PARTICIPATION IN AND IMPACT OF SMALL-SCALE IRRIGATION PRACTICE ON HOUSEHOLD INCOME: THE CASE OF ABAY CHOMEN DISTRICT OF OROMIA NATIONAL REGIONAL STATE, ETHIOPIA

MSc THESIS

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As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by Temesgen Hirko, entitled **"Participation in and Impact of Small-Scale Irrigation Practice on Household Income: The Case of Abay Chomen District of Oromia National Regional State, Ethiopia"** and I recommend that it be accepted as fulfilling the thesis requirement**.**

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As member of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read, and evaluated the thesis prepared by Temesgen Hirko, and examined the candidate. We recommended that the thesis be accepted as fulfilling the Thesis requirement for the degree of Master of Science in Agriculture (Agricultural and Applied Economics).

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DEDICATION

I dedicated this thesis to Oromo people those unfairly displaced from Ethiopian Somali region and passed away by hidden hands.

STATEMENT OF AUTHOR

By my signature below, I declare that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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BIOGRAPHICAL SKETCH

The author was born to his father Hirko Lebeta and his mother Tiru Hulluqa in Horro Guduru Wollega zone of Oromia Region, Ethiopia, on February 21, 1989. He attended his Elementary education at Fincha Model School and Fincha Elementary School, and Secondary and preparatory education at Fincha Senior Secondary School and Fincha Preparatory School respectively.

He joined Haramaya University in November 2008 and successfully completed his Bachelor of Science degree study in Agricultural Economics and graduated on July 9, 2011. Immediately after graduation, the author was employed in former Ethiopian Meat and Dairy Industry Development Institute and worked for 2 years and six months as Monitoring and Evaluation expert. After that, he joined Wolkite University in May 2014 as Graduate Assistant and had worked in teaching Bachelor of Science degree program students in Agricultural Economics.

In October 2015, he joined Haramaya University to pursue his post-graduate study in the department of Agricultural and Applied Economics.

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ABBREVIATIONS AND ACRONYMS

ADEA	Association for the Development of Education for Africa
ADIDO	Abay Chomen District Irrigation Development Office
ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
DOoARD	District Office of Agriculture and Rural Development
EEA	Ethiopian Economic Association
ETB	Ethiopian Birr
FAO	United Nations Food and Agricultural Organization
GDP	Gross domestic Product
GTP	Growth and Transformation Plan
ha	hectare
ILRI	International Livestock Research Institute
Km^2	Square Kilometer
Kms	Kilometers
masl	meters above sea level
Mha	Million hectare
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural development
MoWR	Ministry of Water Resources
NGOs	Non Governmental Organizations
NPC	National Planning Commission
OLS	Ordinary Least Square
PSM	Propensity Score Matching
SSI	Small Scale Irrigation
TLU	Tropical Livestock Unit

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Participation in and Impact of Small-Scale Irrigation Practice on Household Income: The Case of Abay Chomen District of Oromia National Regional State, Ethiopia

ABSTRACT

Ethiopian economy is highly dependent on agriculture which is dominated by traditional rain-fed small-scale farmers. The government is working on irrigation development giving special emphasis to research activities on irrigation at different scales. But the reason for not intensively utilized water potential in and impact of small-scale irrigation on household income has not been systematically assessed in Abay Chomen district. This study was conducted to identify factors that determine household's participation in irrigation and evaluate the impact of participation in small-scale irrigation on household income in the district. In this study, two-stage sampling technique was used to select 167 target respondents. The primary data were collected using an interview schedule and conducting focus group discussions and key informant interview. Various documents were reviewed to collect the secondary data. To analyze the data, double hurdle model was employed to identify the determinants of participation and intensity of participation in small-scale irrigation. The result revealed that number of oxen, market distance, farm distance from irrigation water source, market information and credit use significantly determine participation in small-scale irrigation. The analysis from truncated part of double hurdle model shows that age, number of oxen owned, market distance, education level, road distance and access to credit significantly determine the intensity of participation in small-scale irrigation. The Propensity Score Matching model result also revealed that the irrigation participation had a significant effect on household income. Moreover, different constraints related with lack of market access, topography associated with distance of land from water source, inadequate government support, and poor or nonexistent market linkage, poor irrigation water management and development were forwarded by the participants. To solve the problems and improve small-scale irrigation participation, the government, specially irrigation development office of the district should attempt to hamper factors that hinder participation in small-scale irrigation and enhance factors that initiates participation in small-scale irrigation identified in the study area.

Keywords: Determinants, Double hurdle model, Household income, Participation, Propensity Score Matching, Small-scale irrigation

1. INTRODUCTION

1.1. Background

Agriculture plays a pivotal role in Ethiopian economy (Makombe *et al*., 2011). About 73% of the population is living in rural areas, creating their income from agriculture and relying on a limited resource- land (ADEA, 2014) and 95% of the country's agricultural output is produced by smallholder farmers (MoARD, 2010). The sector remains the mainstay of the country's economy in terms of income, employment and generation of export revenue. Its contribution to GDP, although showing a slight decline over the years has remained very high and it approximately contributes 38.5% of GDP, which is still far greater than the industry's share (15.6% of GDP), even though it was planned to outweigh the contribution of agriculture (NPC, 2015). Agriculture also provides employment opportunities to about 83% of the population and supplies raw materials for 70% of the country's agro-industries (EEA, 2012) and about 70% of Ethiopia's foreign exchange is derived from agricultural exports (FAO, 2015). This indicates that agricultural growth is not only necessary to feed the population, but is also the driving force behind foreign exchange generation in Ethiopia. This shows that agriculture is still being the main source of livelihood and it needs great attention for improvement and transformation of the country's economy.

Ethiopian agricultural practice has been traditionally dominated for centuries by small-scale farmers and its performance has long been adversely affected by shortage of rain and water that left many to sustain their lives on famine relief support (Abebe *et al*., 2011). From the total production, about 97 percent of Ethiopia's food crops are produced by rain-fed agriculture, where as only 3% is from irrigated agriculture (FAO, 2015). Due to high dependency on rain-fed agriculture and other topographic and low adaptive capacity and other related factors, Ethiopia ranks the ninth most susceptible country in the world to natural disasters and weather-related shocks (Tongul and Hobson, 2013). But the small-scale irrigation (SSI) contributes to poverty alleviation by enhancing productivity which leads to an increase in income and promoting economic growth and employment (Garcia-Bolanos *et al.*, 2011). Irrigation also changes the lives of the rural households by increasing their production and productivity. A rapid increase in the area covered by irrigation, especially small-scale water use, provide farmers with opportunities to raise output on a sustainable basis and contribute to the reliability of food supplies (FAO, 2012). This indicates that there should be new means of production through irrigation water application by smallholder farmers rather than strongly relying on rain-fed agriculture. Hence increasing the opportunity and reducing the hindrance to irrigation participation needs to be made because irrigation is one means by which agricultural production can be increased to meet the growing food demands in Ethiopia, since agriculture still plays a critical role in the economy.

There are different traditional and modern irrigation technologies that can be applied in Sub-Saharan Africa (Kay, 2001). Out of these, a wide range of well-established traditional technology options available for use by smallholders include bucket watering, water harvesting, swamp irrigation, spate irrigation, flood plain irrigation using seasonal water and shallow aquifers, and groundwater irrigation. There is still, however, considerable room to improve and adapt these traditional technologies to different circumstances. In recent years, there has been a growing interest in new technologies to apply water, but all irrigation technologies have the potential to raise the productivity of water and labour (Abebe *et al*., 2011). The modern technologies such as trickle and sprinkle irrigation and piped supplies are really only accessible to those farmers who can afford to buy them and who are growing cash crops such as vegetables, fruits and flowers. These technologies are particularly relevant to smallholder farmers in developing countries because they are constrained in many ways, which makes them a priority for development efforts (Mwangi and Kariuki, 2015). This implies that they are unlikely to be taken up by poor farmers to withstand the problem of shortage of rainfall and its fluctuation.

The government of Ethiopia has placed great emphasis on the development of irrigation facilities so as to increase agricultural production and productivity. This may help farmers overcome the cost problem for modern irrigation construction and overcome the problem of shortage of moisture for production. In line with this goal, the government also has planned to undertake a medium and large scale irrigation study and designing activities and making them ready for concerned relevant stakeholders (NPC, 2015). This shows that the experts from universities and research institutions engaged in conducting research activities on participation in irrigation practice at different levels contributes to the success of this goal.

The irrigation potential in Oromia region is the highest from the country, but its level of utilization is not as per its potential (Anonymous, n.d.). Horro Guduru Wollega is one of the wettest zones from the region even though its farming system is highly dependent on rain-fed farming (Monenus, 2016). Although Abay Chomen is the district found in this zone consisting of high irrigation potential, the potential available for irrigated farming is not intensively used (DOoARD, 2016). 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. Therefore, this study was mainly concerned with finding out the factors that determine the farmers participation in irrigation practice and intensity of participation and the impact of participation in small-scale irrigation on household income.

1.2. Statement of the Problem

The population of the world is increasing and hence the food demand, but not the supply side. Sources indicate that compared to 2009, by 2050, a 70% more food production is required to meet the global food demand and 100% for developing countries (Dubois, 2011). This shows that the growth in food demand for developing countries is very high as compared to developed countries, and this phenomena is the same for Ethiopia. The population of Ethiopia has been increased and it is above one hundred million currently. To feed this highly increasing population, extensive system of increasing the agricultural product may not satisfactorily work since the supply of land is constant. Irrigation plays a fundamental role in world food provision but, until recent years, it has performed below expectations in Sub-Saharan Africa (Garcia-Bolanos *et al*. 2011). In Ethiopia, despite the rapid population growth and food demand, the production of agricultural outputs using modern technology at smallholder level is at its minimal stage (FAO, 2015). The traditional system of production and rain-fed agriculture alone could not guarantee to feed this rapidly increasing population and it needs supplementation from irrigated agriculture.

Agriculture, the main source of livelihood in Ethiopian economy is mainly rain-fed 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). In line with this, the agricultural practice in the country in general and in the study area in particular is rain-fed agriculture and seasonal. While the country has high potential to irrigate its agriculture, about 97 percent of Ethiopia's food crops are produced by rain-fed agriculture, where as 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 challenges (ATA, 2016), but the determinants of participation in irrigation are not exhaustively identified in specific areas of the country.

Oromia region's many areas are susceptible to the problems arising from the shortage of rainfall. Horro Guduru Wolega zone in which Abay Chomen district is one of its districts, the zone in general and the district in particular has been affected by the onset delay in rain and its early cessation in different years. For instance, the 2012 *meher* rains was late by two to four weeks in Horro Guduru and also in other zones of Oromia region (MoARD, 2013). On the other hand, excessive rains, flooding and hailstorm, and early cessation of rain were reported in Horro Guduru Wollega zone in the same year. In addition, the zone experienced a reduction in crop production by 27% from that of the planned mainly due to the late onset and early cessation of the seasonal rains in 2012. Not only from the planned, especially estimate of maize production, the main staple food crop in the zone, has shown 24% decrease from that of 2011 due to early cessation of rains, and Abay Chomen district was one of the affected districts that has fallen in the list of districts needing food aid (MOARD, 2013).

The farmers in Abay Chomen district fails to produce when there is shortage of rainfall despite its plenty of water resource potential that can be applied to agriculture. The farmers in the study area, Abay Chomen district, has been affected by the extreme events of climate change such as drought, flood and hailstone that lead the farmers to crop failure in different years (DOoARD, 2016). But irrigation can change the life of rural households (Abebe *et al*., 2011) and this can help the farmers to overcome the problem of shortage of rainfall and crop failures due to hailstorm and flood. In addition to this, according to Dereje and Desalegn (2016), small-scale irrigation (SSI), both directly and indirectly, has a great impact on enhancing farmers' livelihoods through different dimensions, such as diversification of crops grown, as well as increased agricultural production, household income, employment opportunity and participation in community decisions, but this opportunity is not well used in the study area and the impact of the irrigation on household income is not analyzed empirically, even though impact evaluation is the major policy issue. The use of small-scale irrigation, even the traditional irrigation system is not as expected in the study area, even though the small-scale irrigation, particularly traditionally irrigated land (almost half of the total irrigated area) and the number of farmers involved at the country level indicate the significant economic and social role of this small-scale irrigation for rural society (FAO, 2015).

Abay Chomen district has high potential of water resource but its utilization is perceived to be very low specially by smallholder farmers. The district has rivers such as Fincha river, Amarti and many water streams flowing throughout the year and seasonally, swamps and seasonal wet lands that can serve as irrigation area during the dry season after the rain quits, but it is not intensively used (ADIDO, 2017). The use of water for agriculture is the highest withdrawal of water resource even though it is not that much in Abay Chomen district. The reason for not intensively utilized water potential in the study area and the impact of small-scale irrigation on household income has not been systematically assessed. Because there was no study conducted on why the farmers did not used the water potential available in the district intensively and irrigation impact analysis was not conducted in the study area. Not only in the study area, specially the study on intensity of participation in irrigation practice is scanty as a whole in the country and globally. Therefore, it needs such an analysis and come up with the points of solution so that the policy actions and extension activities as well as further researches can be undertaken. This may encourage the farmers to participate in irrigation and utilize water resource on their farming to boost their production directly. Furthermore this can change their standard of living by increasing their income and contribute to the economic growth of the country.

1.3. Research Questions

This study has tried to answer the following questions.

1) Which institutional, socio-economic and other factors influence participation in irrigation practice by farmers in the study area?

2) Which factors determine the intensity of participation in irrigation practice by farmers in the study area?
3) What is the impact of irrigation practice on household income?
4) What are the opportunities and challenges of practicing irrigation technologies to farmers in Abay Chomen district?

1.4. Objectives of the Study

The overall objective of the study was to analyze irrigation practice by smallholder farmers to come up with the areas of improvements in the sector with the help of the following specific objectives.

1. To identify determinants of participation in small scale irrigation by farmers in Abay Chomen district;
2. To examine the determinants of the intensity of participation in irrigation by farmers in the study area;
3. To analyze the impact of irrigation practice on household income; and
4. To identify opportunities and challenges of irrigation practices in Abay Chomen district.

1.5. Significance of the Study

The findings of this study could assist development activities underway and to be planned in the future. Such information about decisions on matters of agricultural technologies is important for researchers and extension workers engaged in development and diffusion of irrigation technologies. Because they can utilize the results of this study in setting research and extension agenda. Furthermore, information on farmers’ characteristics will give a feedback and enable researchers to modify and redirect research activities towards the most important problems. It will also be useful to farmers in devising ways to increase their productivity and hence enhanced income and reduced poverty.

1.6. Scope and Limitations of the Study

This study was limited by different factors such as time, resource and availability of data. The participation and intensity of participation and impact analysis in a certain technology is conducted by using different types of data. For example it is undertaken by the use of the time series data, Panel data and cross-sectional data by different scholars. Panel data and time series data can give more information for such study than cross-sectional data. But because of problem of availability of data as well as limited resources and time to complete the study these data types could not be used. In addition to this, it is better if the study can be conducted in the area including more districts, but due to the above--mentioned limitations it could not cover more districts and the findings of the study cannot be generalized for more than one district. Therefore, the research was only concentrated to the investigation of the determinants of participation in irrigation practice and intensity of participation by farmers and its impact on household income in Abay Chomen district by using cross-sectional data collected from the sample farmers and available secondary data. Hence, the results of the study are applicable to the study area and other areas with similar physical and socioeconomic settings.

1.7. Organization of the Study

The thesis consists of five main chapters including this chapter, which provides general information in its introduction. Chapter two is a review of literature (empirical and theoretical). Chapter three presents the methodology used in this study while the fourth chapter is about the results and discussion. The last chapter, chapter five, presents the summary, conclusion and recommendations drawn from the result.

2. LITERATURE REVIEW

This chapter covers the concepts and theories, challenges and opportunities of irrigation as well as potential and adoption situations at different levels. In addition to the above mentioned issues this section presents the theoretical and conceptual frameworks and empirical studies on irrigation practice by farmers.

2.1. Definitions and Concepts

2.1.1. Definition of Basic Terms

Highly rain-fed agriculture, which is in most cases unreliable and resulting in poor yields and the changing weather conditions would further exacerbate poverty situation, exposing small holder farmers to negative impact of climate change (Todaro, 2012). In this study, participation in irrigation practice can be considered as one of technology option available to farm households owing to it enables them to carry out multiple cropping, diversify their production and overcome moisture deficiency partially or fully and increase their income.

Irrigation comes from the Latin word “moist” or “wet,” but it means the purposeful wetting of something. But in this particular case of study the definition that directly link is that the definition of irrigation according to English Dictionary.com. It defines irrigation as the artificial application of water to land to assist in the production of crops. Reddy (2010) also defined Irrigation as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops. This is an on purpose action made by human beings to apply water for growing crops, especially when there is a shortage of rainfall and during dry seasons.

Small-scale irrigation can be defined based on the area of land irrigated and it differ from country to country. In Ethiopia small-scale irrigation schemes are understood to include traditional small-scale irrigation schemes up to 100 ha and modern communal schemes up to 200 ha (Awulachew *et al*., 2005 after MoWR, 2002).

Participation in a certain technology (adoption) on the other hand is also defined in different ways by various authors. Adoption according to Rogers (1983) is a decision to make full or partial use of an innovation (new method of doing things) at best appropriate course of action available. Another authors Loevinsohn *et al*. (2013), defines adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation. Citing the work of Feder *et al*. (1985), Bonabana-Wabbi (2002) defines adoption as a mental process an individual passes from first hearing about an innovation to final utilization of it. Adoption is in two categories; rate of adoption and intensity of adoption. The former is the relative speed with which farmers adopt an innovation, has as one of its pillars, the element of 'time'. On the other hand, intensity of adoption refers to the level of use of a given technology in any time period.

Even though it is difficult to bring into one single definition from the above definitions of the respective terms, participation (adoption) in small-scale irrigation practice can be generally defined as the use of an innovation (new way) of crop production by applying the artificial water to crop land purposively.

2.1.2. Theory of Common-pool Resources

The common pool resources and common property are terms most commonly used interchangeably by different researchers, but they are different. A common property is private property owned by a group of co-owners. Common property defines an institutional arrangement that confers a set of people with a bundle of rights. Common property, where the rights to exploit a resource are held by persons in common with others, lies in between the two extremes of exclusive possession and open access (Wade, 1987). Common pool refers to a class of resources which cannot be managed as private property. Property rights constitute institutions as they define the manner in which the rights holder and others interact over the use of a resource not between the owner and non owners personal aspect (Mukhopadahyay, 2012). Property rights more precisely refers to a fundamental institution governing who can do what with resources. Irrigation system is common pool resource (CPR), specially when the water source is ground water (Ostrom, 2002). Ground water resources belong to the category of common goods that are non-exclusive (it is very expensive to exclude a user from making use of the resource), which distinguishes them from private property, and most of the time they are rivalrous (consumption of the good by one user can reduce the amount available to other user), which differentiates them from public goods (Leyronas *et al*., 2016).

2.1.3. Management and Use of Common-pool Resources

The management of common property resource needs rules and well-defined group of users. Therefore, enforcement of rules needs a cooperation and collective action. The creation of cooperation or undertaking collective action involves substantial costs. This costs are referred as transaction costs in institutional economics (Dolsak and Ostrom, 2003). But if users are able to undertake collective action, then they are able to reduce transaction cost since lower transaction costs are associated with high social capital, cooperation and collective action (Mukhopadahyay, 2012).

Collective action is an action taken by more than one person directed towards the achievement of common goal or the satisfaction of common interest, given that, a goal or interest that cannot be obtained by an individual acting on his own (Wade, 1987). Since irrigation water is a common-pool resource it is difficult to control the use of such resources. Therefore, it is best managed if the community forms cooperation and manage it in collective. Empirical evidence shows that small to medium sized irrigation systems in Nepal confirms that best performing irrigation systems, are those managed by the community as compared to those systems owned and operated by a national governmental agency (Ostrom, 2002). In recent years the demand for a greater role for local community involvement in the governance of resource commons have been strengthened by scholarly work on local community based governance of natural resources (Agrawal and Benson, 2011).

Irrigation water is a common-pool resource, which can take the form of communal, private or state property, or not be subject to any form of ownership (Bosa, 2015). Common pool resources are used in common when the appropriation is difficult and monitoring the use and exclusion of non members is difficult and costly. Therefore, irrigation water resource is used in either of the above mentioned property regime and it is not necessarily governed by the common property right regime.

2.1.4. Production and Productivity

Production is defined as the organized activity of transforming resources into finished products in the form of goods and services and the objective of production is to satisfy the demand of such transformed resources (Bates and Parkinson, 1983). Production is basically an activity of transformation , which connects factor inputs and outputs (Samuelson and Marks, 2012,) Production consists of various processes to add utility to natural resources for gaining greater satisfaction from them by changing the form and place of natural resources, making available materials at times when they are not normally available and making use of personal skills in the form of services. The process of producing goods in modern economy is very complex. The process depends on basic factors of production in economics. These factors include land, labour, capital and entrepreneurship ability. Land is special term used in economics, because it represents natural resources, fertility of soil, water, air, natural vegetation etc. Water resource is the special resource in agriculture without which no agricultural commodity is produced, since agricultural production and productivity are especially sensitive to spatial and inter-temporal variations in natural factors of production (Pardey *et al*., 2012).

Productivity is economic output per unit of input (Atkinson, 2013). The unit of input can be land, labor hours (labor productivity) or all production factors including labor, machines and energy (total factor of productivity). Therefore productivity measures how efficiently production inputs, such as land, labour and capital, are being used in an economy to produce a given level of output. Productivity is considered a key source of economic growth and competitiveness and, as such, is basic statistical information for many international comparisons and country performance assessments. The productivity of a given resource, for example, cultivable land could be improved by combining it with other resources such as irrigation water. Firms use more of the unit of input as far as the additional output per additional unit of input is increasing (Debertin, 2012). Agricultural producers also increase the use of irrigated area of land given that it ensures an increase in output due to an increase in unit area of irrigated land.

2.2. Challenges and Opportunities of Irrigation Development in Ethiopia

There are many challenges that face the irrigation development in Ethiopia. Some of these challenges are more or less related with technical constraints and knowledge gaps. In this case the challenges indicated here are typical for small-scale irrigation. Gebremedhin and Asfaw (2015), identified the challenges for Ethiopian irrigation development as: (1) inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities, (2) inadequate knowledge on improved and diversified irrigation agronomic practices, (3) shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods (4) scheme based approach rather than area/catchments based approach for the development of SSI Schemes, (5) inadequate baseline data and information on the development of water resources, (6) lack of experience in design, construction and supervision of quality irrigation projects, (7) low productivity of existing irrigation schemes, (8) inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development, (9) poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers.

Besides challenges there are many opportunities that enhance irrigation development in Ethiopia. These opportunities stem from both the natural favorability of the country for irrigation and the emphasis given to irrigation development by the government of the country and the stakeholders. Out of these opportunities the first thing is that emphasis and priorities are given to irrigation in the growth and transformation plan of the country (NPC, 2015). The second one is that there is indigenous knowledge and introduction of promising household water harvesting and micro-irrigation technologies. The other thing is there is high commitment by Government, donors and NGOs to support and encouragement to private sector and public enterprises and involvement in irrigation development (ILRI, 2016). In addition to the above opportunities the most important promising opportunity is availability of abundant water resources and land suitability as well as availability of inexpensive labor.

2. 3. Irrigation Potential and Participation Situation

2.3.1. Irrigation Potential and Participation Situation in Ethiopia

Modern irrigation was started at the Awash river basin with bilateral cooperation of Ethiopia and Dutch company, during the 1950s for the productions of commercial crops such as sugar cane and cotton (Gebremedhin and Asfaw, 2015). Resent source indicates that, the total area of irrigated land in Ethiopia increased from 885,000 ha to 2.4 million ha in from 2011 to 2015 with a plan of increasing irrigated land to 4 million by 2020 (ATA, 2016), including the 658,340 ha of land developed with high and medium irrigation schemes (NPC, 2015). But there is a plan to expand the high and medium schemes to about 954,000 hectares by the end of the GTP-II (2019/20). Evidence also shows that, in Ethiopia, farm size per household is 0.5 ha and the irrigated land per households' ranges from 0.25 - 0.5 ha on average (MoA, 2011).

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). It 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 and Tripathi, 2015). But Ethiopia is using a very little of its abundant water resource potential for irrigated agriculture (ATA, 2016). Even though there is no similar evidence about the potential it have from different sources, it has a high potential. The estimated total irrigable land potential in Ethiopia is 5.3 Mha assuming use of existing technologies, including 1.6 Mha through rain water harvesting and ground water (Awulachew, 2010). This indicates that there are potential opportunities to vastly increase the area of irrigated land. According to Awulachew (2010) given 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.

2.3.2. Irrigation Potential and Participation Situation in Oromia Region

Oromia has 63 river systems and 688 tributary streams which annually generate 58 billion cubic meters of surface water, the equivalent of half the nation's surface water resources. Despite this large water resources potential, Oromia's agricultural sector is almost entirely dependent on rain-fed farming. Irrigated agriculture constitutes just under 5 percent of the potential and about 2.14 percent of the total cultivated land (Anonymous, n.d.). The same source also indicates that, in Oromia region, out of the estimated 1.7 million ha of potential irrigable land, only 85,400 ha has been developed so far, which is about 5% of the potential.

The development of irrigated agriculture in Oromia is at its infancy and its contribution to food supply is insignificant the same as for the whole country. The demand for food, fiber and energy by the increasing population of Oromia and the country as a whole is expected to grow substantially in the years ahead. Rain-fed agriculture through area expansion and intensification alone is not enough to provide the basic requirements of food, clothing and energy for the rising population. Hence, the development of irrigation will be essential to augment rain-fed agriculture. In order to decrease dependence on rain-fed agriculture, the regional government is in process of developing cost-effective irrigation schemes, especially in areas with less reliable rainfall (MoARD, 2013).

2.3.3. Irrigation Potential and Participation Situation in Horro Guduru Wollega

Horro Guduru Wolega is one of the wettest zones of Oromia region. It has a long rainy season which starts in spring and continues to autumn. The amount of rain-fall of the zone is dependent on altitude and the aspect of land in relation to rain bearing winds. The climate of rural areas of the zone is divided in to temperate (34.78%); sub-tropical (35.46%), and tropical (29.78%) (Monenus, 2016). This shows that the dominant climate of the zone is sub-tropical followed by temperate, and tropical. These climatic types are the best for the production of different weather crops. The presence of huge water potential as a result of long rainy season and higher altitude has given the zone great advantage to produce different types of crops and hence to increase food security of the zone (Ibid).

Despite its high water potential, Horro Guduru Wolega zone faces the problem of crop failure due to the climatic variability and drought spells because of the high dependency on rain-fed agriculture. For example it has faced a problem of decline in the production of crops on the year 2012 (MoARD, 2013). There are many opportunities in the zone that can enhance irrigated farming, because it has many rivers and streams that can be applied to agriculture. But its potential and level of utilization does not approach to each other.

2.4. Theoretical Framework

2.4.1. Theoretical Framework for Participation Decision in Irrigation Practice

The participation in a certain technology depends on the advantage it will bring to the participant. The advantages can be seen in different ways either the increase in the physical outcome or in the satisfaction of the participant. Therefore, the participation decision of the farmers in irrigated farming is based on the utility difference they obtain between the use of irrigated farming and not using irrigated farming. The utility theory will be used in the formulation of participation decision of households in irrigation.

In this particular study, the decision whether to participate in irrigation practice or not, depends on the expected utility of participating and not participating in irrigated farming. The farmers participate in irrigated farming when they expect that the utility from participating in irrigation is greater than not participating in it. Otherwise if the expected utility from using irrigated farming is lower than the expected utility from not using it, the decision of the farmers will be non participation in irrigated farming. Utility is assumed to depend on income, but also takes into account other factors such as socio economic, demographic and institutional factors that affect income of the farmer. The objective of producer is profit maximization but profit is used to purchase goods and services that maximizes the utility of the owner of the firm (Debertin, 2012). Therefore utility theory based on production choice was used as a theoretical basis for the participation decision of the farmers in small-scale irrigation comparing the utility of non participation (status quo) with participation (the new state).

We could denote utility for the two states as follows:

Utility for the status quo would be:

$$U_{0j} = u(Y_j, \boldsymbol{Z}_j, q^0\varepsilon_{0j})$$

And utility for the final state would be:

$$U_{1j} = u(Y_j, \boldsymbol{Z}_j, q^1\varepsilon_{1j})$$

Based on this model, respondent *j* adopts irrigation practice, if the utility with the participation in irrigated farming exceeds utility of the status quo.

$$U_1\left(Y_j, \boldsymbol{Z}_j, q^1\varepsilon_{1j}\right) > U_0(Y_j, \boldsymbol{Z}_j, q^0\varepsilon_{0j})$$

where U_0 denotes the utility function from the status quo, U_1 denotes the utility from participation in irrigation, Y is income, q^0 and q^1 are the alternative levels of the good indexes with and without irrigation practice respectively, (with $q^1 > q^0$, indicating that q_1 refers to the improved total output of the farmer after participating in irrigation). Zj is a vector of individual characteristics.

Assuming that farmers maximize utility, the decision by farm household j to participate in irrigation practice (IRRIG =1) or not participating in irrigation practice (IRRIG= 0) is based on a comparison of expected utilities of both situations. Using the difference in expected utilities gives the following decision rule:

$$IRRIG = \begin{cases} 1, if\ E\left[U_j^1 - U_j^0|Zj\right] > 0 \\ 0, if\ E\left[U_j^1 - U_j^0|Zj\right] \leq 0 \end{cases}$$

Where E is the expectation operator, U_1 and U_0 are the same as mentioned earlier. Farmers differ in the way they form expectations on the utility levels of both choices. These differences are due to characteristics of the farmer. The vector Zj accounts for variables that are assumed to have an impact on the utilities of both choices and the way expectations are formed on these utilities.

2.4.2. Theoretical Framework for Intensity of Participation in Irrigation Practice

The area of land allocated for irrigated farming is based on the expected return from irrigating more land based on the costs involved and the level of output expected from a unit increase in the area of irrigated land. The expected return from irrigated farming depends on the production and the returns to scale of production. Therefore, the theoretical framework for analyzing how farmers decide on the share of irrigated land, starts with a production function.

Assuming that the production function is given as follows:

$$Q = f(X, L, A_I, A_{NI}) + \varepsilon.g(X, L, A_I, A_{+NI})$$

where Q is output, X are variable inputs, L is labor, A_I is irrigated land, A_{NI} is non-irrigated land. The function $f(X, L, A_I, A_{NI})$ gives the mean output level and $\varepsilon.g(X, L, A_I, A_{NI})$ reflects the variation in output, where ε is a random term that reflects the production risk (e.g. due to drought, rainfall fluctuation, hailstone) and where $g(X, L, A_I, A_{NI})$ indicates how inputs and other variables relate to these production risks. Some inputs may reduce the effects of these risks, whereas others may increase it. Important assumptions are that output is increasing in A_I at a decreasing rate ($\partial f/\partial A_I > 0$; $\partial^2 f/\partial {A_I}^2 < 0$), and that irrigated land is risk-reducing ($\partial g/\partial A_I < 0$; $\partial^2 g/\partial {A_I}^2 < 0$).

The one-period benefit of an additional unit of irrigated land is given by the marginal value product (MVP), which is the combined value of the marginal increase in output and the marginal decrease in output risk due to an additional unit of irrigated land:

$$\text{MVP} = p.\frac{\partial Q}{\partial A_I} = p\left[\frac{\partial f(X, L, A_I, A_{NI})}{\partial A_I} + \varepsilon.\frac{\partial g(X, L, A_I, A_{NI})}{\partial A_I}\right]$$

where p is output price.

The decision of the farmers on the allocation of land for irrigated farming depends on the net return from the increase in the unit area of land irrigated and the cost requirement for irrigating an extra unit area of land. If the return, MVP of a unit of area of irrigated land is greater than the cost of the unit area of irrigated farming land, the farmer increases the allocation of land for irrigation. Recognizing that both benefits and costs are a function of A_I, the optimal size of irrigated land, A_I^* can be determined. If expected benefits are higher than the acquisition costs, A_I^* is positive, otherwise it is zero. The irrigation cost per unit area C_I incurred is a function of credit D, income saved from various sources (e.g. Non-farm income, N), family size as labor, L, other factors and the area of irrigated land A_I:

$$A_I = \begin{cases} A_I^*, if\ p\left[\frac{\partial f(X, L, A_I, A_{NI})}{\partial A_I} + \varepsilon.\frac{\partial g(X, L, A_I, A_{NI})}{\partial A_I}\right] - C_I[D, N, L, A_I] > 0 \\ 0 \qquad \text{otherwise} \end{cases}$$

Optimal land allocated to irrigation is thus, a function of variables affecting the returns and costs of irrigation as a function of irrigated area of land. Therefore, the theoretical framework for the analysis of intensity of participation in irrigation practice depends on the microeconomic theory, the optimal allocation of resource for production (Debertin, 2012).

2.5. Empirical Studies on Determinants of Irrigation Practice

Different studies have been conducted by different scholars on the determinants of adoption of irrigation practice by farm households in different countries of the world. The scholars found different factors that determine participation in irrigation practice by small-scale farm households using different models and hypothesizing different regressors that influence irrigation practice. Therefore, this section has been concerned with review of previous empirical studies to come up with convincing information with most commonly significant variables affecting adoption of irrigation practice to use them as a basis of the hypothesis for this study.

Several studies revealed different results concerning how economic variables such as income, cultivable land holding/farm size, number of oxen owned by household affects the small-scale irrigation practice by farmers. For instance, Kinfe *et al*. (2012) and Abebaw *et al*. (2015) by using binary probit model and binary logit respectively, found that income of the farmer affected the irrigation participation by smallholder farmers positively. They revealed that, a household with higher income would be able to spend on irrigation than low income households and they take part in irrigation practice more than lower income farm households.

Land holding on the other hand is found negatively influencing the irrigation practice by farmers (Edo, 2014). But Beyan *et al*. (2013), indicates that, there was positive relationship between land holding and irrigation practice by farmers. The different findings concerning the cultivable land holding was due to difference in the underlying conditions in the areas those researchers have undertaken their study. For instance the case of negative relationship between land holding and irrigation practice found by Edo (2014), indicated that it was resulted because the farmers with larger land size were found allocating their land for rain-fed agriculture and animal husbandry. Beyan *et al*. (2013), revealed that, fragmentation of cultivable land is a problem of crop diversification for most of the farmers in the study area.

Other studies indicate that farm size is found positively affecting participation in irrigation practice by smallholder farmers (Abebaw *et al*., 2015; Sithole *et al.*, 2014). These sources found as it has a positive significant effect on the participation decision of the households, that the farmers with large farm size were found participating in irrigated farming than their counterparts but the reason behind this finding is not explained by the researchers. This variable also shows that a positive influence on the area of land allocated for irrigation by the farmers (Wang *et al*., 2015).

Oxen ownership also influences the small-scale irrigated farming decision positively (Gebrehaweria *et al*., 2014). This finding was related with the risk taking behavior is more for wealthier farmers as compared to poor farmers. Even though it is not explained, this result might be related with the source of draft power used in preparing the land for irrigated farming. The farmers with larger number of oxen can use their oxen for preparing the irrigation farm easily and the households with lower number of oxen may face difficulty in land preparation and may not be able to participate in irrigated farming.

The total livestock owned by the households also shown positive significant effect on the irrigation participation decision of the households (Hadush, 2014). Farmers with higher TLU were found with higher probability of participating in the irrigation practice. In general, the above finding shows that farmers with larger value of the variable were found participating in irrigation practice more than those with lower values.

Further studies conducted by different scholars revealed that educational status of the household head had a positive significant influence on the irrigation practice decision of farmers (He *et al*., 2007; Tewodros *et al.*, 2013; Muhammad *et al*., 2013; Edo, 2014; Nhundu *et al*., 2015; Abebaw *et al*., 2015). From these studies it indicate that education is the very important variable that influences the irrigation practice by farmers and needing policy action in different setup of different countries. Not only the participation decision, this variable also influenced the area of land allocated under improved technology of irrigated farming positively. It shows that educated farmers allocate more land for the water saving irrigation technology such as subsurface drip irrigation (Wang *et al*., 2015; Pokhrel *et al.*, 2016). Another explanatory variable, training on irrigation technology issues has shown positive significant influence on participation in irrigation practice (Abebaw *et al.*, 2015; Nhundu *et al*., 2015). This implies that farmers who attended more irrigation technology training were found with higher probability of participating in irrigation practice than their counterparts.

The demographic factor such as sex of a respondent is mostly used as one of determinant factors of participation in irrigation and found that male headed households are the most likely participant in small-scale irrigation practice (Kinfe *et al*., 2012; Muhammad *et al*., 2013; Gebrehaweria *et al*., 2014) and irrigate more area (Abebe *et al*., 2011). For instance, the study by Kinfe *et al.* (2012), revealed that the finding is linked with different factors related with the sex of the respondent that are more favorable for male than female such as suitability of easily solving labor shortage due to physical, technological, socio-cultural and psychological fitness of farm instrument to males than females and other related factors.

Age is another demographic factor that shows negative significant influence on participation in irrigation (He *et al*., 2007; Beyan *et al*., 2014; Edo, 2014; Gebrehaweria *et al*., 2014; Sithole *et al.*, 2014; Nhundu *et al*., 2015). These findings indicate that, younger household heads are more innovative in terms of technology adoption and are more likely to take risk than older household heads. As evidences has depicted, this findings by different scholars, implies that the older the farmers, the more reluctant they may be in participating in irrigated farming due to tiredness on one hand or the wealth they have accumulated during their adulthood on the other. This variable, (age), also shown that it affects the area of land allocated for improved irrigation technology negatively (Wang *et al*., 2015; Pokhrel *et al*.,2016). This indicate that the more aged the farmers, they allocate more of their land to non improved traditional farming practice rather than improved technology such as irrigated farming, because older farmers have shorter plan of living at this age.

The institutional factor, access to market information used as a regressor shown a positive significant influence on participation in irrigation practice (Kinfe *et al*., 2012; Abebaw *et* *al*., 2015). This implies that the farmers who have access to market information was found to have higher irrigation participation probability than those that does not have market information. Farmers that have market information on input and output price would be attracted by the benefit of irrigated farming and would be market oriented that enhance their participation. This variable was also found influencing the area of land allocated for irrigation, such as center pivot irrigated farming (Pokhrel *et al*.,2016). The farmer nearby the market can have high information on input and output price as well as demand and the distance also matters. But other source indicate that, the area of land allocated for irrigation is negatively related with the distance of the market (Abebe *et al*., 2011). This finding was related with the competition for water used in irrigation. Proximity of market will lead to the shortage of water per individual and leads to lower allocation of farm land for irrigated farming.

Access to credit is also an institutional factor positively affecting participation in irrigation practice by smallholder farmers (Muhammad *et al*., 2013; Sithole *et al.* 2014; Nhundu *et al*., 2015). This finding is related with the reason that access to credit enables farmers to overcome their financial constraints associated with production and participation in irrigation and also encourages group formation and learning. Access to credit could enable farmers to use the technologies by purchasing the inputs on time.

The distance of farm from irrigation water source is also another factor that have a significant discouraging effect on participating in irrigated farming (Kinfe *et al*., 2012; Beyan *et al*., 2014; Sithole *et al*., 2014). Based on the findings of these scholars, long distance plot of farm land from water source lead farmers for extra cost when compared to nearest farmers to water source in many ways such as opportunity cost of time, cost of irrigation water access. This have forced the distant farmers from the water source to practice irrigated farming less than their counterparts.

The studies by Tewodros *et al.* (2013) and Hadush (2014) shows that family size significantly and positively affected the irrigation participation decision of the farmers. They indicated that, the households use the family members as a labor force and easily undertake the irrigation activity than lower family size households because of labor intensive nature of small-scale irrigated farming.

Beyan *et al*. (2014) and Hadush (2014), shows that the households participating in the paying nonfarm activity were found to participate in irrigation practice more than those not participating in nonfarm activities. These studies indicated that, the positive relationship between nonfarm activity and irrigation practice by farmer was due to the reason that the income from nonfarm activity was used to cover the irrigation costs such as inputs required and enable those farmers participate in irrigation easily as compared to their counter parts.

2.6. Studies on Impact of Participation in Irrigation

Impact evaluation is an important policy issue nowadays. Impact evaluations have been conducted by different agents with different goals. Different methods can be used to evaluate the impact of the program based on different underlying conditions and availability of data. Among these methods, Difference-in-Difference which is based on before versus after and with and without data, propensity score matching which depends on creating counterfactual or comparison groups based on observable characteristics or propensity score, are some of them. Here in this section, previous studies on impact of irrigation was reviewed and analyzed briefly.

Participants in irrigated farming were found to be in a better position in terms of income and thereby improved household poverty and food security than non-participants (Nhundu and Mushunje, 2012). From Heckman two step treatment effect model, participation in small-scale irrigation was found to have positive and significant effect on income of farm households (Kinfe *et al*. 2012; Sisay and Fekadu, 2013; Abraham *et al*. 2015; Agerie, 2016) and on household poverty reduction (Adeoti, 2009),

In the irrigation impact evaluated with the help of propensity score matching indicates a positive significant effect of participation on rural household income (Nicoletti, 2011; Hadush, 2014; Shiferaw and Mengistu, 2015) and on household poverty alleviation (Tewodros *et al*. 2013). Woldegebrial *et al*. (2015) also used PSM and reported a significant difference between participants and non-participants in irrigation on income, overall expenditure and asset accumulation. Using both PSM and Difference-in-Difference Dillon (2011) found a significant increase in total household consumption, agricultural production, informal food sharing and livestock holding due to participation in small-scale irrigation in Northern Mali regardless of estimation methods used.

2. 7. Conceptual Framework

There are many factors that influence the participation in small-scale irrigation practice by farm households. The findings of diffirent studies conducted on irrigation participation in different parts of the world gives an indication on different factors that can influence the irrigation participation of farmers. These factors which affect farmers' participation in irrigation practice are categorized into demographic, socio-economic, physical, institutional and knowledge source variables either negatively or positively related to SSI practice participation among farm households and the area of land irrigated by farmers.

Based on literature review and empirical studies, a conceptual framework has been formulated by taking into consideration household heads characteristics (demographic), socio-economic, institutional, physical and social capital could affect farmers' participation in small-scale-irrigation water use in the study area. The diagram of the conceptual framework is shown in Figure 1 below. The arrows that point two ways indicates that there is an interaction between the concepts in both ways. The arrows that are pointing only unidirectional shows the effect is only from one to the other but not the reverse.

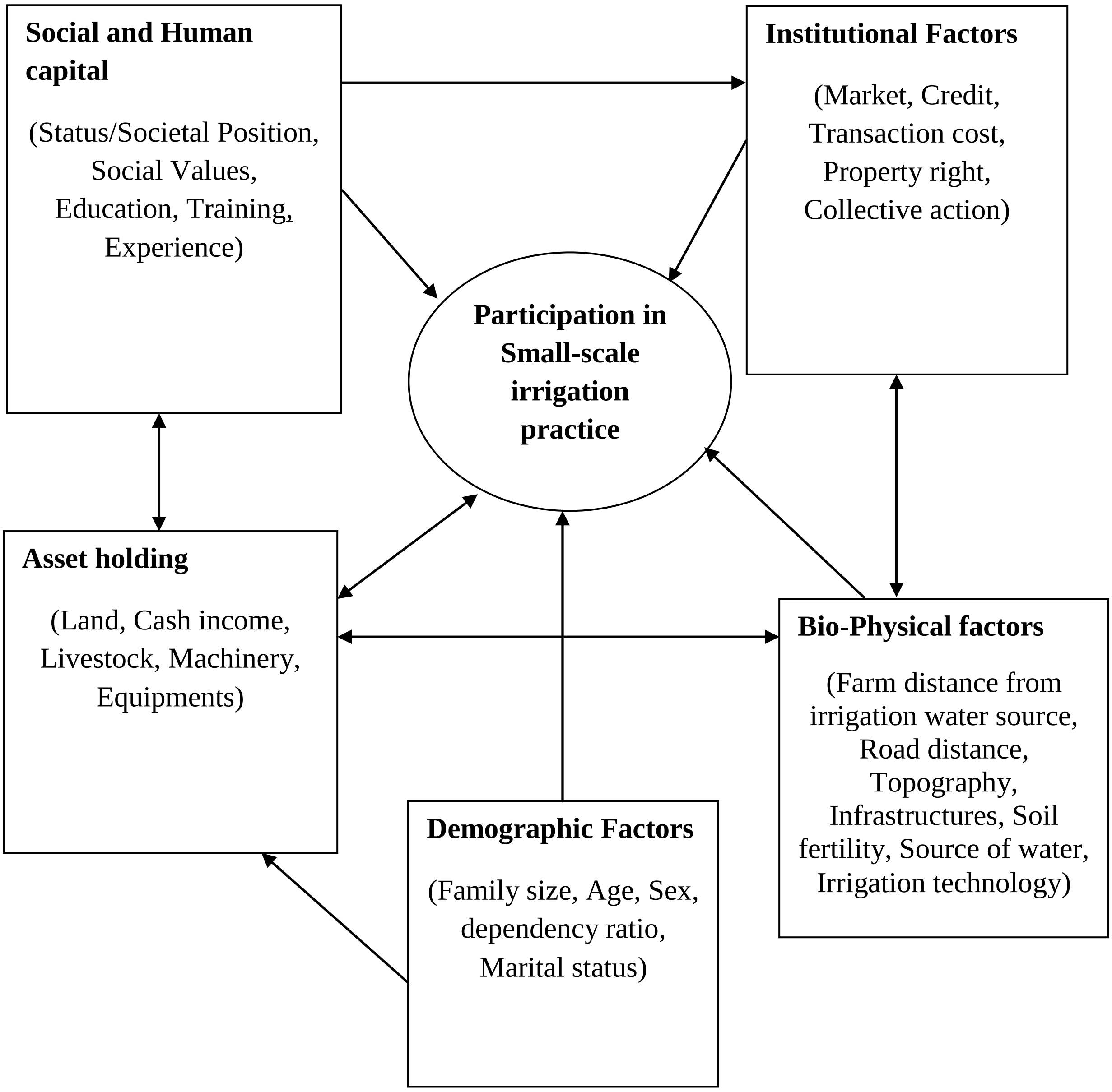


Figure 1: Conceptual framework
Source: Own design

2.8. Methodological Framework

2.8.1. Methods for Participation and Intensity of Participation Analysis

The models that are used in analyzing participation and intensity of participation are reviewed in this subsection. Based on the dependent variables in this study, participation decision of the farmers and intensity of participation in small-scale irrigation practice, there are various models that can be used. Tobit model, Heckman two-step procedure and

Double hurdle model are the models suited to analyze the factors determining the probability of participation and intensity of participation under different underlying assumptions.

Tobit model is an improvement to probit model and it can be used to analyze both the participation decision of the farmers in small-scale irrigation (probability of participation) and the intensity of participation in irrigation practice (proportion of irrigated land) by the farm households in this particular study by the use of single non-linear least square estimation using maximum likelihood method. The likelihood-function consists two parts, that is probit-part or the slope of the line in the Tobit part and linear part which is the uncensored part of the model. Therefore, Tobit model can be used to analyze the factors influencing household's participation decision in small-scale irrigation practice and the intensity of participation in irrigation practice by the farmers simultaneously using a single coefficient (Gujarati, 2004).

Another alternative model for such study is Heckman two-step procedure proposed by James Heckman (Heckman, 1979). The Heckman two-step procedure is an improvement to Tobit model. It accounts for sample-selection bias. This alternative consists of a two-step estimating procedure. The first estimation is the probability of participation, which is done on the basis of the probit model as determinants of participation. Then we estimate the second, OLS regression model by adding the variable called inverse mills ratio *(*IMR) calculated using our selection equation as an independent variable, if it is significant, for intensity of participation. Heckman treats the selection bias as an omitted variable bias. The Heckman procedure yields consistent estimates of the parameters as of Tobit model, but they are not as efficient as Tobit model maximum likelihood estimates.

Different scholars use different models for the purpose of participation decision and intensity of participation. For instance double hurdle model was used by Efa *et al*. (2016), in conducting a study on determinants of market participation and intensity of marketed surplus of *teff* producers by reasoning out double hurdle model is an improvement to standard Tobit model. Really double hurdle is an improvement to standard Tobit model but it has its own additional assumption under which we can use a double hurdle instead of Tobit model. The assumption of double hurdle model is that the two dependent variables are independent and they are to be determined by different sets of explanatory variables (Burke, 2009).

Double hurdle model have two parts which are estimated by two hurdles. The first one is the probit model used in estimating the factors determining the probability of participation in small-scale irrigation practice and the second one is truncated regression that is used to estimate the intensity of participation in small-scale irrigated farming by the farmers. Based on Burke (2009) double hurdle model with the two parts is specified using two different latent variables, to model each decision process, with a probit model to determine participation decision and a truncated regression model to determine the intensity of participation in small-scale irrigation.

2.8.2. Methods of Impact Evaluation

Impact evaluation is an important policy issue either to improve the program intervention or strengthening the existing activity to be sustainable. But evaluating the impacts of improved technologies is not straightforward because they are designed and implemented in a complex and ever-changing environment (Stern *et al*., 2012). Another problem is the bias resulting from self-selection in the adoption of the technological innovation (Caliendo and Kopeinig, 2005; Khandker *et al*., 2010). Furthermore, there may be a hidden bias that results from unobserved heterogeneity in the participation decision, which can, in turn, influence the outcome of participating in a technological innovation (Smith and Todd, 2005).

There are several methods by which impacts can be evaluated under non-experimental or quasi-experimental approaches. These include randomized selection methods, propensity score matching, regression discontinuity design, difference-in-difference and instrumental variable estimation methods (Khandker *et al*., 2010).

The difference in difference design for empirical analysis of causal effects has a long history in and outside econometrics and it is one of the most heavily used empirical research designs to estimate the effects of policy changes or interventions in empirical microeconomics nowadays (Lechner, 2010). Difference in difference could be an attractive choice when using research designs based on controlling for confounding variables or using instrumental variables is deemed unsuitable, and at the same time, pre-treatment information is available (Albouy, n.d.). It has the advantage that the basic idea is very intuitive and thus easy to understand for an audience with limited econometric education. Compared for example to matching methods it has the further advantage, that there is no need to control for all confounding variables, since we have double difference. In many applications, time is an important variable to distinguish the treated and control groups in difference in difference (Roberts and Lemmon 2007). Difference in difference has the assumptions such as the model in equation (Outcome) is correctly specified, the error term is on average zero and error term is uncorrelated with the other variables in the equation (Albouy, n.d.). This method is best applied under the mentioned assumptions and merits.

Regression discontinuity (RD) is one of the rigorous non-experimental impact evaluation approach that can be used to estimate program impacts in situations in which candidates are selected for treatment based on whether their value for a numeric rating exceeds a designated threshold or cut-point (Jacob and Zhu, 2012). It is based on the cut-off point in observable characteristic, often called the rating variable. RD techniques are considered to have the highest internal validity (the ability to identify causal relationships in this research setting), but their external validity (ability to generalize findings to similar contexts) may be less impressive, as the estimated treatment effect is local to the discontinuity (Baum, 2013). The treatment is not randomized, but there is some process that deterministically dictates whether a unit is treated or not, cut-off point. In this design, units receive treatment based on whether their value of an observed covariate is above or below a known cut-off (Calonico *et al.*, 2013). But when using Instrumental variable for causal inference, one must assume the instrument is exogenously generated as if by a coin-flip (Lee and Lemieux, 2010). This implies that in the instrumental variable method there is a variable that is randomized that is correlated with the treatment.

Propensity score matching (PSM) has two key underlying assumptions (Baum, 2013). The first one is conditional independence, there exists a set X of observable covariates such that after controlling for these covariates, the potential outcomes are independent of treatment status. The other one is common support, for each value of X, there is a positive probability of being both treated and untreated. It is used when it is possible to create a comparison group from a sample of non-participants closest to the treated group using observable variables. Both groups are matched on the basis of propensity scores, predicted probabilities of participation given some observed variables. Propensity score matching consist of four phases most commonly: estimating the probability of participation, i.e. 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).

Sometimes the interest of impact analysis may be determining the average treatment effect on the treated (ATT) of irrigation practice. But the estimation of this effect may be impossible based on the before and after because in the absence of baseline data and it needs substituting the counterfactual mean of treated, by the mean outcome of untreated (Caliendo and Kopeinig. 2005). Even though it is possible based on the with and without data it will be biased estimator under selectivity biasness. For such a problem, PSM provides an appropriate solution (Rosenbaum and Rubin, 1985). 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. Therefore, propensity score matching could be used in an instance of such problem.

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 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 participation or intervention.

Nearest-neighbor matching: It is one of the most straightforward matching procedures. Each program beneficiary is matched to the non-beneficiary unit with the closest propensity score. Non-beneficiaries for which there are no beneficiaries with a sufficiently similar score are discarded from the sample; the same is true for beneficiaries for which there is no similar non-beneficiary. A variation of nearest-neighbor matching matches multiple (for example, the five) non-beneficiaries to one single beneficiary with different caliper distance. But matching on more distant neighbors can reduce the variance of the estimator at a cost of an increase in bias. Therefore, reasonable distance should be taken to reduce the bias. Variants of nearest neighbor matching include “with replacement” and “without replacement,” where, in the former case, an untreated individual can be used more than once as a match and, in the latter case, is considered only once. These different nearest neighbor matching shall be tested to estimate the treatment effect on the treated.

Radius caliper matching: To avoid the risk of poor matches, radius matching specifies a “caliper” or maximum propensity score distance by which a match can be made. The basic idea of radius matching is that it uses not only the nearest neighbor within each caliper, but all of the comparison group members within the caliper. In other words, it uses as many comparison cases as are available within the caliper, but not those that are poor matches (based on the specified distance). In short, in ‘radius caliper’ matching a maximum propensity score radius, a ‘caliper’ is established, and all non-beneficiaries within the given radius of a beneficiary are matched to that beneficiary.

Kernel matching: is a nonparametric matching estimator that compare the outcome of each treated person to a weighted average of the outcomes of all the untreated persons, with the highest weight being placed on those with scores closest to the treated individual. One major advantage of this approach is the lower variance, which is achieved because more information is used. A drawback of these method is that some of the observations used may be poor matches. Hence, the proper imposition of the common-support condition is of major importance for this approach. When applying kernel matching, one also has to choose the kernel function and the bandwidth parameter.

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, sampling method and sample size, data type, data sources and method of data collection , method of data analysis, and description of variables and hypothesis are presented.

3.1. Description of the Study Area

Abay Chomen District is one of the 9 districts in Horro Guduru Wollega zone of Oromia regional state of Ethiopia, containing 19 kebeles, located at 9^o 31’ 42” to 9^o 59’ 48” N latitude and 37^o 10’ 03” to 37^o 28’ 44” E longitude and the capital of the district Fincha town is 289 kms northwest of Addis Ababa. The District is bordered on the east by Ababo Guduru district, on the southeast by Guduru district, on the south by Fincha river, on the south west by the Jimma Geneti district, on the northwest by Amuru Jarte district and on the north by the Abay river which separates it from the Amhara region. The area receive high rainfall in one season of the year. The total area of the District is estimated to be 801.7 km^2; approximately 45, 37, 4, 3 and 11% of the total area are cultivated land, non-cultivated, water bodies, settlements, and woodlands and forests, respectively (Tegbaru, 2014).

The Ethiopian population projection by CSA for 2017, based on 2007 national census reported a total population for this district to be 64,672, of whom 33,263 (51.43%) were male and 31,409 (48.57%) were female; 15,232 or 23.55% of its population were urban dwellers (CSA, 2013). The majority of the inhabitants were Protestant, (59.73%), while 31.84% reported Ethiopian Orthodox Christianity, 5.5% reported their traditional beliefs, and 1.61% were Muslim (CSA, 2007).

The altitude of the study area ranges from 1,061 to 2,492 meters above sea level (masl) with two agro ecological zones, mid-highland and low land. The northern part of the district (low land), which is mainly situated at altitude ranging from 1,138 to 1,687 masl in the Nile River Basin, is owned by Fincha Sugar Factory and is entirely being used for irrigated sugarcane (*Saccharum officinarum* L.) production. At altitudes ranging from 2,213 to 2,492 masl (mid- highland), smallholder farmers practice mixed farming systems that integrate both crops and livestock (animals used for traction, meat and milk). These areas are under intensive cultivation and maize (*Zea mays* L.), teff (*Eragrostis tef* (Zucc.) Trotter), bread wheat (*Triticum aestivum* L.), niger seed (*Guizotia abyssinica*), barley (*Hordeum vulgare* L.) and faba bean (*Vicia faba* L.) are the major crops grown by rain-fed agriculture (CSA, 2013). Areas situated at altitude ranging from 1,061 to 1,138 and 1,687 to 2,213 masl are mainly woodlands and forests, and non-cultivated escarpments (Tegbaru, 2014).

The recent years meteorological data of the nearby representative stations, Fincha Sugar Factory and Shambu Meteorological Stations showed that the mean annual minimum and maximum temperatures of the district are 13.4 and 27.2 ^{0}C, respectively, and the mean annual rainfall is 1,399 mm (Tegbaru, 2014). The area has a uni-modal rainfall pattern and the highest intensity of rainfall is recorded in the month of July. The area is characterized as hot to warm moist lowland and tepid to cool moist mid-highlands based on the classification of agro-ecological zones of Ethiopia (Alemayehu, 2006).

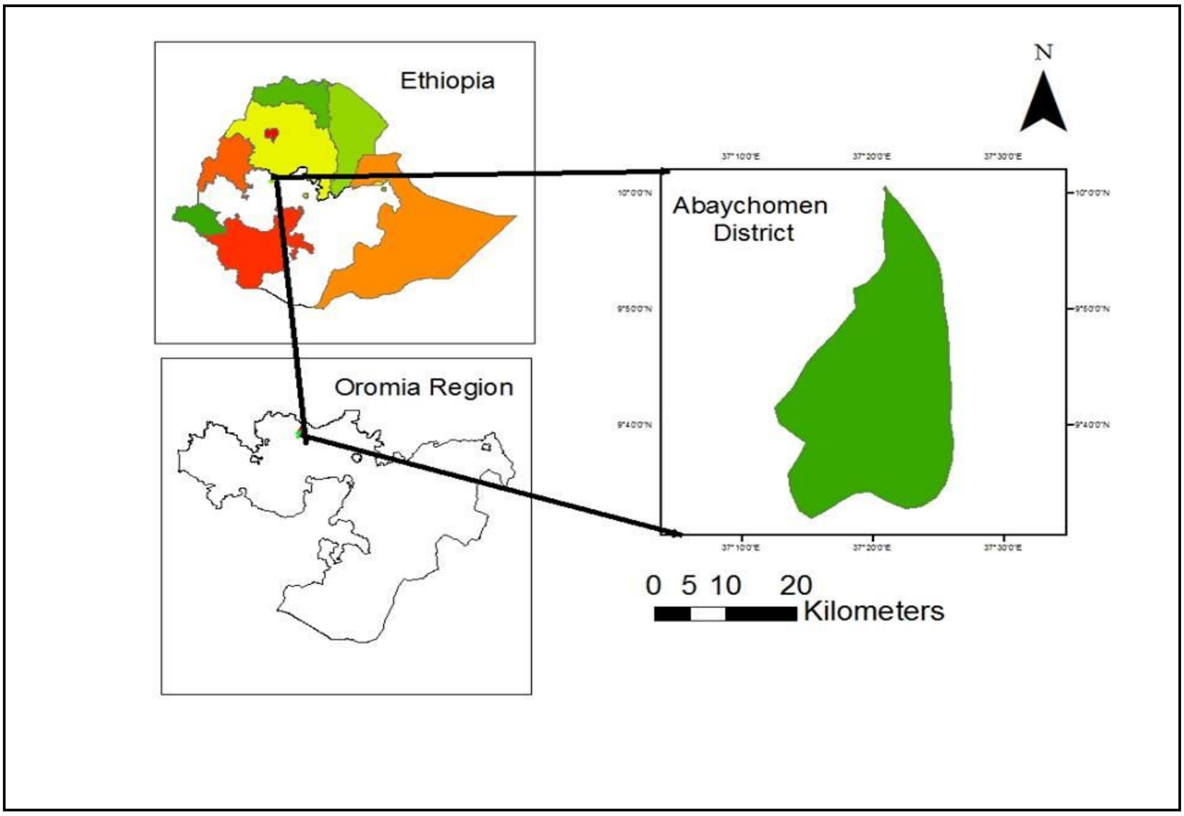


Figure 2. Location Map of Abay Chomen District, Oromia, Ethiopia

Source: Own design with the help of GIS expert

3.2. Sampling Method and Sample Size

The farming households were actually the ones making day to day decisions on farm activities. Therefore, a household was the basic sampling unit. In this study, a two-stage sampling technique was used to generate the required primary data. At the first stage, three kebeles from 16 non urban, mid-high land farmer kebeles in the district were selected randomly. On the second stage, by stratifying the households into participant and non-participant, a probability proportional to sample size sampling procedure was employed to select 167 sample households from which 80 participants and 87 non-participants were randomly selected, after preparing sample frame of participants and non-participants in the selected kebeles. But five observations (three participants and two non-participants) were excluded from the analysis due to missing values and 162 sample, 77 participants and 85 non-participants were used in the analysis. This sample size is assumed to represent the population, since the district is more or less homogeneous in terms of climate, resource endowment and other factors related to the issue of the study.

To determine the representative sample from the study area, the formula for sample size determination adjusting degree of precision to 0.07 due to shortage of resource, following Cochran (1977) has been used. And the sample size from each kebele was determined by proportionality formula.

Therefore, sample size is determined by formula (1).

$$n = \frac{Z^2 * (p)(q)}{d^2} \qquad (1)$$

Where n - sample size

Z - standard normal deviation (1.81 for 93% confidence level)

P = 0.5 (The proportion of the population participating in irrigation, that is 50%) due to unknown variability

q = 1-P =0.5 (50%)

d - desired degree of precision, (0.07) in this case

Proportional sampling technique has been used to select the sample from each of the three kebeles. The sample selected from each selected kebeles was proportional to the sample population in each kebele and the formula for this purpose was determined by formula (2).

$$n_i = \frac{N_i(n)}{\sum N_i} \quad (2)$$

Where n_i - the sample to be selected from i's kebele

N_i - the total population living in selected i's kebele.

$\sum$ - The summation sign

$\sum N_i$ – The sum of total population in the selected three kebeles

n – total sample size

Table 1. Distribution of sample selected from the three kebeles

Name of Kebeles	Total number of households	Sample selected (Non-Participant/Participant)	Proportion
Ganjii Qeexala	353	62 (32/30)	37.13%
Hoomii	185	33(17/16)	19.76%
Jaree	408	72(38/34)	43.11%
Total	946	167(87/80)	100%

Source: Survey data, 2017

3.3. Types of Data, Data Sources and Methods of Data Collection

For this study, both quantitative and qualitative data from primary and secondary sources were collected. The source for primary data was the sample farmers in Abay Chomen district and the source for secondary data are local offices, higher governmental organizations, different publications and policy documents. To obtain primary data, semi structured questionnaire, with both closed and open-ended questions was used as a tool to collect data from sample households. For the sake of conducting this study, important variables on economic, social and institutional factors related with the households in the study area were collected. For the purpose of getting data on the determinants of irrigation practice, the questionnaire covered a range of topics including demographic characteristics of households and socioeconomic structure; market access, access to credit, area of irrigated land, distance of farm land from water source, educational status, cultivable land size and other related factors were considered.

For the collection of primary data, enumerators, with at least secondary education that can speak local languages were recruited. Necessary care was taken in recruiting the enumerators. They were given an intensive training on data collection procedures, interviewing techniques and the detailed contents of the questionnaire. The households' questionnaire was translated in to local language (Afaan Oromoo), to convey the questions effectively to the rural interviewees and it was pre-tested, administered, filled by the trained and experienced enumerators. Strict supervision was made by the researcher during the course of the survey.

Secondary data were collected from documents and publications of different organizations and relevant local offices as well as journal documents. Moreover, available documents such as policies, strategies, guidelines and reports relevant to irrigation has been reviewed. In order to get relevant and detailed information about households' irrigation practice and its influencing factors in Abay Chomen district, focus group discussion and key informants interview was made in the study area. For both, focus group discussion and key informant interviews, unstructured interview (guiding question) was used as a tool of data collection. Three focus groups, one from each selected kebeles consisting of 8 to 10 purposively selected farm household heads were used for collecting the detailed data using guiding questions and the district office of irrigation development coordinator and irrigation extension coordinator were interviewed considering them as key informants. These data were more of qualitative and they were used in supporting the quantitative data.

3.4. Methods of Data Analysis

3.4.1. Descriptive Statistics

In this study, descriptive statistics was used to explain the different characteristics of the farm households in the study area. The descriptive Statistics such as minimum, maximum, mean and standard deviation were used for these analysis. The statistical significance of the variables were tested for both dummy and continuous variables using chi-square (χ^2) and student t-test statistics, respectively.

3.4.2. Econometric Model Specification

3.4.2.1. Participation models specification

The dependent variables in this study are the participation decision of the farmers in small-scale irrigation practice and intensity of participation in small-scale irrigation practice. Since one of the dependent variables of this study, household's participation decision in small-scale irrigation practice is dichotomous (binary), it takes a value of 1 if the household has participated in small-scale irrigation practice and zero otherwise. If the scope of this study is only the participation decision of the farmers, it is possible to use either binary logit or binary probit model. As indicated in Gujarati (1995), logit or probit models are widely applied to analysis of determinant studies for a limited dependent variable and their result is similar. Contrary to this, Green (2003) suggests that although both model results with similar outputs, the logit model is easier in estimation, even though this is not the problem nowadays, since it is the work of the computer software within the couple of seconds. This two models are used only for the analysis of probability of participation in particular technology. This means they are only suited in determining the probability models but not for linear models. Tobit model, Heckman two step and Double hurdle model are the models suited to analyze the factors determining the probability of participation and intensity of participation under different underlying assumptions.

Initially it was assumed that the intensity of participation depends on the participation decision of the farmer in small-scale irrigation practice. Based on this assumption, Tobit model following Tobin (1958), was initially proposed to be used for the purpose of analyzing the determinants of participation of farmers in small-scale irrigation practice, by using one coefficients estimate, to estimate both the probability and intensity of participation. After collecting the data, the estimation was undertaken by Heckman two step procedure and lambda (λ) which indicates the inverse mills ratio (IMR) was insignificant, which indicates that there was no significant sample selectivity bias and the use of Heckman two-step procedure is inappropriate.

Furthermore, it was found that the two dependent variables were determined by different sets of explanatory variables from double hurdle model result, which fulfil the assumption of double hurdle model not Tobit. In addition to the above condition, test on the best fit of the models among Tobit and Double hurdle model using log-likelihood ratio test following Newman *et al.* (n.d.), was made and Double hurdle was found to be the best fit than Tobit model and the test can be referred from appendix part (Appendix Table 1). The coefficients for the two dependent variables were absolutely different and their significant variables were not the same for the two dependent variables. Therefore, the Double hurdle model was selected and used for the sake of analyzing the determinants of participation decision (first hurdle) and intensity of participation in small-scale irrigation (the second hurdle).

Intensity of participation in irrigation practice by the farmers was measured in terms of the proportion of land allocated to irrigated farming by farmers. Therefore, this variable (proportion of irrigated land) is continuous limited dependent variable. It can be zero or some value greater than zero. Truncated regression as one part of double hurdle model has been used in estimating the intensity of participation in irrigation practice by farmers by using the data that is truncated from below with the lower limit of proportion of Irrigated land at zero.

Double hurdle model have two parts which are estimated by two hurdles. The first one is the probit model used in estimating the factors determining the probability of participation in small-scale irrigation practice and the second one is truncated regression that is used to estimate the intensity of participation in small-scale irrigated farming by the farmers.

Based on Burke (2009) the double hurdle model with the two parts is specified using two different latent variables, to model each decision process, with a probit model to determine participation decision and a truncated regression model to determine the intensity of participation in small-scale irrigation.

Participation decision equation is specified as follows:

$$Y_{i1}^{*} = X_1 \beta_1 + \varepsilon_{i1}, \ \varepsilon_{i1} \sim N(0, \delta_1^2)$$

$$Y_{i1} = \begin{cases} 1, \text{if } Y_{i1}^{*} > 0 \\ 0, \text{if } Y_{i1}^{*} \leq 0 \end{cases}$$

Intensity of Participation Equation is specified as:

$$Y_{i2}^{*} = X_2 \beta_2 + \varepsilon_{i2}, \ \varepsilon_{i2} \sim N(0, \delta_2^2)$$

$$Y_{i2} = \begin{cases} X_2\,\beta_2 \;+\; \varepsilon_{i2}, \text{if } Y_{i1} = 1 \text{ and } Y_{i2}^* > 0 \\ 0, \text{if } Y_{i2}^* \leq 0 \end{cases}$$

where Y_{i1}^* is unobserved (latent) variable for the participation decision in small-scale irrigation,

Y_{i1} is the observed discrete decision of the farmer whether he/she has participated or not in small-scale irrigation practice,

The subscript i refers to the ith household,

the subscripts 1 and 2 refers to the variable and parameters related with the participation equation and the intensity of participation, respectively.

X_1's are the index of explanatory variables determining the participation decision of the farmers in small-scale irrigated farming,

β_1's refers to the index of parameters related with explanatory variables determining participation decision of the farmer,

ε_{i1} is the error term of the participation equation which is normally distributed ($\varepsilon_{i1} \sim N(0, \delta_1^2)$), with zero mean and constant variance,

Y_{i2}^* is unobserved (latent) variable for the intensity of participation in small-scale irrigation,

Y_{i2} is the observed actual proportion of land allocated for small-scale irrigation by the farmer,

X_2's are the index of explanatory variables determining the intensity of participation in small-scale irrigated farming by the farmers,

β_2's refers to the index of parameters related with explanatory variables determining intensity of participation in small-scale irrigation by the farmers,

ε_{i2} is the error term of the intensity of participation equation which is normally distributed ($\varepsilon_{i2} \sim N(0, \delta_2^2)$) with zero mean and constant variance,

Analysis of marginal effects of participation decision (probit part of double hurdle)

The marginal effects that would be determined from the estimation of probit part of double hurdle model in this particular study interest can be determined by using the formula of partial derivations/ partial effects based on Burke (2009).

The marginal effect, the effect of a unit change or discrete change in explanatory variables on the probability of participating in small-scale irrigated farming can be given as follows.

$$\frac{\partial P(Y_{i1} = 1/X_i)}{\partial X_j} = \beta_j \phi(X\beta)$$

Where β_j is the coefficient on X_j and $\phi(X\beta)$ is the standard normal probability density function evaluated at $(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots)$.

For the continuous explanatory variables, these marginal effects are used to calculate elasticity at the sample means because the slope of the dependent variable is not constant at different per unit change of the variables. For the discrete or categorical variables, the marginal effects are used to calculate percentage changes in the dependent variable when the variable shifts from zero to one, *ceteris paribus.*

3.4.2.2. Impact evaluation strategies

For several underlying conditions, the propensity score matching method was used in this particular study. Propensity Score Matching (PSM) is used when it is possible to create a comparison group from a sample of non-participants closest to the treated group using observable variables. Both groups are matched on the basis of propensity scores, predicted probabilities of participation given some observed variables. Propensity score matching consist of four phases most commonly: estimating the probability of participation, i.e. 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).

For this study, in analyzing the impact of irrigation practice on household income, propensity score matching has been used for several reasons. Firstly, there was no baseline data on participants and nonparticipants as it is common in many research works conducted on impact evaluation. Secondly, the participants in small-scale irrigation may be self-selected to participate. Furthermore, the available field data was based on a cross-sectional survey. Finally, it is possible to identify some features, in this case socio-economic, institutional and physical characteristics, to match the participants and non-participants.

The interest of the impact part of this study was determining the average treatment effect on the treated (ATT) of irrigation practice. 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). Even though it is possible based on the with and without data it will be biased estimator under selectivity biasness. To solve this problem, PSM was used because it provides an appropriate solution (Rosenbaum and Rubin, 1985). 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.

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 matching and kernel matching. These matching methods use different means of matching the treated to the control group to determine the average effect of a given program participation or intervention.

The above three matching algorithms were tested to be used in the estimation of the impact of participation in small-scale irrigation and the best of the three was selected after undertaking the test for the three most common PSM algorithms. But there is no clear rule for determining which algorithm is more appropriate in each context. However, a key issue that has been considered was that, the selection of the matching algorithm implies a bias / efficiency trade-off. For instance, by using only one nearest neighbor we guarantee that we are using the most similar observation to construct the counterfactual. This minimizes the bias, since the characteristics between both units will be, in general, very similar. However, using this technique ignores a lot of information from the sample, since many untreated units are not used for the estimation. Therefore, the reduction in the bias comes with an increase in the imprecision of the estimates caused by a higher variance, i.e., a decrease in efficiency. On the other hand, when using many neighbors, the estimator is more efficient since it exploits a larger quantity of information from the untreated pool, but at the expense of increasing the bias by using poorer matches.

The choice of the matching algorithms was based on the most important tests to reduce the bias and inefficiency simultaneously. These test include mean bias, the number of matched sample, the value of pseudo R square, and the number of the balanced covariates. When considering the mean bias, the one with lowest mean bias is better matching algorithm. Based on number of samples matched, the one with the highest matched number of observation is the best and selected. When coming to the value of the pseudo R square after matching, the matching algorithm with the lowest pseudo R square is the best matching algorithm. On the other hand, the matching algorithm with the highest number of balanced covariates is more appropriate. Hence, based on the overall test of the these criteria the kernel caliper matching algorithm was selected and used in the determination of the effect of participation in irrigation on household income.

3.5. Description of Variables and Hypothesis

3.5.1. Dependent Variables

Participation decision of farmers in small-scale irrigation practice

The first dependent variable was participation in small-scale irrigation practice taking value of 1 if the farmer participated and 0 if not participated in small-scale irrigation practice. The main intension here is to identify the factors determining the participation of the farmers in small-scale irrigation practice.

Intensity of participation in small-scale irrigation practice by farmers

This variable is a continuous variable measured in terms of proportion of land irrigated by the farmers. It represents the actual proportion of land under small-scale irrigated farming by the households in 2016/2017. It take zero value if the farmer is non participant and takes continuous value greater than zero if the farmer is participant.

3.5.2. Explanatory Variables

For explanatory variables, there is no underlying principle for what variables should be included in the model (Anderson et *al*., 2009). Hence, the study was based on economic theory and empirical studies conducted previously to know which independent variables influence individual participation in small-scale irrigation practice at farm household level.

Therefore, the regressors found most commonly affecting irrigation practice are defined and hypothesized below and the summary of the expected signs and hypothesis is given in Table 2.

Age of household head (Age): This variable is continuous measured in years. From the findings of different studies age of household head is found negatively affected the participation in irrigation practice by farmers and intensity of participation (He *et al*., 2007; Beyan *et al*., 2014; Edo, 2014; Gebrehaweria *et al*., 2014; Sithole *et al.*, 2014; Nhundu *et al*., 2015; Wang *et al*., 2015). Therefore, this variable was hypothesized as influencing the small-scale irrigation practice participation and intensity of participation of the farmers negatively.

Sex of the respondent (Sex): This variable is dummy variable taking value of 1 if the sex of the household head is female or 0 if the sex of the household head is male. This variable is found that as the probability of participating in irrigation practice and irrigated area will be higher for male headed household as compared to female headed households as sources from different studies indicate (Muhammad *et al*., 2013; Gebrehaweria *et al.*, 2014; Kinfe *et al*., 2012). In most cases the small-scale irrigation in rural areas is carried out as extra farm activity and supplementary source of income for covering the extra household expenditures and the effort required may be hard to female headed households to participate in small scale irrigated farming. Therefore, this variable was hypothesized as, if the household head is female there would be low probability of participating in small-scale irrigation practice and less area of land to be irrigated when found participating in irrigated farming.

Educational status of the respondent (Education level): This variable is continuous variable measured in terms of years of schooling, taking zero if the farmer is illiterate and some value greater than zero if the farmer is literate. This variable is found by different researchers as the literate respondent most probably participate in small-scale irrigation practice than illiterate counterparts (Abebaw *et al*., 2015; Muhammad *et al.*, 2013; He *et al*., 2007; Edo, 2014). This can be due to the knowledge on the technologies they can get from education or by reading or utilizing the social medias. On the other way round, the literate farmers may be able to plan for getting higher income by using both irrigated farming and rain-fed rather than being reluctant to participate in small-scale irrigation practice than illiterate farmers. Based on these reasons, this variable was hypothesized as being more an educated the respondent the more probability of participating in small-scale irrigation practice and irrigating more area of land than illiterate counterparts.

Total annual income of the household (Income): This variable is continuous variable, which is the total annual income measured in Ethiopian Birr. Evidences (Kinfe *et al*., 2012; Abebaw *et al*., 2015) show that this variable is positively and significantly affecting the small-scale irrigation practice participation of the farmers. The higher the total income of the household, the higher the probability of participation in small-scale irrigation practice by the farmers. This could be the case if the farmers with higher income can cover the irrigation cost easily than lower income households. The farmers with higher income can easily buy the inputs required for irrigated farming than lower income households. Therefore, this variable was hypothesized as influencing the small-scale irrigation participation decision of the farmers and its intensity positively.

Number 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; Sithole *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 and intensity of participation positively.

Land holding size (Land size): This variable is continuous variable measured in terms of hectare. Those farmers having larger area of cultivable land were found to participate more in irrigation practice than their counterpart as the evidences indicate (Beyan *et al*., 2013; Abebaw *et al*., 2015; Sithole *et al.*, 2014). But it is found influencing the participation decision negatively by Edo (2014) and it is found positively influencing the area of land allocated for irrigation positively (Wang *et al*., 2015). Large size of cultivated land is sometimes seen as social status. Because the status they have in the society may encourage those farmers to participate in irrigated farming to maintain their status in the society. Therefore, this variable was hypothesized as influencing the small-scale irrigation participation without predetermination of the direction and influencing the area of land allotted for irrigated farming by the farmers positively.

Distance of the nearest market (Market distance): This is a continuous variable measured in hours it takes the farmer to arrive at the nearest market on foot. This variable is directly related to transaction cost and it is used as a proxy. When transaction cost increases it discourage participation in irrigation. Sources indicate different results, that the farther the distance of the market from the farmers residence area, the lower the probability of the farmers participation in small-scale irrigation practice (Kinfe *et al*., 2012). But study by Hadush (2014) indicated a positive relationship between participation and distance to the nearest market from irrigation. The finding of Kinfe *et al*. (2012), can be due to the cost of transportation to take the outputs produced from irrigation farm, the less accessibility of transportation means. But the other one by Hadush (2014) could be competition for irrigation water at nearby market leads to shortage of water and lower the irrigation practice by individual farmer. Therefore, this variable was hypothesized as influencing the participation decision of the farmers in irrigation practice and its intensity without predetermination of the direction.

Market information: 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 by several studies (Abebaw *et al*., 2015; Kinfe *et al*., 2012; Pokhrel *et al*.,2016). This may be rendered that the information on the market, such as input and output price enable the farmers to be benefited from the production under irrigated farming. If the farmers does not have an information on the demand of the product, they may not be encouraged to produce since they do not know that production will have positive return or loss. Therefore, this variable was hypothesized to influence the irrigation participation and proportion of irrigated land positively.

Training on issue of irrigation (Training): This variable is dummy variable which take a value of 1 if the farmer has got at least one training on the issue of irrigation or 0 if the farmer did not get any form of training regarding irrigation issue. It is indicated by evidences that the farmers that obtained training on irrigation were found to participate in irrigation practice and irrigate more area, as compared to the farmers that did not get any training on irrigation (Abebaw *et al*., 2015; Nhundu *et al*., 2015). Training can create awareness in the farmers on the advantage of irrigation, the management of irrigation, and the knowhow and this may enable the farmers to participate more in irrigated farming. Therefore, this variable was hypothesized to influence participation 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 (use) by different researchers was found affecting the irrigation practice decision of the farmers positively (Muhammad *et al*., 2013; Sithole *et al.*, 2014). The farmers having access to credit are able to buy irrigated farming inputs required on time than those who do not have credit access. If the farmers cannot get budget to purchase the inputs from their own fund and if they do not have access to credit on the proper time and place, they may be unable to undertake the irrigated farming and it affects them negatively. Therefore, this variable was hypothesized to affect participation decision and intensity of participation in irrigation positively.

Distance of plot of land from water source (Farm distance): This variable is continuous variable measured in terms of walking hours on foot. It is found by different scholars as it hampers participation in irrigation practice (Kinfe *et.al*, 2012; Beyan *et al*., 2014; Sithole *et al.*, 2014). This factor leads to the higher cost for the farmers to bring the irrigation water to their plot of land, or even they may be unable to apply the irrigation water to their plot of land because of high cost required. Thus, this may force the farmers having the plot of land far from the source of irrigation water not to practice small-scale irrigated farming at all. Therefore, this variable was hypothesized to influence participation in small-scale irrigation and intensity of participation negatively.

Family size: Family size is a quantitative 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 (Hadush, 2014; Tewodros *et al*., 2013). This may be the case when the family members are used as the labor force in irrigated farming. This will reduce the cost incurred in hiring external labor. It also enable the availability of labor on time at the time of irrigation reducing the searching time for labor. Therefore, this variable was hypothesized to influence participation in small-scale irrigated farming and its intensity positively. This means that the higher the family size of the household, the higher the probability of participation in small-scale irrigation practice and the higher the area of land the farmer will irrigate.

Total livestock owned (Livestock): This is a continuous variable measured in Tropical Livestock Unit (TLU). The sources show that the higher the total livestock owned by the respondent the higher the probability of participation in small-scale irrigation practice (Hadush, 2014). This result could be related with the possibility of using the livestock sale at the time of irrigated farming as a source of income that can be used for expending on irrigated farming. This means the wealth can be used for more investment. Therefore, this variable was hypothesized to enhance participation in small-scale irrigation practice participation of farmers and intensity of participation.

Access to nonfarm activity (Nonfarm activity): This variable is dummy variable taking on 1 if the respondent has involved non-farm activity or 0 otherwise. The related evidences show that the farmers having access to non-farm income were found participating in irrigation practice than those not having access to non-farm income (Beyan *et al*., 2014; Hadush, 2014). This may be due the reason that the farmers having access to non-farm income may use this extra income on the expenditures required in irrigated farming. Therefore, based on these reasons the variable was hypothesized to influence participation in irrigated farming positively.

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

List of explanatory variables	**Nature and measurement units of variables**	**Hypothesized direction of significance**	**Some of the supporting evidences**
Age of household head (Age)	Continuous (years)	Negative	Beyan *et al*.., (2014); Edo, (2014); Gebrehaweria *et al*., (2014); He *et al*., (2007), Wang *et al*.,(2015)
Sex of household head (Sex)	Dummy (1 if female, 0 otherwise)	Negative	Muhammad et al., (2013); Gebrehaweria *et al*., (2014); Kinfe *et al*., (2012)
Educational status (Education)	Continuous (class year)	Positive	Abebaw *et al*., (2015); Muhammad *et al*., (2013); He *et al*.,(2007); Edo, (2014)
Income (Income)	Continuous (ETB)	Positive	Kinfe *et al*., (2012); Abebaw *et al*., (2015)
Number of oxen (Oxen)	Continuous (TLU)	Positive	Gebrehaweria *et al*., (2014); Sithole *et al*., (2014)
Cultivable land size (Land size)	Continuous (hectare)	Positive/Negative	Abebaw *et al*., (2015); Wang *et al*., 2015; Sithole *et al*. L., (2014)
Market distance	Continuous(hours)	Negative/Positive	Kinfe *et al*., (2012), Hadush, (2014)
Market Information	Dummy (Access=1, 0 otherwise)	Positive	Abebaw *et al*., (2015); Kinfe *et al*., (2012); Pokhrel *et al*.,(2016)
Training	Dummy (1 if trained, 0 if not)	Positive	Abebaw *et al*., (2015); Nhundu *et al*., (2015)
Credit access(Credit)	Dummy (1 if used, 0 if not)	Positive	Sithole *et al*., (2014); Muhammad *et al*., (2013), Abebaw, (2011)
Distance of plot of land from water source (Farm distance)	Continuous (hours)	Negative	Beyan *et al*., (2014); Sithole *et al*., (2014); Kinfe *et.al*, (2012)
Family size	Discrete	Positive	Hadush, (2014); Tewodros *et al*. (2013)
Total Livestock owned (Livestock)	Continuous (TLU)	Positive	Hadush, (2014)
Access to non-farm activity (Non-farm activity)	Dummy (Access=1, 0 otherwise)	Positive	Beyan *et al*., (2014); Hadush, (2014)

4. RESULTS AND DISCUSSION

This chapter is concerned with the discussion of the results obtained from the survey data and secondary data from both qualitative and quantitative analysis. Therefore, it includes the descriptive analysis of the farm household characteristics in the study area, factors determining the participation decision of the farm households in small-scale irrigated farming as well as factors determining the intensity of participation and the impact of small-scale irrigation on household income. Lastly, major challenges (constraints) and opportunities in small-scale irrigated farming in the study area are presented in this chapter.

4.1. Descriptive Analysis

4.1.1. Socioeconomic Characteristics of Sample Farmers

Under this sub-section, the socioeconomic, institutional and environmental features of the farm households in Abay Chomen district are presented.

The summary of socioeconomic characteristics of the farmers along with the mean difference test (t-test) of continuous variables is presented in Table 3. As it can be observed from Table 3, the mean, standard deviation, minimum and the maximum values of the variables are computed for the entire sample and for the groups, participants and non-participants. After estimating the mean values, the significance of mean difference test was undertaken by two-group mean comparison test for the continuous variables. The distribution of the categorical variables related with irrigation participants and non-participants is given on Table 4. The proportion of the respondents falling into these categories are given and the difference of the proportion across participants and non-participants was tested by using chi-square test. The detailed discussion of both continuous and categorical variables is presented under different conceptual groups.

4.1.1.1. Demographic characteristics

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 practice. The mean age of non-participants was 44.13 years with minimum and maximum age of 20 and 82 years, respectively, and that of participants was 39.51 years, with minimum and maximum values of 20 and 70 years, respectively. The descriptive analysis revealed significant difference in age of household heads between participants and non-participants in irrigation. The mean difference age of household head between the non-participants and participants was significant at 5% (Table 3). The result indicated that the age of non-participants was higher as compared to participants.

Family size: The mean family size of the total sample households in the study area was about 6, with minimum and maximum family size of 2 and 12 respectively (Table 3). The descriptive analysis revealed that there was no significant difference in the family size of households between participants and non-participants in irrigation practice.

Sex of household head: Concerning the sex of household head, about 93 % of the total household heads were male, where as the proportion of the male headed households for participants and non-participants were about 95% and 92%, respectively (Table 4). The chi-square test result on this variable shows that there was no significant difference between participants and non-participants

4.1.1.2. Social and human capital

Education level: The mean years of education of the total households in the study area was 3.68 in terms of years of schooling, where as the non-participants and participants had a mean education level of 1.78 and 5.78 years of schooling, respectively (Table 3). There was significant difference in the education level between participants and non-participants household heads at 1% level of significance. The result indicates that, the education level of the non-participants was lower as compared to participants.

Training on irrigation issues: For the total observation about 42% of households did not obtain training on irrigation issue. About 62.4% of the non-participants and 19.5% of the participants had no training on irrigation (Table 4). There was highly significant difference between the participants and non-participants in terms of participation in training at 1% significance level. The result on this variable indicates that the irrigation participant households had obtained training on irrigation more than non-participant households.

Irrigation experience: The mean irrigation experience of the total households in the study area was 3.89 years, with minimum and maximum experience of 0 and 32 years, respectively with the standard deviation of 5.4 year. But the mean irrigation experience of the non-participants was 1.21 with the minimum and maximum experience of 0 and 15 respectively and standard deviation of 2.65, where as that of the participants was 6.84, 0 and 32 respectively with standard deviation of 6.09 (Table 3). The descriptive analysis revealed that there was significant difference in the year of experience of households between participants and non-participants in irrigation practice. The mean difference of irrigation experience between the non-participants and participants was negative and it was highly significant at 1%. This implies that the experience of the participants was higher as compared to non-participants. Someone may assume that the irrigation experience of non-participants would be zero, but in this particular case of study the experience of non-participants on average was different from zero, because they were participating in irrigated farming some years ago, but not practicing currently. This indicates that, there was dis-adoption in irrigated farming and it is one problem observed in the study area which needs further analysis for the reason behind dis-adoption by researchers in the future.

4.1.1.3. Asset holding/Economic characteristics

Total income of the household: This was analyzed as characterizing the farm households in the study area related with the irrigation participation. The mean annual income of the sample households in the study area was Birr 39956.31, with minimum and maximum annual income of Birr 2873 and 210360, respectively. But the mean annual income of the non-participants was Birr 30175.35 with minimum and maximum annual income of Birr 2873 and 113575 respectively, where as that of the participants is Birr 50753.48, with minimum and maximum annual income of Birr 6036.5 and 210360 respectively. The descriptive analysis revealed that there was significant difference in the annual income of households between participants and non-participants in irrigation. The mean difference between the non-participants and participants was significant at 1% significance level. This implies that the income of the participants was higher as compared to non-participants.

Number of oxen owned: Concerning the number of oxen owned, the number of oxen owned by total households in the study area was 2.56 on average, and the minimum and maximum number of oxen was 0 and 8, respectively. The mean number of oxen owned for the non-participants was 1.6, where as that of the participants was 3.61. 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 irrigation practice. This implies that the number of oxen of the participants was higher as compared to non-participants.

Cultivable land size: This was also 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 cultivable land size calculated for the total sample households in the study area was 2.82 ha, with minimum and maximum cultivable land size of 0.25 and 10 ha, respectively. On the other hand, the mean cultivable land size of the household for non-participants was found to be 2.36 ha, with the minimum and maximum cultivable land size of 0.25 ha and 8.5 ha, respectively, where as that of the participants is 3.31 ha, with minimum and maximum of 0.25 ha and 10 ha, respectively. The descriptive analysis revealed that there was significant difference in the cultivable land size of households between participants and non-participants in irrigation practice at 1% level of significance. This implies that the participants have higher cultivable land size on average when compared to that of non-participants.

Total livestock holding: It was one of the economic (asset holding) characteristics of the farm household analyzed in the study area. The mean total livestock holding of the total households is 11.47 TLU. But the mean livestock holding of the non-participants was 10.32 TLU, while that of the participants was 12.75 TLU. There was significant difference at 5% 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.

Access to non-farm activity: The proportion of households that does not have access to non-farm activity was about 83% for the total sampled households. The proportion of households that have access to non-farm activity for non-participants was about 81% where as that of participants was about 84.4% and the chi-square value of the proportionality test for this variable indicates that there was no significant difference.

Table 3. Summary statistics of continuous variables

For the Total Observation =162					Non-participants=85				Participants=77				Mean diff.
Variable	**Mean**	**Std. Dv.**	**Min**	**Max**	**Mean**	**Std. Dv.**	**Min**	**Max**	**Mean**	**Std. Dv.**	**Min**	**Max**	**test (t value)**
Age	41.93	12.85	20	82	44.13	12.83	20	82	39.51	12.51	20	70	2.32**
Income (1000)	39.96	28.56	2.87	210.36	30.18	22.25	2.87	113.58	50.75	30.91	6.04	210.36	-4.90***
Oxen	2.56	1.51	0	8	1.6	1.00	0	6	3.61	1.25	0.00	8.00	-11.35***
Land size	2.82	1.82	0.25	10	2.36	1.57	0.25	8.50	3.31	1.95	0.25	10	-3.43***
Market distance	1.04	0.62	.03	2.42	1.14	.63	.15	2.42	0.96	0.61	0.03	2.25	1.90**
Farm distance	11.06	5.85	0	25	15.22	4.56	3	25	6.46	2.97	0	14	14.32***
Family size	5.67	1.87	2	12	5.74	1.96	2	12	5.60	1.77	2	10	0.49
Livestock	11.47	6.69	0	33.46	10.32	6.29	0.12	29.84	12.75	6.92	0	33.46	-2.34**
Education	3.68	3.84	0	13	1.78	2.15	0	10	5.78	4.19	0	13	-7.76***
Road distance	0.397	0.165	0.08	0.78	0.46	0.16	0.08	0.78	0.33	0.14	0.08	0.75	5.29***
Experience	3.89	5.40	0	32	1.21	2.65	0	15	6.84	6.09	0	32	-7.76***

** and ***, indicates significant at 5% and 1% level of significance

Source: Own computation from the survey data, 2017.

4.1.1.4. Institutional characteristics

Market distance: This variable was analyzed across the farm households as their characteristics in the study area related with irrigation practice. This factor is a proxy for transaction cost. From the descriptive analysis, the mean walking distance of the market for the total sample households in the study area was 1.04 hour, with minimum and maximum market distance of 0.03 hour and 2.42 hour (2:25), respectively. But the mean walking market distance of the non-participants was 1.14 hour with the minimum and maximum market distance of 0.15 hour (0:09 minutes) and 2.42 hour (2:25) respectively, where as that of the participants was 0.96 hour (0:58), with minimum and maximum values of 0.03 hour (about 2 minutes) and 2.25 hour (2:15) respectively. 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 practice at 5% significance level. The result indicates that the market distance for the non-participants is higher as compared to that of participants.

Market information access: Market information access on input and output price was also analyzed across participants and non-participants in small-scale irrigation practice. For the total observation, 46.3% of households does not have any information on input and output prices, where as 77.7% of non-participants and 11.7% of the participants have no information on input and output prices. The chi-square value indicates that there was highly significant difference between participants and non-participants on accessibility of market information concerning input and output price at 1% level of significance.

Credit use: This variable was another significant categorical variable that was analyzed across participants and non-participants. For the total sampled households, about 62.4% did not use credit, where as the proportion of those did not use credit are 80% for non-participants and 42.9% for participants. Chi-square test indicated highly significant difference between participants and non-participants at 10% significance level.

4.1.1.5. Physical characteristics

Distance of plot of land from water source was used in the analysis of the characteristics of the farm household in the study area. The mean walking distance of land from irrigation water source for the total households in the study area was found to be 0.18 hour (0:11), with minimum and maximum walking distance of 0 and 0.42 hour (0:25), respectively. But the mean distance of land for the non-participants was 0.254 hour (0:15) with the minimum and maximum distance of 0.05 hour (0:03) and 0.42 hour (0:25), respectively, where as that of the participants was 0.11 hour (0:07) mean walking distance, the minimum and maximum walking distances were 0 hour and 0.23 hour (0:14) respectively. The descriptive analysis on this variable revealed that there was significant difference between participants and non-participants in irrigation practice at 1% level of significance. This implies that the distance of farm land from irrigation water for non-participants was higher as compared to participants.

Distance of main road from farm: The mean distance of main road from farm for the total households in the study area was found to be 0.397 hour (0:24), while the mean figures are 0.46 hour (0:28) and 0.33 hour (0:20), concerning the distance of main road from farm for non-participants and participants, respectively. There was significant difference on the main road distance of households between participants and non-participants at 1%. The result of the analysis shows that the distance of main road from farm for non-participants was higher as compared to participants.

Table 4. Distribution of the categorical variables across participant and non-participants

For the Total Observation =162			**Non-participants=85**	**Participants=77**	**Chi^2 value**
Variable		**Frequency (proportion/%)**	**Frequency (proportion/%)**	**Frequency (proportion/%)**	
Training	Not trained	68 (41.98)	53 (62.35)	15 (19.48)	30.49 ***
	Trained	94 (58.02)	32 (37.65)	62 (80.52)	
Sex	Male	151 (93.21)	78 (91.76)	73 (94.81)	0.59
	Female	11 (6.79)	7 (8.24)	4 (5.19)	
Market info.	No access	75 (46.30)	66 (77.65)	9 (11.69)	70.7 ***
	Access	87 (53.70)	19 (22.35)	68 (88.31)	
Credit	No access	101 (62.35)	68 (80.00)	33 (42.86)	23.74 *
	Access	61 (37.65)	17 (20.00)	44 (57.14)	
Non-farm activity	No Access	134 (82.72)	69 (81.18)	65 (84.42)	0.29
	Access	28 (17.28)	16 (18.82)	12 (15.58)	

* and ***, shows significant at 10% and 1% level

Source: Own computation result from survey data, 2017

4.1.2. Types of Irrigation Used

From the total participant sample households, the majority (78%) uses the traditional river diversion (Table 5). Motor pump was the other irrigation type used by the farmers in the study area. There were about 9% of the participants that use motor pump irrigation. The lower number of the farmers use modern micro dam. This was the micro dam constructed by the Sustainable Land use and Management (SLM) project and the farmers around this project uses this modern micro dam irrigation. The other 10% of the participant households use other means of irrigation such as hand dug bucket watering and flood plain and draining wet lands.

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

Irrigation type	Frequency	Percent	Cumulative
modern micro dam	2	2.6	2.6
traditional river diversion	60	77.92	80.52
motor pump	7	9.09	89.61
Others	8	10.39	100.00
Total	77	100.00	

Source: Own computation from survey data, 2017

4.1.3. Irrigated Land Size Per Household

The average irrigated land size for the study area for the whole population was found to be 0.1892 ha which was less than the national average which has been previously estimated to lie between 0.25 to 0.5 ha per household (MoA, 2011a). The standard deviation of this average for the total sample was higher than the mean irrigated land size, which indicates that there was high variation, because it includes the non-participants for which the irrigated land size was zero.

The mean irrigated land size for the study area for the irrigators was found to be 0.398 ha and it was within the range of national average. The minimum and maximum irrigated land size for the participants was found to be 0.125 and 2 ha with the standard deviation of 0.326 ha which was less than the mean value which indicates that it was less varied than that of for the whole sample (Appendix Table 2).

4.2. Factors Determining Participation in Small-Scale Irrigation

The probit regression part of double hurdle model result, given on Table 6, reveals that out of the 14 explanatory variables, five explanatory variables were found significantly determined the participation decision of the farmers in small-scale irrigated farming, at different significance levels. These variables include number of oxen, market distance, farm distance from irrigation water source, market information and credit use. These variables influences the participation decision of the farm household in different directions.

Number of oxen (Oxen): This variable was found be significant at 1% significance level and positively related to household participation decision in small-scale irrigation practice. It shows that all other factors being kept constant, predicted probability of small-scale irrigation participation decision increases as the number of oxen of the household increases. When coming to the marginal effect of this variable, 0.1992 indicates that a unit increase in the number of oxen leads to increase in probability of participating in small-scale irrigated farming by 19.92%, holding other factors constant at their mean level. This finding is inherent in the area, because farmers that have large number of oxen use their oxen as draft power for land preparation rather than using other mechanized way of land preparation and they are more likely involve in small-scale irrigated farming. The study result was consistent with the work of Gebrehaweria *et al*. (2014) and Sithole *et al.* (2014).

Market distance: This variable was found negatively and significantly affected the participation decision of the farmers in small-scale irrigation at 1% significance level. The estimated marginal effect of this variable, (-0.3106), indicates that the probability of participating in small-scale irrigated farming decreases by 31.06% as the market distance increases by one walking hour on foot. This finding was the same with the finding of Kinfe *et al*. (2012) and contradictory with the finding of Hadush (2014). The possible reason for this finding is that the farther the farmer from the market center, they face the problem of taking their product to the market easily and this may have lead them not to participate or participate less in small-scale irrigated farming as compared to the farmers nearer to the market.

Table 6. Estimated participation model part of double hurdle (probit part)

Variables	Coefficient	Robust Std. Err.	Z	Marginal Effect
Age	-0.0057	0.0190	-0.30	-0.0015
Road distance	-0.4205	1.7406	-0.24	-0.1085
Oxen	0.7723***	0.2527	3.06	0.1992
Land size	0.0939	0.1692	0.55	0.0242
Market distance	-1.2043***	0.3520	-3.42	-0.3106
Farm distance	-0.5030***	0.1175	-4.28	-0.1297
Family size	-0.1167	0.1153	-1.01	-0.0301
Livestock	-0.0549	0.0392	-1.40	-0.0142
Education	-0.0756	0.0972	-0.78	-0.0195
Sex	0.7530	0.6533	1.15	0.2459
Market information	3.0370***	0.9078	3.35	0.6700
Training	0.6435	0.5519	1.17	0.1590
Credit use	0.6693*	0.3847	1.74	0.1849
Non-farm activity	0.9144	0.5785	1.58	0.2911
Constant	2.132	1.570	1.36	
Number of observation = 162				
		Wald chi2(14) = 64.87		
		Prob > chi2 = 0.0000		
Log pseudolikelihood = -14.770713		Pseudo R2 = 0.8682		

*and *** indicates significant at 10% and 1% respectively.
Source: Own computation from survey data, 2017

Distance of plot of land from water source (Farm distance): This variable was significant at 1% level of significance and have a negative relationship with household participation decision in small-scale irrigation practice. It indicates that as distance of plot of land from irrigation water source increases by one walking hour on foot, the probability of participating in small-scale irrigated farming decreases by 12.97%, holding other factors constant. This finding is not surprising, because in developing world, where mechanization is at its minimal stage and every activity is handled manually, an increase in distance of farm land from irrigation water source highly hinders irrigation activity. This phenomena is due to difficulty of bringing water to one's farm land since it involves higher cost as the land becomes more farther from the water source. This finding is in-line with the findings of studies by Kinfe *et al*. (2012), Beyan *et al*. (2014) and Sithole *et al.* (2014).

Market information: Market information on the input and output price by the farmers was found significantly determining the participation decision of the farmers in small-scale irrigation at 1% probability level. It positively influenced the participation decision of the farmers in small-scale irrigated farming. The result of marginal effect of this variable, 0.67, reveals that the predicted probability of participating in small-scale irrigation increases by 67% for the farmers having the market information on input and output price as compared to the farmers who do not have market information. The possible reason for this result may be the encouragement that could be obtained from the possible profitability of irrigated farming expectation when there is access to market information on input and output prices. This finding was consistent with the findings of Kinfe *et al*. (2012) and Abebaw *et al*. (2015).

Credit access (Credit): Access to 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 10% level of significance. From the result of the probit part of double hurdle model, it indicates that the predicted probability of participating in small-scale irrigation increases by 18.49% for the discrete change in this variable from 0 to 1 (change from non user of credit to credit user). In other words it implies that the probability of participating in small-scale irrigation practice for the farmers that have credit access was higher by 18.49% as compared to those farmers who do not have credit access. This result is not surprising, because the farmers in the study area uses credit for irrigated farming as well as rain-fed farming to buy inputs. The same result was found by researchers such as Muhammad *et al*. (2013), Sithole *et al. et al*. (2014) and Nhundu *et al*. (2015).

4.3. Factors Determining Intensity of Participation in Small-Scale Irrigation

The intensity of participation in small-scale irrigation was one of the dependent variables in this study. It was specified as truncated part of double hurdle model under methodology part of this study. Therefore, factors determining the intensity of participation in small-scale irrigation by the farmers in Abay Chomen district was analyzed using the truncated part of double hurdle model. The result is presented on Table 7. The factors that were found to have significant determining power on the intensity of participation were six variables, out of 14 explanatory variables included in the model. These significant variables that determine the intensity of participation were age, number of oxen owned, market distance, education level, road distance and access to credit.

Age of household head (Age): The age of the household head was found significantly affected the intensity of participation in small-scale irrigated farming of farm households at 10% level of significance. The value of the coefficient of this variable indicates that the proportion of land allocated under irrigated farming decreases by 0.78 % as the age of the household head increases by one year (Table 7). This indicates that the aged the farmer, the lower the intensity of participation in small-scale irrigated farming. This was because the farmers who lived long have more wealth than younger farmers do and hence they may not want to exert more effort for their livelihood. The other reason for this finding could be related to the reason that older farmers do not have long term planning and they do not worry about the development on long term and they do not want to invest their time and energy in tiresome job that will bring the long term benefit and improvement in the productivity of their production. This finding was in agreement with the work of scholars such as Wang *et al*. (2015) and Pokhrel *et al*. (2016).

Table 7. Estimation of truncated part of double hurdle model

Variables	Coefficient	Robust Std. Err.	Z
Age	-0.0078*	0.0042	-1.87
Experience	0.0044	0.0054	0.81
Oxen	0.1281**	0.0544	2.35
Market distance	-0.2284**	0.1157	-1.97
Farm distance	-0.0121	0.0125	-0.97
Family size	0.0054	0.0179	0.30
Total livestock	-0.0022	0.0080	-0.27
Education level	0.0351***	0.0130	2.69
Road distance	-0.0579*	0.0335	-1.73
Sex	0.1416	0.1436	0.99
Market information	0.0500	0.1544	0.32
Training	-0.0237	0.0861	-0.27
Credit use	0.1921**	0.0935	2.05
Non-farm activity	-0.0418	0.1212	-0.34
Constant	0.2515	0.2698	0.93
/sigma	0.2947***	0.0724	4.07
Limit: lower = 0		Number of observation = 77	
upper = +∞		Wald chi2(15) = 33.55	
Log pseudolikelihood = 25.02105		Prob > chi2 = 0.0039	

*, **, and ***, shows significant at 10%, 5% and 1% respectively

Source: Own estimation from survey data, 2017

Number of oxen owned (Oxen): This variable was found significantly and positively determined the intensity of participation at 5% significance level. This implies that, all other factors being kept constant, the proportion of irrigated land increases by 12.81%, as the number of oxen owned by the household increases by one. This was because farmers that have large number of oxen uses their oxen as draft power on time for land preparation, as it is common in the country and they were more easily able to prepare large area of land than the households that have lower number of oxen and hence more likely involve in small-scale irrigated farming.

Market distance: The result revealed that distance of the market from residence was found negatively and significantly affected the intensity of participation in small-scale irrigation practice by the farmers at 5% significance level. This implies that the proportion of land irrigated by a farmer decreases by 22.84% as the market distance increases by one walking hour on foot. This finding is consistent with the work of Abebe *et al*. (2011).

Education level of household head (Education): This variable was found significantly affected the intensity of participation in small-scale irrigation by the farm households at 1% significance level. It shows that an increase in the year of schooling of household head by one year, leads to an increase in the proportion of land irrigated by the farmer by 3.51%. The same finding was reported by the scholars such as Wang *et al*. (2015) and Pokhrel *et al.* (2016).

Main road distance from farm land (Road distance): The distance of main road from farmland significantly influenced the intensity of participation in small-scale irrigated farming by the farm households at 10% significance level. The coefficient of this variable indicates that an increase in the distance of main road from the farmland by one walking hour on foot, leads to a decrease in the proportion of irrigated land by 5.79%, holding other factors constant. This result would be related with the problem of transporting the product to the market. It was evident that when the farmland is far from the main road, farmers face the difficulty of selling their product at a time and their product will be spoiled, since most of the products are easily perishable. Because of this reason, this factor may have forced farmers to irrigate smaller area of land.

Credit use (Credit): This variable was also found significantly and positively influencing the intensity of participation in small-scale irrigated farming by the farmers, at 5% level of significance. From the result of truncated regression, it indicates that the proportion of land covered by irrigation increases by 19.21% for the discrete change in this variable from 0 to 1 (change from the farmer that did not used credit to the farmer that used credit). In other words, the proportion of land irrigated by the farmers those used credit exceeds the proportion of land irrigated by the farmers with who did not used credit by about 19.21%. This finding is in-line with the result reported by Abebe *et al.* (2011).

4.4. Impact of Small-Scale Irrigation on Household Income

This subsection is concerned with the impact evaluation of participation in small-scale irrigation by farmers on household income. The impact evaluation in this particular case of study was conducted by the use of propensity score matching (PSM) method of impact evaluation mainly because of the absence of baseline data. PSM consists of four phases: estimating the probability of participation, i.e. 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 (Staurt, 2010). Therefore, the above main issues are presented in this subsection.

4.4.1. Estimation of Propensity Score

Any model relating a binary variable to a set of predictors can be used. Therefore propensity scores can be constructed using a logit or probit regression to estimate the probability of a unit's exposure or assignment to the program, the probability of participating in small-scale irrigation, conditional on a set of observable characteristics that may affect participation in small-scale irrigation. In this study, the propensity scores are constructed using the logit regression, because it is the most common model for propensity score estimation as stated in Staurt (2010). Then the overlap condition was determined for the total observations. In order for the propensity scores to correctly estimate the probability of participation, the characteristics included in the propensity score estimation has been well-considered and were exhaustive. However, it is very important that characteristics which may have been affected by the treatment are not included and for this reason the income of the household that is affected by the treatment is excluded from the covariates included in the estimation of propensity score. Table 8, shows the value of the covariates related with the estimation of propensity scores for the individual observations, that is the probability of assigning the observation to participate in small-scale irrigation.

Table 8. Logit model coefficients in estimation of propensity score

Variables	**Coefficient**	**Std. Err.**	**Z**	**P >Z**
Age	-0.0062	0.0441	-0.14	0.888
Oxen	1.4673	0.6202	2.37	0.018
Land size	0.1289	0.4213	0.31	0.76
Market distance	-2.1502	1.3051	-1.65	0.099
Farm distance	-0.9093	0.2943	-3.09	0.002
Family size	-0.1404	0.3643	-0.39	0.7
Total livestock	-0.0953	0.1022	-0.93	0.351
Education level	-0.1390	0.2543	-0.55	0.585
Road distance	-0.7965	4.3357	-0.18	0.854
Sex	1.4452	3.5461	0.41	0.684
Market information	5.4115	1.8820	2.88	0.004
Training	1.2627	1.4234	0.89	0.375
Credit access	1.3298	1.5127	0.88	0.379
Non-farm activity	1.4716	1.5546	0.95	0.344
Constant	4.9869	4.0031	1.25	0.213
Number of observation = 162		LR chi2(14) = 194.37		
		Prob > chi2 = 0.0000		
Log likelihood = -14.906577		Pseudo R2 = 0.8670		

Source: Own estimation from survey data, 2017

The common support region (overlap condition) for the estimated propensity score is constructed based on the summary statistics of the participants and non-participants. Therefore, the common support region was determined by taking the maximum of the minimums and minimum of the maximums for the two groups propensity scores. Based on this technique the common support region was found to be between the value of propensity score of 0.1237672 and 0.9587823 (Table 9). As a result of the overlap condition, 25 observations (8 non-participants and 17 participants) were found to be out of the common support and hence they were excluded from the observations used to analyze the impact of participation in small-scale irrigation on household income (treatment effect on the treated). The common support estimated by kernel density is given in appendix part (Appendix figure 4).

Table 9 . Summary of common support region for estimated propensity score

Variable		Obs	Mean	Std. Dev.	Min	Max
Propensity score	Non-participants	85	0.055007	0.166728	1.21e-16	0.9587823
	Participants	77	0.934874	0.159041	0.1237672	1
	Common support	137	0.5474796	0.274977	0.1237672	0.9587823

Source: Own computation from survey data, 2017

4.4.2. Selecting a Matching Algorithm

Once the propensity scores are estimated, units in the treatment group (beneficiaries) are then matched with non-beneficiaries with similar propensity scores, or probability of participating in the program. There are a number of matching algorithms which can be employed in undertaking the impact evaluation to get the effect of the treatment. The most common matching algorithms used in PSM include: nearest neighbor matching, radius matching and kernel matching. These matching methods use different means of matching the beneficiaries to the control group to determine the average effect of certain program participation or intervention.

The test for three common matching algorithms in PSM with different criteria were used to test among the matching algorithms and within the matching algorithm under different scenarios (different caliper distance and number of nearest neighbor). The simultaneous test of the matching algorithms, the mean bias, the number of matched observations, the number of balanced covariates and the value of the pseudo R square for best nearest neighbor matching are 8.1, 102, 14 and 0.062; for radius matching are 8.9, 102, 14 and 0.081, for kernel matching are 3.7, 101, 14 and 0.051, respectively. Based on this values of the test, the matching algorithm with the lowest mean bias, lowest pseudo R square, approximately equal number of matched observations and equal number of balanced covariates compared to other matching algorithms, kernel matching is found to be the best, in addition to the fact that this matching algorithm consists of more information in estimating the effect which reduces the variance. Therefore, kernel caliper matching was selected because it represents the best matching algorithm. Hence, kernel matching algorithm was selected as the best matching algorithm under PSM and it was used to estimate the impact of participation in small scale irrigation on household income.

Table 10. Tests on propensity score matching algorithms

Matching Algorithm	Mean Bias	Pseudo R square	No. of matched observations	No of Balanced Covariates
Nearest neighbour	8.1	0.062	102	14
Radius matching	8.9	0.081	102	14
Kernel matching	3.7	0.051	101	14

Source: Own computation from survey data, 2017

4.4.3. Checking for Balance

Once units are matched, the characteristics of the constructed treatment and comparison groups should not be significantly different; i.e., the matched units in the treatment and comparison groups should be statistically comparable. Balance is tested using a t-test to compare the means of all covariates included in the propensity score in order to determine if the means are statistically similar in the treatment and comparison groups. This test, t-test is preferred when the evaluator is concerned with the statistical significance of the results (Solivas, Ramirez and Manalo, 2007). If balance is not achieved; i.e., the means of the covariates are statistically different, a different matching option or specification should be used until the sample is sufficiently balanced. In this case, the balance for the covariates is tested for balance in the mean of covariates across the participants and non-participants and it revealed that the balanced test of the covariates is satisfied by t- test. In addition to the above statistical test, the balance of covariates to be trustworthy, the absolute standardized differences of means of covariates should be less than 25% and the overall absolute mean bias should be between 5 and 2% (Rubin, 2001). This criteria has also been satisfied because the individual covariates mean difference between participants and non-participants is less than 25% and the overall absolute mean bias is 3.7% which is between 5 and 2%. The result of the test is given in Table 11.

Table 11. Test of balance of covariates after matching

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>t
Age	U	39.51	44.13	-36.5		-2.32	0.022
	M	40.25	40.66	-3.2	91.2	-0.09	0.925
Oxen	U	3.61	1.60	177.6		11.35	0.000
	M	2.88	2.81	5.9	96.7	0.11	0.909
Land size	U	3.31	2.36	53.7		3.43	0.001
	M	2.66	2.65	0.4	99.3	0.01	0.992
Market distance	U	0.96	1.14	-29.9		-1.90	0.059
	M	0.84	0.84	-0.1	99.7	-0.00	0.998
Farm distance	U	6.46	15.22	-227.6		-14.32	0.000
	M	7.53	7.83	-7.8	96.6	-0.27	0.788
Family size	U	5.60	5.74	-7.7		-0.49	0.627
	M	6.06	6.05	0.8	89.2	0.02	0.984
Livestock	U	12.75	10.32	36.7		2.34	0.021
	M	10.34	10.81	-7.1	80.5	-0.21	0.832
Education	U	5.78	1.78	120.2		7.76	0.000
	M	4.88	5.05	-5.2	95.7	-0.15	0.882
Road distance	U	0.33	0.46	-83.4		-5.29	0.000
	M	0.40	0.40	-0.6	99.3	-0.02	0.987
Sex	U	0.05	0.08	-12.1		-0.76	0.445
	M	0.00	0.00	0.0	100.0	.	.
Market Information	U	0.90	0.22	183.1		11.55	0.000
	M	0.50	0.48	5.3	97.1	0.11	0.916
Training	U	0.78	0.38	88.8		5.62	0.000
	M	0.56	0.53	7.8	91.2	0.20	0.846
Credit	U	0.57	0.20	82.0		5.24	0.000
	M	0.25	0.27	-5.1	93.8	-0.14	0.886
Non-farm act.	U	0.17	0.19	-5.0		-0.32	0.750
	M	0.19	0.20	-2.6	49.3	-0.07	0.946

Overall balance indicators of covariates

Sample	Pseudo R^2	LR chi2	p>chi2	Mean Bias	Median Bias
Unmatched	0.868	194.64	0.000	81.7	67.9
Matched	0.051	2.25	1.000	3.7	4.2

Note: U-Unmatched, M- Matched

Source: Own computation from survey data, 2017

From the result of testing for balance of the covariates between the treated and comparison group, it shows that there was no significant difference between the two groups on the covariates after matching because the t-test shows absence of significant difference. Therefore, the covariate balance criteria is satisfied.

4.4.4. Estimation of the Effect of Treatment and Interpretation of Results

The estimation of the impact of a certain technology intervention is based on the above mentioned steps of propensity score matching when we do not have the baseline data. Following the 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 and its neighbor or neighbors from the constructed comparison group. The difference in averages of the subjects who participated in the intervention and those who did not can then be interpreted as the impact of the program. The impact evaluation of the average treatment effect on the treated of participation in small-scale irrigation for this study was conducted using kernel matching. Bootstrap method was used to estimate standard errors for matching estimator to account for the fact that the propensity score is also estimated. Table 12 shows the impact of participation in small-scale irrigated farming on household income.

Table 12. Impact of participation in irrigation on household income

Variable	**Sample**	**Treated**	**Controls**	**Difference**	**Std. Error (bootstrapped)**	**T-stat**
Annual	Unmatched	50753.48	30175.35	20578.13	4203.18	4.90
Income	ATT	34834.22	27092.88	7741.33	4157.89	1.86*

* indicates significant at 10% and 1% significance level respectively

ATT- Average Treatment effect on the Treated

Source: Own estimation using kernel matching from survey data, 2017

After estimating the treatment effect, sensitivity analysis, Rosenbaum bound estimation was conducted between the gamma values of 1 and 3, by adding 0.25 on 1 and continuing up to 3, to test whether the treatment effect on the treated is sensitive to the hidden bias (unobservables) (Appendix Table 4). The sensitivity analysis is conducted at gamma 1, 1.25, 1.5…3. The analysis result indicated that the average treatment effect on the treated is not sensitive to an increase in hidden bias (unobservables) up to 200%.

From Table 12, the average treatment effect on the treated is about ETB 7741 and it is significant at 10% significance level. This finding is consistent with certain studies conducted on impact of participation in irrigated farming on household income using propensity score matching (Nicoletti, 2011; Dillon, 2011; Hadush, 2014; Shiferaw and Mengistu, 2015). Therefore, irrigation practice in the study area should be encouraged and the problems hindering small-scale irrigation practice should be attempted to be solved by government and any other stakeholders. The estimation by the three matching algorithms is given in appendix part to show that the estimation is robust, appendix Table 3. Kernel matching and nearest neighbour matching shown almost similar results but the result from radius matching was insignificant.

4.5. Challenges/Constraints and Opportunities in Small-Scale Irrigation Development in the Study Area

There are many challenges and opportunities in the study area related to the small-scale irrigated farming. From the survey as well as key informant interview and focus group discussion it has been indicated that the farmers face many challenges in small-scale irrigation practice. Besides the challenges the data from different sources shown that there are opportunities for small-scale irrigation development. These Opportunities and challenges are discussed below.

4.5.1. Challenges/Constraints

Out of the challenges pointed out by the farmers, lack of market at the time of harvest holds the first rank. The farmers faces shortage of market demand at the time of harvest where prices are very low. This problem forced the farmers to sell their product at low price. There was no market linkage and this lead the farmers to be discouraged to participate in small-scale irrigated farming. The detail of the major challenges/constraints are discussed under this subsection.

The most critical challenge that was indicated in the study area by the focus group discussion as well as by the farmers interviewed was the problem of the topography of the farm land related with available irrigation water source (traditional diversion of surface water). Most of the farmers in the study area also indicated that they were unable to irrigate larger area of land because of difficulty to bring the water from surface water source by traditional river diversion. This problem has a high linkage with the distance of farm land from irrigation water source as surface water was the main source of irrigation water for the majority of the farmers and limited their participation and intensity of participation in small-scale irrigation.

The key informant interview figured out the following major constraints in the study area. These includes lack of knowledge on the efficient use of irrigation by the farmers. Not only the farmers, but also there was lack of trained man power on the irrigation technology and design. This lack of skilled man power lead to the loss of irrigation water when using in irrigated farming since it was dependent on traditional and less effective irrigation technologies such as totally earthen canals.

The lack of market and linkage to other market such as regional or national market was one of the major constraints in the study area. This lack of market lead the farmers not to participate in irrigated farming, or to irrigate lower area of land even if they are participants in irrigated farming.

The other problem pointed out by the key informants was lack of awareness on the sustainable use of water. This problem was inherently shown in the area that the conservation system of water resource was not carefully considered. This problem comes from the lack of knowledge on how to conserve and utilize this resource sustainably. The problem stems from the types of trees to be planted around the water sources and around the irrigated farming areas to use the water efficiently.

Lack of strong linkage between micro finance institutions and smallholder horticultural crop producers of the rural household was explained as it was very weak and it was pointed out as one of the other major constraints restraining the farm households to participate in irrigated farming. In addition to these challenges, as pointed out by key informants, there was no research to overcome the problems and research based extension systems are not adequate to improve the knowhow of the farmers and the development of irrigation systems.

4.5.2. Opportunities

There are opportunities that can help the farmers to be involved in irrigated farming at smallholder level as it was indicated by different sources of information such as sample respondents, focus group discussion and key informants. One of the major opportunities is the availability of surface water in the area. The district has many rivers such as Fincha, Amarti, Neshe, Gogoldas, Korke and many water streams flowing seasonally and throughout the year. Concerning the surface water, since many water streams are flowing throughout the year and high rainfall that can be stored and used for irrigation in the area, mini dams can contribute significantly for irrigating farm land in the area at many low leveled lands around the streams.

The other opportunity is that there is availability of favorable climate condition and ground water in the area. It can be used as an opportunity to produce more than once a year if the farmers could be able to access the ground water by means of treadle pump, hand pump and motor pump, even though the motor pump was indicated as costly both for buying and the energy required in terms of fuel. In the study area, the majority of the farmers indicated that the ground water would be more advantageous to practice small-scale irrigation on their farm land for participants and to increase the area of irrigated land and be benefited from the increase in the production that could be obtained from irrigation and hence increase their income and improve their standard of life. This does not only increase the farmers' standard of living but also contribute to overcome the problem of shortage of food in the other areas of the country if effective and efficient market linkage is created.

The other thing that can be taken as an opportunity for irrigation development in the study area is a great emphasis given for irrigation development by the government at country level. But the study area did not get any government support in terms of irrigation infrastructural development. The area has used more of the indigenous knowledge with little support from consultation of agricultural experts. Therefore, if the government give more support in terms of modern irrigation infrastructure, the study area would be more beneficial for its society as well as feeding the other areas and contributing to economic development of the country.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

This study examined the factors determining participation and intensity of participation in small-scale irrigation by the farm households. It also analyzed the impact of participation in small-scale irrigation on household income. In addition to the above issues it has also identified some of the major opportunities and constraints that the farmers in the study area faced in irrigated farming. The study used double hurdle model to analyze the determinants of participation and intensity of participation in small-scale irrigation and it also used propensity score matching to determine the impact of small-scale irrigation on household income in the study area. The sample of 167 farm households selected by multi-stage sampling technique were used in the analysis.

Participation in small-scale irrigation and intensity of participation in small-scale irrigation are shown to be independent of each other and determined by different sets of explanatory variables. After identifying the best fitting model, the study identified the economic, demographic, institutional and physical factors jointly determined the participation of the farm households in small-scale irrigated farming. It also identified that the different set of explanatory variables such as economic, institutional, farm characteristics and household characteristics were found determining the intensity of participation in small-scale irrigation practice.

For the participation decision of the farmers in small-scale irrigation, the first hurdle of double hurdle model was used by including 14 explanatory variables hypothesized based on previous empirical studies conducted by different scholars and economic theories. Out of these explanatory variables, five of them were found to be significant determinants of participation decision of the farmers in small-scale irrigation. These variables were number of oxen, market distance, farm distance from irrigation water source, access to market information and access to credit. Number of oxen, market information and access to credit positively and significantly determined participation decision of the farmers in small-scale irrigation, while farm distance from irrigation water source and market distance were negatively and significantly determined the participation decision in small-scale irrigation.

This implies that, those farmers who have higher number of oxen, have market information, and have credit access were found participating more in irrigation than those farmers with lower number of oxen, lack market information and non use of credit. On the other hand those farmers with farther distance of land from irrigation water source and farther distance from market were found less participant in small-scale irrigation as compared to those farmers that have land closer to irrigation water source and found nearer to the market.

The intensity of participation in small-scale irrigation was analyzed using truncated regression part of double hurdle model, taking 14 different explanatory variables included in the model. Out of these included explanatory variables, six of them were found to determined the intensity of participation in small-scale irrigation significantly. These variables include age of household head, number of oxen, market distance, education level, road distance and access to credit. Of these explanatory variables, age, market distance and road distance negatively and significantly determined the intensity of participation in small-scale irrigation. This finding reveals that households with older age of household head, farther from market and farther from main road, irrigated lower proportion of land as compared to those farmers with lower value of these variables.

Education level, number of oxen, and access to credit where found positively and significantly determining the intensity of participation in small-scale irrigation by the farmers. This implies that, the farmers with higher level of education, higher number of oxen and those that have access to credit were found irrigating higher proportion of land as compared to their counter parts.

The impact analysis of participation in small-scale irrigation on household income by propensity score matching using of kernel matching algorithm revealed that there was a significant difference on the income of households between participants and non-participants due to participation in small-scale irrigated farming. The average treatment effect on the treated was ETB 7410 and it was significant at 10% significance level. Therefore, the irrigation practice should be encouraged in the study area.

Furthermore, there were many challenges and opportunities pointed out by the farmers and key informants in the study area. The major challenges pointed out include shortage of market demand and low market price at time of harvest, topography of land related with difficulty of bringing water to one's farm land, lack of market linkage, lack of skilled man power on irrigation issues and lack of knowhow were the major constraints figured out in the study area. The opportunities consists of the availability of surface water, favorable climate condition and availability of ground water. These opportunities can be used to the maximum possible benefits if there is a collective action by the farmers. Effective support from different institutions, governmental and any other concerned civic associations could also be key role player. Therefore, it needs calling up on these stakeholders to take part in enhancing the irrigated farming by reducing the hindrances and strengthening available enabling factors in the study area.

5.2. Recommendations

The findings of this study leads to the following specific recommendations.

Market experts of the district should disseminate market information on the input and major products prices, so that the farmers can use the information in deciding the type and timing of crop produced by irrigated farming in Abay Chomen district.

To enable farmers have oxen for farming, the mechanisms such as credit facilities should be put in place so that the farmers can use it for buying the oxen for rain-fed as well as irrigated farming.

The credit system and utilization means need to be facilitated 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 Abay Chomen district.

The study also revealed that farm distance from irrigation water source was found to be hindrance for participation in irrigation with significant effect. This variable was found to be one of the most important determinants of participation in irrigation. Therefore solutions for distance of farm from water source, such as ground water development and water harvesting should be considered and encouraged for the farmers to use it in irrigating their farm land.

Local market linkage between producers and small traders as well as linkage to other markets should be created to the farm-gate if possible to reduce the hindrance coming because of market distance and access problem that discourages participation and intensity of participation in irrigation.

Age was negatively related with intensity of participation in irrigation, hence adult farmers should be encouraged and the aged farmers should be linked to younger farmers to increase the proportion of irrigated land by pooling the resource.

Road distance was found to be a barrier for participation in small-scale irrigation in the study area; therefore, road infrastructure and transportation facility should be improved to enable farmers easily transport products to market.

Household head’s education level was found to be significant determinant of the intensity of participation in small-scale irrigation. Therefore, the farmers should be educated by a means that fits with their living condition, such as adult education.

The study also revealed that there was dis-adoption in the study area as it can be seen from descriptive result on experience in irrigation, but the reason behind dis-adoption was not covered by this study. Therefore, further study should be conducted on the reasons for dis-adoption in small-scale irrigation in the study area.

6. REFERENCES

Abebaw Abiyu, Mesfin Tebeje and Ermias Mekonnen. 2015. Determinants of small-scale irrigation utilization by smallholder farmers' in rift valley basin, Wolaita zone, Ethiopia. *Journal of Natural Sciences Research.* 5(21): 2224-3186.

Abebe Ejigu, Bihon Kassa and Gebremedhin Yihdego. 2011. Determinants of land allocation to irrigation and its wealth effect: Evidence from northern Ethiopia. *Journal of the Drylands*, 4(2): 310-319.

Abebe Hailegabriel. 2000. Development strategies and the Ethiopian peasantry: Supply response and rural differentiation. Shaker Publishing: Maastricht.

Abraham Gebrehiwot Yihdego, Addis Adera Gebru and Mesfin Tilahun Gelaye. 2015. The impact of small–scale irrigation on income of rural farm households: Evidence from Ahferom Woreda in Tigray, Ethiopia. *International Journal of Business and Economics Research*, 4(4): 217-228.

ADEA (Association for the Development of Education for Africa). 2014. Ethiopia Country Report For The 2014 Ministerial Conference On Youth Employment, Abidjan, Côte d'Ivoire, 21-23 July, 2014

Adeoti, I. 2009. Factors influencing irrigation technology adoption and its impact on household poverty in Ghana. *Journal of Agriculture and Rural Development in the Tropics and Subtropics;* 109(1): 51-63.

ADIDO (Abbay Chomen District Irrigation Development Office). 2017. Plan and Performance Irrigation Development Activity Monitoring Report, First Round.

Adugna Eneyew. 2014. Five key constraints to small-scale irrigation development in Ethiopia, socioeconomic view: Review paper. *Global Advanced Research Journal of Management and Business Studies*, 3(10):441-444

Agerie Nega Wassihun. 2016. Determinants of smallholder rural farm households' participation in small scale irrigation and its effect on income in North Gondar zone of Amhara Regional State, Ethiopia. *International Journal of Research and Development;* 5(6): 592-601.

Albouy, D. n.d. Program Evaluation and the Difference in Difference Estimator. *Economics* 131 *section note*: 1- 4

Alemayehu Mengistu. 2006. Country Pasture/Forage Resource Profiles. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy.

Anderson, C., Mekonnen, Ayana. and Stage, J. 2011. Impacts of the Productive Safety Net Program in Ethiopia on livestock and tree holdings of rural households. *Journal of Development Economics*, 94(1):119-126.

Anonymous. n.d. Irrigation sector overview in Ethiopia.

Arun, Agrawal and Catherine S. Benson. 2011. Common property theory and resource governance institutions: Strengthening explanation of multiple outcomes. *Environmental Conservation*, 38(2): 199-210.

Asres Kebede. 2003. Impact of incentive system on soil and water conservation activities in Ambassel area, South Wollo, Ethiopia. MSc Thesis, Haramaya University, Ethiopia.

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

Atkinson, R.D. 2013. Competitiveness, Innovation and Productivity: Clearing up the Confusion, The Information Technology and Innovation Foundation.

Awulachew, S. B, Merrey, D. J., Kamara, A. B., Van Koppen, B., Penning de Vries, F., Boelee, E. and Makombe, G. 2005. *Experiences and opportunities for promoting small–scale/micro irrigation and rainwater harvesting for food security in Ethiopia*. Colombo, Sri Lanka: IWMI. v. 86p. (Working paper 98)

Awulachew, S.B. 2010. Irrigation Potential in Ethiopia. Constraints and opportunities for enhancing the system. International Water Management Institute(IWMI).

Bates, J. and Parkinson J.R. 1983. *Business and Economics*, 3rd ed. Blackwell Publishers, USA.

Baum, C.F. 2013. Propensity Score Matching, Regression Discontinuity, Limited Dependent Variables. Applied Econometrics, Boston College, Massachusett, USA.

Belay Deressa Nemera. 2013. Factors determining adoption of irrigation: the Case of Adami Tulu Jidokombolcha district of Oromia Regional State, Ethiopia. A Thesis submitted to the Wageningen University and Research Centre.

Beyan Ahmed, Jema Haji and Adem Kedir. 2014. Effect of small-scale irrigation on the farm households' income of rural farmers: The case of Girawa district, east Hararghe, Oromia, Ethiopia. *Asian Journal of Agriculture and Rural Development*, 4(3): 257-266

Bonabana-Wabbi, J.. 2002. Assessing factors affecting adoption of agricultural technologies: The case of Integrated Pest Management (IPM) in Kumi district, Eastern Uganda, Msc. Thesis.

Bosa, M. S. 2015. Water institution and management in Cape Verde. *Water journal,* 7(6): 2641-2655.

Caliendo, M. and Kopeinig, S. 2005. *Some Practical Guidance for the Implementation of Propensity Score Matching.* Discussion Paper No. 1588.

Calonico, S., Cattaneo, M. and Titiunik, R. 2013. Robust Data-Driven Inference in the Regression-Discontinuity Design. *The Stata Journal,* 5(2):1-32

Christopher Kevin Nicoletti. 2011. Rural prosperity initiative: Propensity-score analysis of income and crop production effects from a comprehensive micro-irrigation program in Zambia (Doctoral dissertation, Colorado State University).

Cochran W.G. 1977. *Sampling Techniques,* 3rd Ed., New York: John Wiley and Sons, Inc.

CSA (Central Statistical Agency). 2007. National Population and Housing Census of Ethiopia, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2013. Population Projection of Ethiopia for All Regions at Woreda Level from 2014 – 2017. Addis Ababa, Ethiopia.

Debertin, D.L. 2012. *Agricultural Production Economics*. 2nd Edition. University on Kentucky. Upper Saddle River, N.J. USA.

Dereje Mangistie and Desalegn Kidane. 2016. Assessment of the impact of small-scale irrigation on household livelihood improvement at Gubalafto District, North Wollo, Ethiopia. *Agriculture,* 6(3): 01-22.

Dillon, A. 2011. The effect of irrigation on poverty reduction, asset accumulation, and informal insurance: Evidence from Northern Mali. *World Development*; 39(12): 2165-2175.

DOoARD (Abay Chomen District Office of Agriculture and Rural Development). 2016. Annual Report on Rain-fed and Irrigation Agriculture.

Dubois, O. 2011. The state of the world's land and water resources for food and agriculture: managing systems at risk. Earthscan.

Edo Elemo. 2014. Determinants of water utilization for small-scale irrigation among rural households: The case of Dugda Wereda, East Shewa Zone, Oromia Regional State , A Thesis Submitted To School Of Graduate Studies, Haramaya University, Haramaya, Ethiopia.

EEA (Ethiopian Economic Association). 2012. Annual Report on Ethiopian Economy. Addis Ababa, Ethiopia.

Efa Gobena, Degye Goshu, Tinsae Demisie and Tadesse Kenea. 2016. Determinants of market participation and intensity of marketed surplus of teff producers in Bacho and Dawo districts of Oromia State, Ethiopia. *Journal of Agricultural Economics and Development*, 5(2): 020-032

Elinor, Ostrom. 2002. Reformulating the commons, common pool resources. *Ambiente & sociedade,* (10): 5-25.

Elizabeth A. Stuart. 2010. Matching methods for causal inference: A review and a look forward. *Statistical science: Review Journal of the Institute of Mathematical Statistics*, 25(1):1-21.

Emeterio S. Solivas, Girly M. Ramirez and Allan N. Manalo. 2007. The propensity score matching for correcting sample selection bias. *In 10th National Convention on Statistics* (NCS), EDSA Shangri-La Hotel, Mandaluyong City, Philippines (pp.1-2).

FAO (Food and Agricultural Organization). 2012. Comprehensive Africa Agriculture Development Programme, Corporate Document Repository.

FAO (Food and Agricultural Organization). 2015. Ethiopia Country Highlights on Irrigation Market Brief. UNFAO, Rome, Itally. Prepared under Food and Agricultural Organization of United Nations(UNFAO)/International Finance Corporation(IFC) cooperation.

Feder, G., Just, E. R. and Zilberman, D.. 1985. Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* ,33(2): 255-298.

Garcia-Bolanos, M., Borgia, C., Poblador, N., Dia, M., Seyid, O.M.V. and Mateos, L., 2011. Performance assessment of small irrigation schemes along the Mauritanian banks of the Senegal River. *Agricultural water management*, *98*(7):1141-1152.

Gebrehaweria Gebregziabher, Meredith A. Gardiano, Simon Langan J. and Regassa Namara. 2014. Economic analysis of factors affecting motor pump irrigation adoption in Ethiopia. *Academic Journal, Journal Of Development and Agricultural Economics.* 4(3): 257-266

Gebremedhin Gebremeskel and Asfaw Kebede. 2015. Irrigation in Ethiopia: A review. *Academia Journal of Agricultural Research*, 3(10): 264-269.

Godswill Makombe, Regassa Namara, Fitsum Hagos, Seleshi Bekele, Mekonnen Ayana and Deborah Bossio. 2011. *A comparative analysis of the technical efficiency of rain-fed and smallholder irrigation in Ethiopia* (Vol. 143). International Water Management Institute.

Green, W. 2003. *Econometric Analysis*. 5th ed. Prentice Hall. Inc, New York.

Gujarati, D. N. 2004. *Basic Econometrics,* 4th Edition. United States Military Academy, West Point. McGraw-Hill International Editions, USA.

Gujarati, D.N. 1995. *Basic Econometrics*, McGraw-Hill International Editions, (3rd Edition).

Hadush Hailu. 2014. Adoption and Impact of micro Irrigation on Household Income: The case of Eastern Tigray (Doctoral dissertation, Mekelle University).

He, X.F., Cao, H. and Li, F.M. 2007. Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China. *Agricultural water management*, *89*(3): 243-250.

Heckman, J. 1979. Sample selection bias as a specification error. *Econometrica,* 47(-): 153–161.

ILRI (International Livestock Research Institute). 2016. Workshop on Developing Policy for More Effective Management of Water and Livestock Resources for Community Based Irrigation in Ethiopia.

Jacob R. and Zhu P., 2012. A Practical Guide to Regression Discontinuity. www.mdrc.org, accessed on November 14, 2017.

Kay, M. 2001. *Smallholder irrigation technology: Prospects for Sub-Saharan Africa* (No. 3). Food & Agriculture Organization.

Khandker S.R., Koolwal G.B., Samad H.A.. 2010. *Handbook on Impact Evaluation*: *Quantitative Methods and Practices*. World Bank Publications.

Kinfe Aseyehegn, Chilot Yirga and Sundar Rajan. 2012. Effect of small-scale irrigation on the income of rural farm households: The case of Laelay Maichew district, central Tigray, Ethiopia. *The Journal of Agricultural Sciences,* 7(1): 43-57.

Lechner, M. 2010. The Estimation of Causal Effects by Difference-in-Difference Methods. *Foundations and Trends in Econometrics*, 4(3):165–224.

Lee, D. S. and Lemieux, T. 2010. Regression Discontinuity Designs in Economics. *Journal of Economic Literature, 48 (1): 281–355*.

Leyronas, S., Rojat, D., Maurel, F. and Giraud, G. 2016. Towards an analytical framework for the governance of natural resources: The case of ground water, *Papiers de Recherche| Research Papers.*

Loevinsohn M., Sumberg J. and Diagne A. 2013. Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? A Systematic Review.

Mengistu Alemayehu. 2006. Country Pasture/Forage Resource Profiles. *Ethiopia View Article PubMed/NCBI Google Scholar*.

MoA (Ministry of Agriculture). 2011. Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment, Addis Ababa, Ethiopia.

MoA (Ministry of Agriculture). 2013. Food Supply Prospect Report. Disaster Risk Management and Food Security Sector, Ministry of Agriculture (MoA) March 2013, Addis Ababa, Ethiopia.

MoARD (Ministry of Agriculture and Rural Development). 2010. Ethiopia's Agriculture Sector Policy and Investment Framework: Ten Year Road Map (2010-2020), Addis Ababa, Ethiopia.

Monenus Hundara. 2016. The impacts of hydropower projects in Ethiopia: The case of Fincha-Amarti-Nashe (FAN) project in Horo Guduru, western Ethiopia. Fribourg University.

MoWR (Ministry of Water Resources). 2002. Water sector development program 2002-2016, Volume II: Main Report. Ministry of Water Resources, Federal Democratic Republic of Ethiopia, Addis Ababa, October 2002.

Muhammad-Lawal A., Adenuga, A. H. and Jimoh, O. 2013. Determinants of adoption of irrigation technology by small-holder farmers in selected local government areas in Kwara state, Nigeria. *Taraba journal of Agricultural Research,* 1(1): 21-27.

Mwangi M. and Kariuki S. 2015. Factors Determining Adoption of New Agricultural Technology by Smallholder farmers in Developing Countries. *Journal of Economic and Sustainable Development,* 6(5): 208-216.

Newman, C., Hanchion, M. and Matthews, A. 2003. A double-hurdle model of Irish household expenditure on prepared meals. *Applied Economics*, 35(9):1053-1061.

Nhundu, K., Mushunje, A., Zhou, L. and Aghdasi, F.. 2015. Institutional determinants of farmer participation in irrigation development post "fast-track" land reform program in Zimbabwe. *Journal of Agricultural Biotechnology and Sustainable Development.* 7(2): 9-18

Nhundu, K. and Mushunje A. 2012. Irrigation development: A food security and household income perspective. In Problems, perspectives and challenges of agricultural water management. InTech.

Nives, Dolsak, and E. Ostrom. 2003. The challenges of Commons. In The Commons in the New Millennium*: Challenges and Adaptation*, ed. Nives Dolsak and Elinor Ostrom. Vol. Politics, science, and the environment. London: MIT Press.

NPC (National Planning Commission). 2015. Ethiopian second five year (2015/16-2019/20) Growth and Transformation plan, Addis Ababa, Ethiopia

Pardey, P.G., Alston, J.M. and Kang C.C. 2012. Agricultural Production, Productivity and R&D over the Past Half Century: An Emerging New World Order. Invited plenary paper presented at the International Association of Agricultural Economists (IAAE). Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

Pokhrel, B., Krishna, P. and Eduardo, S., 2016, January. Factors Affecting the Choice, Intensity, and Allocation of Irrigation Technologies by US Cotton Farmers. In *2016 Annual Meeting, February 6-9, 2016, San Antonio, Texas*(No. 230199). Southern Agricultural Economics Association.

Pranab, Mukhopadahyay. 2012. Common Property Resources and Collective Action, A Short Review. Madras School of Economics, India. *Dissemination paper-20.*

Reddy, R.N. 2010. *Irrigation Engineering*, Gene-Tech Books, New Delhi - 110 002.

Roberts, M.R. and Lemmon, M. 2007, The Response of Corporate Financing and Investment to Changes in the Supply of Credit, *Working Paper,* University of Pennsylvania.

Rogers, E.M. 1983. *Diffusion of Innovations*. 3rd edition. New York: Macmillan Publishing Co.Inc.

Rosenbaum, P.R. and Rubin, D.B. 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician* 39(1): 33-38.

Rubin D.B. 2001. Using propensity scores to help design observational studies: Application to the tobacco litigation. *Health Services & Outcomes Research Methodology,* 2:169-188.

Samuelson, W.F. and Marks, S.G. 2012. Managerial Economics, 7th Edition. John Wiley & Sons, Inc., USA.

Shiferaw Solomon and Mengistu Ketema. 2015. Impact of irrigation technologies on rural households' poverty status: the Case of Fogera District, North-Western Ethiopia. *Agris on-line Papers in Economics and Informatics,*7(1): 59-67.

Sisay Belay and Fekadu Beyene. Small-scale irrigation and household income linkage: Evidence from Deder district, Ethiopia. *African Journal of Agricultural Research,* 8(34); 4441-4451.

Sithole, N.L., Lagat, J.K. and Masuku, M.B. 2014. Factors influencing farmers participation in smallholder irrigation schemes: The case of Ntfonjeni rural development area, Kenya. *Journal of Economics and Sustainable Development.* 5(22): 157-167

Smith, J.A. and Todd P.E. 2005. Does matching overcome LaLonde's critique of non-experimental estimators? *Journal of Econometrics*, 125(1): 305–353.

Stern, E, Stame N, Mayne J, Forss K, Davies R, Befani, B. 2012. Broadening the Range of Designs and Sharing the Benefits of Trade Methods for Impact Evaluations: Report of a Study Commissioned by the Department for International Monitoring and Evaluation.

Tegbaru Belette. 2014. Fertility Mapping Of Soils Of Abay-Chomen District, Western Oromia, Ethiopia.

Tesfa Worku and Sangharsh Kumar, Tripathi. 2015. Watershed management in highlands of Ethiopia: A Review. *Open Access Library Journal,* 2(06): 1-11.

Tewodros Hailu., Jema Haji. and Mohammed Aman. 2013. Impact analysis of Mede Telila small-scale irrigation scheme on house poverty alleviation: Case of Gorogutu district in eastern Hararghe Oromia National Regional State, Ethiopia. *International Journal of Development and Economic Sustainability,* 1(1): 15-30.

Tobin, J. 1958. Estimation for relationships with limited dependent variables, *Econometrica,* 26(1): 24–36.

Todaro, M. 2012. *Economic Development*, 11th Edition. New York University. Developing countries Economic policy. Addison Wesley publisher, USA

Tongul, H. and Hobson, M. 2013. Scaling Up an Integrated Watershed Management Approach through Social Protection Programmes in Ethiopia: The MERET and

PSNP schemes. Hunger, Nutrition, Climate Justice. A New Dialogue: Putting People at the Heart of Global Development, 15-16 April 2013, Dublin, Ireland.

Wade, R. 1987. The management of common property resources: Collective action as an alternative to privatization or state regulation. *Cambridge Journal of Economics,* 11(2): 95-106.

Wang, J., Klein, K.K., Henning Bjornlund, Lijuan Zhang & Wencui Zhang. 2015. Adoption of improved irrigation scheduling methods in Alberta: An empirical analysis. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques, 40(1):47-61*

William, J. Burke. 2009. Fitting and interpreting Cragg's tobit alternative using Stata. Michigan State University, East Lansing, MI. *The Stata Journal,* 9(4): 584-592.

Woldegebrial Zeweld, Guido Van Huylenbroeck, Assefa Hidgot, M. G. Chandrakanth And Stijn Speelman. 2015. Adoption of small-scale irrigation and its livelihood impacts in Northern Ethiopia. *Irrigation and Drainage*, 64(5): 655-668.

7. APPENDICES

Appendix Tables

Appendix Table 1. Likelihood ratio test of Tobit model specification

Loglikelihood ratio	Tobit = -14.027 Probit = -14.771 Truncated = 26.267
Hypothesis	H0= Tobit Specification H1= Double Hurdle Specification
Test statistic	51.046
Critical Value	$\chi^2_{14,0.05}$= 23.685
Decision	Reject H0

Source: Own computation from survey data, (2017)

Appendix Table 2. Distribution of irrigated land size per household for participants and for all sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Irrigated land size (All sample)	162	.1892	.2999	0	2
Irrigated land size (Participants)	77	.398	.326	.125	2

Source: Own computation from survey data, (2017)

Appendix Table 3. Estimated treatment effect on the treated by three matching algorithms

Matching	Sample	Treated	Controls	Difference	Std. Error (bootstrapped)	t-stat
	Unmatched	50753.48	30175.35	20578.13	4203.18	4.90
Nearest neighbor (2)	ATT	34731.59	26105.06	7750.01	4270.71	1.81
Radius caliper (0.25)	ATT	34731.59	27846.01	6885.59	13486.7	0.51
Kernel caliper (0.1)	ATT	34834.22	27092.88	7741.33	4157.89	1.86

Source: Own computation from survey data, (2017)

Appendix Table 4. Sensitivity analysis result of outcome variable after matching by Rosenbaum bounds

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	.000202	.000202	26459	26459	23222.5	29811
1.25	.000779	.000038	26150	28135	22654.5	32718.5
1.5	.001939	7.4e-06	24898.5	28914	19986	32718.5
1.75	.003751	1.4e-06	24898.5	29386.5	19986	34394.5
2	.006192	2.8e-07	24330.5	29482	19986	34394.5
2.25	.009188	5.6e-08	23222.5	29482	19986	35646
2.5	.012644	1.1e-08	23222.5	29482	19418	38978
2.75	.016468	2.2e-09	23222.5	29482	19418	38978
3	.020573	4.5e-10	23222.5	29482	19418	38978

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, (2017)

Appendix Table 5. Conversion rate of livestock into standardized unit (TLU)

Animals	Total Livestock Unit (TLU)
Calf	0.25
Weaned calf	0.34
Heifer	0.75
Cows& Oxen	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: Abebe (2000), cited in Asres (2003).

Appendix 6. Questionnaire

General Identification information

Research site: District --------------------------, Kebele --

Name of interviewee:---,Mob:---------------------------

Date of interview: --

Sample respondents' identification number: ---

I. Demographic Background information of the household head

1.1**. Sex**: 1) Male 2) Female

1.2. **Age**: ---.

1.3. Marital status: 1) Married 2) Single 3) Widowed 4) Divorced

1.4. **Education** level: 1) Literate 0) Illiterate; if literate the formal education in grade: ------

1.5. How many **family members** do you have? ------------------------,

1.6. Could you please tell me their characteristics?

No	Name	Sex	Age	Marital status	Education level
1					
2					
3					
4					
5					

Code **Sex**: 1) male 2) female, **Marital status**: 1) married 2) single 3) widowed 4) divorced **Education**: 1) illiterate 2) literate,

II. Irrigation practice

2. Have you ever experienced in irrigation activity? 1) Yes 0) No

2.1. If yes, for how long you have been practicing irrigation activity? ----------------- (yrs)

2.2. Which small-scale irrigation type do you use? 1) modern micro dam 2) traditional river diversion 3) motor pump 4) treadle pump 5) others specify (if any),----------------------

2.3. Have you cultivated your irrigable plot in full scale? 1) Yes 0) no

2.3.1. If no, write the most important inhibiting factors in the following table:

Factor	**Rank**	**How do you respond?**
Shortage of Water		
Labor		
Input		
Credit		

2.4. How many times you produce per year on irrigable land? 1) once 2) twice 3) three times 4) four times

3. If you are not using small scale irrigation schemes, what are the main reasons for not using? 1) Shortage of land for irrigation 2) lack of awareness about irrigation 3) production input problems 4) lack of oxen 5) problem of sufficient irrigation water

4. Have you used irrigation planning? 1) Yes 0) no

4.1. If yes, what criteria you used to decide when and type of irrigated crops?
1) Price of the crop 2) cost of production 3) cash income from the sale of the crop

6. Do you have access to irrigation water? 1) Yes 0) no

6.1. If yes, what is the main source of your irrigation water? 1) Hole 2) river 3) lake 4) well 5) others

6.2. How **far is your irrigation plot** from water source? ------------------------km (hour)
How far is the nearest farm land? ------------------------km (hour)
The furthest farm land ------------------------km (hour)

6.3. Do you participate in irrigated farming group? 1) Yes 0) no

6.4. If yes what is the number the member of the group_____. The area of land irrigated by the group_______(ha), type of crop produced___________

III. Socio-Economic status of the household

1. What is the total **farm land** you have (owned)? ________(hectares)

1.1. Have you rented in/out? 1) Yes 0) no, rented in____(hectares)
rented out____(hectares)

1.2. How much of your land is used by irrigation? _____________(hectares).

1.3. Have you cultivated the total of your irrigable land during the last crop production season? 1) Yes 0) no

2. Have your own active **family members** (11 years and above) participated in farm activity? 1) Yes 0) no

2.1. If yes, specify the number of the family members engaged in the farm activity:__________

2.1.1. What type of activity they are engaged in? 1) Weeding 2) harvesting 3) threshing 4) watering 5) planting 6) ploughing

3. What are the main sources of the labor for your irrigation activity? 1) Family labor 2) hired labor

3.1. Did you face any labor shortage during the last production season? 1) Yes 0) No

3.1.1. If yes, how did you solve the labor shortage? 1) Through hiring additional daily laborers 2) through *debo/jigi* 3) using family labors

3.1.2. Can you easily get labor to hire when you are in need? 1) Yes 0) No

3.1.3. How much you pay for daily laborers' in cash per day? _______________(ETB).

4. Do you produce livestock? 1) Yes 0) no

4.1. If yes, indicate number and types of **livestock** you owned currently in the following table:

Types of Livestock		Number of Livestock	Livestock Sold	
			Number	Average Unit Price (ETB)
Cattle	**Oxen**			
	Cows			
	Bull			
	Heifer			
	Calves			
Sub-total				
Sheep and Goat	Goat			
	Sheep			
Equines	Horse			
	Donkey			
Poultry	Chickens			

4.2. What is the area of land allocated for animal husbandry?__________(hectares)

5. Would you give information on cropping of your irrigation plot and rain-fed agriculture for 2016/17 production season?

Type of Agricultural activity	Type of crop	Area	Input								Amount Harvested	Unit Price
			Seed		Fertilizer		Pest. and herb.		Fuels			
			Amount(kg)	Cost(ETB)	Amount(kg)	Cost(ETB)	Amount(kg)	Cost(ETB)	Amount(kg)	Cost(ETB)		
Irrigation	Onion											
	Tomato											
	Potato											
	Cabbage											
	Maize											
	Peppers											
	Sugar cane											
	Others											
Rain-fed	Maize											
	Teff											
	Niger seed											

	Wheat											
	Bean											
	Pea											
	Others											

6. Do you or any members of your family have non-farm job? 1) Yes 0) no

6.1. If yes, please indicate type of work and income from it in the following table:

No	Family Members	Type of Job	Income(ETB/month)
1			
2			
3			
4			

IV. Physical and environmental problems

1. Did diseases and pests affect your crop production in the last season? 1) yes 0) no

1.1. If yes, how do you treat diseases and pest infections? _______________________

2. What is the topography of your farm land? __________________________________

3.1. Does the topology of your farm land affect irrigation activity? 1) yes 0) no

3.1.1. If yes how it affect? ____

V. Institutional Support and other related services

1. Do you have access to agricultural inputs for your irrigation activity? 1) Yes 0) no

1.1. If yes, what type of improved technology you used? Please could you list amount and their price in the following table?

Type of Inputs		Unit Price	Amount used Per hectare
Fertilizers	DAP		
	UREA		
Herbicides			

1.2. If you are not per recommended rate what are the main reasons for not using? 1) Financial problem to afford 2) no credit facility 3) problem of supply 4) lack of awareness 5) high price of input

1.3. How do you judge the price of input? 1) Very expensive 2) expensive 3) fair

1.4. Is there any responsible institution that provides input as per recommended schedule?
1)Yes 2) no

2. Do you have access to extension services? 1) yes 0) no

2.1. If yes, what type of extension service did you get during last production season?
1) Marketing information 2) crop husbandry 3) irrigation management system

4) fertilizer application and pest management 5) credit service 6) post harvesting processing

2.2. Where do you obtain extension services? 1) Development agent 2) farmers group 3) FTC 4) radio 5) NGO 6) district agricultural office

2.3. Have you ever been visited by agricultural development agents? 1) yes 0) no

2.3.1 If yes, how many times did they contact you? 1) twice a week 2) once a week 3) monthly 4) seasonally

2.4. Did you practically use any of the advices on your farm land during last production season? 1) yes 0) no

2.4.1. If no, why didn't you use it? 1) irrelevant 2) not timely 3) lack of finance to afford

2.5. Is there any governmental or non-governmental organization working on irrigation development in your local area? 1) yes 2) no

2.5.1. If yes, do you have any relation with them? 1) yes 2) no

2.5.1.1. If yes, specify their contribution for your irrigation development: ____

3. Have you get any type of **training** on irrigation utilization means? 1) yes 2) no

3.1. If yes, by whom the training was given? 1) trained farmers 2) by agricultural expert 3) by local NGOs working on the irrigation development 4) DA

3.2. Do you think the training given was sufficient? 1) yes 0) no

3.3. If no what type of training you want to be added?_____________________

4. Is there any water user association in your local area? 1) yes 0) no

4.1. If yes, are you the member of the water association? 1) yes 0) no

4.1.1.If yes, could you indicate any benefits you gained by being the member of water association:____

5. Do you get **market information** about price of input and output for your irrigation product? 1) yes 0) no

5.1. If yes, what is the source of information? 1) intermediaries 2) radio 3) from other farmers

6. Where do you sell your products produced by irrigation? 1) Local market 2) on-farm 3) regional market 4) federal market

6.1. How **far is the market you mentioned** from your farmland? _________kms.

6.2. How far is your farmland from the main road? __________________kms

7. How do you sell your products? 1) as individual 2) as the members of informal groups

3) as a cooperative

8. How you perceive the price of irrigation products during harvesting season? 1) cheap
2) fair 3) expensive 4) fluctuate

9. Did you get reasonable price for your product at the place you used to sell to?
1) yes 0) no

11. Can you find buyer for your products? 1) yes 0) no

11.1. If yes, could you explain the major most marketing problems?
1) price fluctuation 2) low demand for the product 3) long distance 4) road problems
5) lack of storage facility 6) competition from other producers 7) high price of input

12. Have you used **credit** in last production season? 1) yes 0) no

12.1. If yes, what is the source of credit? Please could you mention the source of the credit in the following table?

No	Source of Credit/money	Purpose	Amount	Interest Requested
1				
2				

A. What are the major opportunities in your local area to utilize small scale irrigation water? ---

B. What are the main constraints you face during utilization of small scale irrigation water in your local area? ---

C. Please mention any major problems (technical, social, economic, environmental and other
related) associated with the irrigation development activity in your local area

D. Give your views as to what interventions must be made for better implementation of modern irrigation technologies on your farm land: --
----

E. What help do you need from the government or non-governmental organization to irrigate your farm land? :---

Thank you!

Appendix 7. Interview guide for key informants

1. What is the trend of irrigation activity in the past five years in the district?
2. How do you view the strength and weaknesses, of the irrigation systems? (in relation to technical and social aspects), What are the opportunities and challenges?
3. What are the existing policies in relation to agriculture in general and irrigation in particular and how do you view them?
4. Is there any restriction on the use of existing rivers for irrigation?
5. How do you view the role played by Ethiopian government in irrigation development in the district?
6. What are important strategies for irrigation development in the area?
7. What are the cultural and religious factors that affect the household's economic activity? and their holdings?
8. What is the agro-climatic condition of the study area?
9. What are the major social organizations in the area and what are their roles?
10. What are non-farm activities available in the district?
11. What do you think are the major environmental problems in the area?

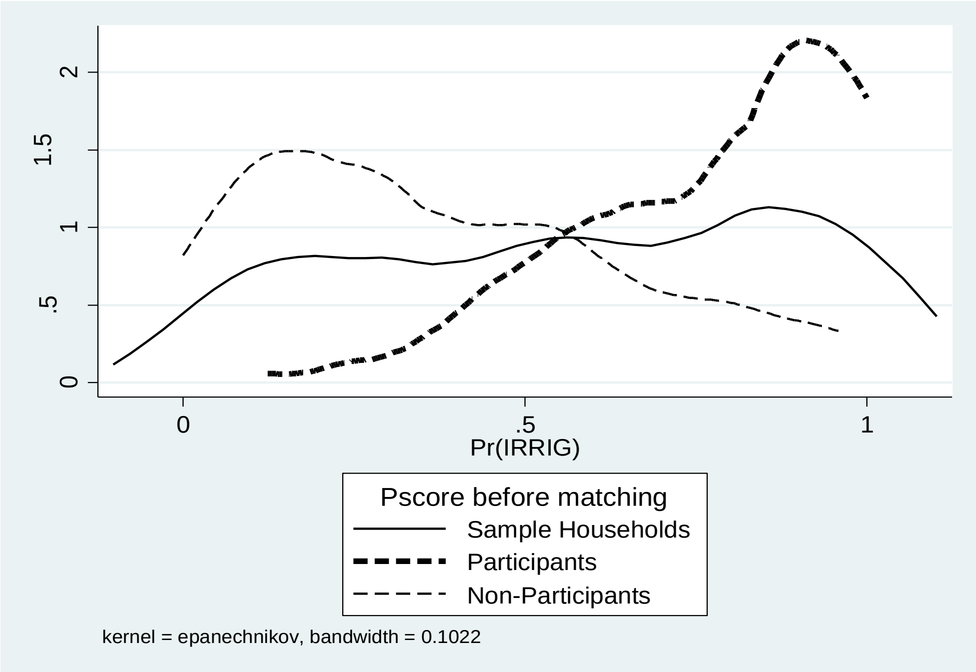
Thank you!

Appendix 8. Guiding questions for focus group discussion

1. What are the major opportunities in your local area to utilize small-scale irrigation water?
2. How do you view the strength and weaknesses, of the irrigation systems? (in relation to technical and social aspects)
3. What are the main constraints you face during utilization of small-scale irrigation water in your local area?
4. Is there any restriction on the use of existing rivers for irrigation?
5. How do you view the role played by the government in irrigation development in the area?
6. What are important strategies for irrigation development in the area? What type of irrigation water source do you think is more advantageous for the community in the area?
7. What are the indicators for wealth ranking according to the local community standards? Is there any relationship with irrigated farming?
8. What are the cultural and religious factors that affect the household’s economic activity and their holdings?
9. Discuss the following issues in your group; access to basic school facilities, health facilities, drinking water (for humans & animals), irrigation services, road infrastructure, credit facilities, access to modern farm inputs (fertilizer, improved seeds, pesticides, herbicides, veterinary drugs).
10. What are the major social organizations in the area and what are their roles in irrigated farming?
11. What are non-farm activities available in the district and how do you view its advantage related to irrigated farming?
12. What do you think are the major environmental problems in the area related with irrigation?

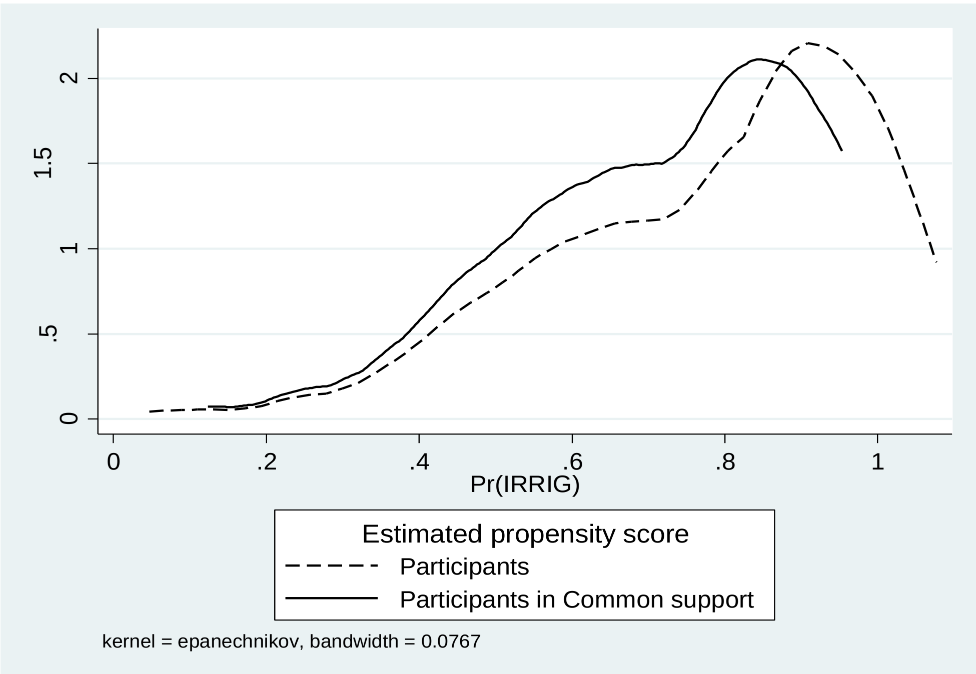
Thank you!

Appendix Figures



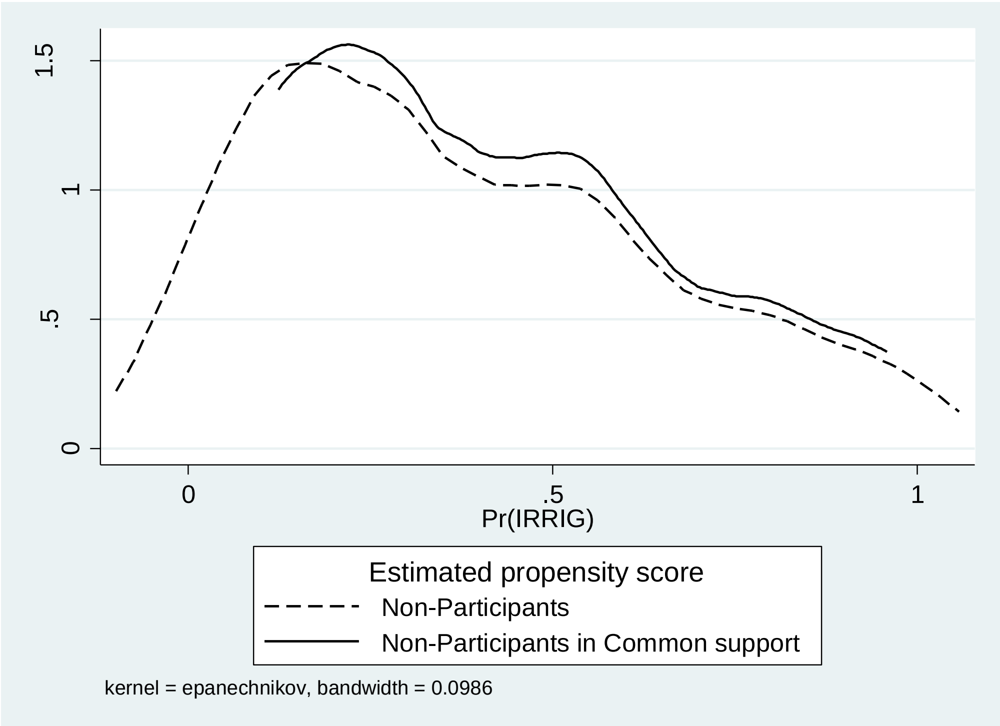
Appendix Figure 1. Kernel density of propensity scores before matching

Source: Own estimation from survey data, (2017)



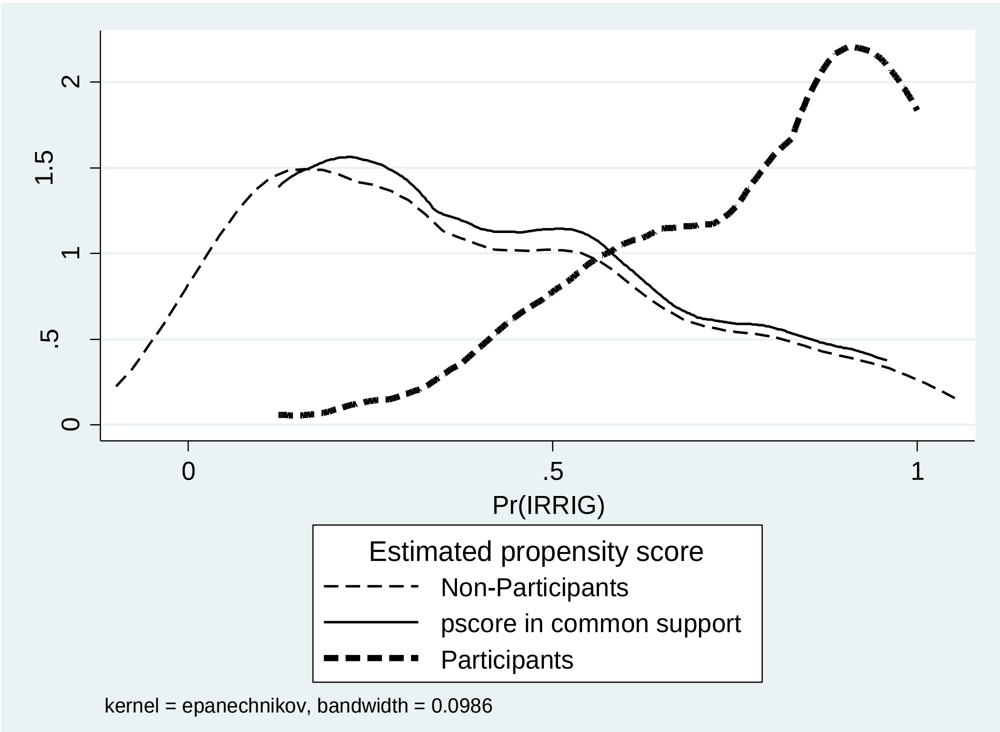
Appendix Figure 2. Kernel density of propensity scores of participants

Source: Own estimation from survey data, (2017)



Appendix Figure 3. Kernel density of propensity scores of non-participants

Source: Own estimation from survey data, (2017)



Appendix Figure 4. Common support region of propensity scores by kernel density after matching

Source: Own estimation from survey data, (2017)