rent in machinery									
9	Transportation									
10	Other specify									

4.1. 1. Income from livestock and livestock products

34. Do you own livestock? 1) Yes 0) No

35. If **"yes"**, please can you mention all the livestock owns and give the details?

Type of livestock	Number owned at present	If you want to sell one today, how much would you receive? (birr)		Did you buy any livestock during the last 12 months?	
		Number bought (0 if not bought)	Total purchase value (birr)	Number sold (0 if not sold)	total sales value (in birr)
Calves					
Bulls					
Oxen					
Heifers					
Cows					
Sheep					
Goats					
Donkey					
Horses					
Mules					
Chicken					
Other (specify)					

36. During the past 12 months, how much did you spend on hired labor for herding? (Birr) _
37. During the past 12 months, how much did you spend on animal feed? (Birr) _______
38. During the past 12 months, how much did you spend on veterinary services? (Birr)______
39. During the past 12 months, how much did you expense on other related to livestock?____(in birr)
40. What was your gross income from selling animal products during the last 12 months? (2011 E.C), could you give the detail in the following table?

Type of animal product produced	Amount consumed by Household	Unit	amount sold	Unit	Price per unit	Total revenue	Total cost in cash (Birr)	Total cost in kinds (Birr)?
Meat								
Hides/Skins								
Butter/cheese								
Milk/Cream								
Eggs								
Honey								
Beeswax								
6Other specify								

Code:1. Kilogram, 2.Kubaya, 3.Sini, 4.Litre, 5.Number, 6. Others specify

41. In the past 12 months (2011 E.C), did you rent out ox/oxen for income? 1) Yes 0) No
42. If **"yes"**, how much did you earn from it in the past 12 months (2011 E.C)? ____(bir)
43. In the past 12 months (2011 E.C), did you rent in ox/oxen? 1) Yes 0) No
44. If **"yes"**, how much did you pay for oxen rent in past 12 months (2011 E.C)? _____(birr)
45. Have your own active family members participated in farm activity? 1) Yes 0) No
46. If yes, specify the number of the family members involved in the farm activity: ________
47. Can you easily get labor to hire when you are in need? 1) Yes 0) No
48. During the last 12 months (2011 E.C.), did you hire in labor (excluding work party labor) to work on the farm? 1) Yes 0) No

Types	Number of workers hired in		Payment for individual per day	How many days did they work in total		Produced crop	Total payment in cash (Birr)	Produced crop	Total payment in kind – in the form ofCrops	
	Male	Female		Male	Female		Amount		Amount	Unit
Rain fed produce										
irrigated produce										

49. During the last 12 months (2011 E.C), did you sell your crop by-product? 1) Yes 0) No

50. If your "yes", what types of by-product you can sell? 1. Teff straw 2. Maize Straw 3. Sorghum straw 4. Other (Specify______________)

51. What is your total income and cost on this by-product? Total income_________ (in birr), Total cost __________ Net income________ (in birr)

4.1.2. Household income from forest

52. Is there a forest in reach of your household member? 1) Yes 0) No

53. If your response yes, could you please tell us some details about the timber and non-timber forest products you got from the forest in the past 12 months (2011 E.C)?

Forest products	Average quantity collected per need	Unit	Number of need per month	Amount own used per month	Amount sold per month	UnitPrice	Gross income per Month	Total Cost For purchased input	Total Cost for hired labor	permit /transport/marketing cost	Othercosts	Totalcost
Timber												
Fuel wood												
Charcoal												
Spices												
Medicines												
Others specify												

4.2. Household Income from Non-Farm/Off-Farm

54. During the last 12 months (2011 E.C), did you or any household member work off the household's farm for wage payment? 1) Yes 0) No

55. If yes, would you please give us the details of the off-farm (wage) payment activities and income?

ID CODE of hh member	specify the kind of work (**Unit**)	Average days worked per month	Number of months worked in 2011 E.C	Wage received? **(birr)**	Total income in 2011 E.C **(birr)**

Unit: 1. Farm worker for pay 2.Professional: teacher, health worker.3. Skilled laborer: builder, carpenter 4.Unskilled non-farm 5. Others Specify

56. During the last 12 months (2011 E.C), did you or any household member work in off-farm business activities? 1)Yes 0) No
57. If yes, would you please give us the details of the off-farm business activities, the expenditures and income?

Id Code of hh member	specify the kind of work **(unit)**	Average input expenses per month (including hired labor) **(birr)**	Total expenses in 2011 E.C **(birr)**	Revenue per month **(birr)**	Total revenue in 2011 E.C **(birr)**

Unit: 1. Small shop 2. Petty trade 3. Hair dressing 4. Local drink maker 5. Handcraft 6. Making and selling wood products 7. Others specify

58. During the last 12 months (2011 E.C), did you or any household member received income from transfers (e.g. remittances, donations, food aid, Others)? **1) Yes 0) No**
59. If yes, would you please give us the details of these incomes?

Type of transfer	Who receives the transfer?	Who sends the transfer	From where is the transfer sent?	Total amount received **(birr)**
Remittances				
Donations				
food aid				
Others				

Thank you!

❖ Checklist for focus group discussion

1. What are the major factors affects small-scale irrigation participation in your community?
2. How the governments give attention on irrigation development in the area?
3. What help do you need from the government or non-governmental organization to develop irrigation in your local community?
4. Which types of small-scale irrigation is mostly found in the community area?
5. What type of irrigation water source do you think is more advantageous for the community in the area?
6. What are the major social organizations in the area and what are their roles in irrigated farming?
7. What are non-farm activities available in the community? What is the effect of those non-farm activities on small-scale irrigation participation?
8. What is your general opinion on the role of small-scale to household irrigation on household income?

Thank you!

❖ Checklist for key informants interview

1. What is the trend of irrigation activity in the past five years in the district?
2. What are the existing policies in relation to agriculture in general and irrigation in particular and how do you view them?
3. How do you view the role played by government in irrigation development in the district?
4. What are the major factors that affect the household participation in small-scale irrigation?
5. What are important strategies for irrigation development in the area?
6. What do you think are the major environmental problems in the area?

Thank you!