IMPACT OF SMALL SCALE IRRIGATION SCHEME ON RURAL HOUSEHOLD FARM INCOME: A CASE STUDY ON LOKA ABAYA WOREDA, SIDAMA ZONE, SOUTHERN ETHIOPIA.

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Abstract
Small-scale irrigation is one of the most important irrigation systems designed to increasing income of farm households and reducing risks associated with erratic rainfall. The present study is an attempt to examine the impact of small-scale irrigation scheme on income of farm households. A cross sectional data were obtained using a sample of 299 respondents selected through multi-stage random sampling techniques from three Loka Abaya in Woreda Sidama in Southern, Ethiopia in 2017/18 cropping year and secondary data were sourced from the official reports. The primary data were collected from selected 132 irrigation user households and 167 non-user households drawn based on proportion to population size. The impact of small-scale irrigation scheme use on household farm income from maize and tomato production yields was analysed using Propensity Score Matching (PSM) method. Twelve explanatory variables were hypothesized that determine households' probability of participation in small-scale scheme use. The study found that ten variables like gender, age, family size, land size, slope of farm land, access to credit, contact with agricultural development agent, irrigation related training, access to distance of market and livestock ownership significantly influence households' use of small scale irrigation. The result of PSM analysis indicates that participation in irrigation use has increased annual household farm income by 5439.05 birr for irrigation users than that of non-user households which is significant at 1% level. The sensitive analysis result has indicated that the impact results estimated by this study were insensitive to unobserved selection bias, which concludes that irrigation has positive and significant impact on annual farm income. The study has also found that shortage of improved seed, dependence of surface water, lack of market information, disease and pest, backward agricultural trend, inappropriate use of water considering crop water demand were the main problems encountered in irrigation use in the area. Therefore, governmental and nongovernmental organization should work to provide remedial solution to these problems to improve the livelihood of rural farmer households.

Key words: Farm income, SSI scheme, PSM, Loka Abaya.

1. INTRODUCTION

Agriculture is the foundation of the majority of the population living in Sub- Saharan Africa. The greater part of this is rain-fed and vulnerable to drought. The key constraint on further increase in agricultural production is the scarcity of agricultural water. Therefore, national or international planners are strongly attracted to irrigation as a means of supporting future food strategies. Yet agriculture in the region remains largely subsistence, production has not kept pace with population growth, food self-sufficiency has declined, the household income is required to afford to buy non-agricultural products and other services.

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Ethiopia can be considered as the water tower of Africa as it is endowed with ample water resources with 12 river basins with an annual runoff volume of 122 billion m3 of water and an estimated 2.6-2.65 billion m3 of ground water potential (Awulachew*et al*., 2007). The total irrigated area under small-scale irrigation in country has reached to 853,000 hectares during PASDEP –(2009/10) .Implementation period and the plan set for the development of small scale irrigation is 1850,000 hectares, which is planned to achieved by the end of the five years GTP (Growth and Transformation Plan) of in 2015 (GTP, 2010; cited in Leta, 2018).

Many households at Loka Abaya woreda (one of low rain-fed area) are engaged in irrigation practices focussing on production of maize and tomato and their livelihood is improving from time to time (LWAO, 2018).

Ethiopia being a developing country where persistent drought induced famine is the cause for both social and economic crises for which the need for irrigated agriculture cannot be ignored. Ethiopia cannot meet its large food need through rain-fed agriculture alone. The agricultural trends is dominated by seasonal rainfall. Most of the time the economy is based on extremely fragile and vulnerable to the challenges of climatic affect which often cause total crop failure and subsequent shortage food and drought. To alleviate the food insecurity and rural income poverty that is existing in Ethiopia, the government has implemented different strategies to achieve increasing productivity of the small holder farming :- through the promotion of small-scale irrigation, Utilization of surface and ground water for irrigation, improving the traditional irrigation system supported by financial and material resources, and constructing modern small scale irrigation schemes .

2. Objective

1. To evaluate impact of small-scale irrigation scheme on rural household income from maize and tomatoes crops.

3**. Literature review**

The study conducted by Abraham *et al*., 2007 in Ethiopia has revealed that higher farm income encourages farm households to participate and specialize in irrigation.

A study conducted in China (Zhou *et al*., 2009) concluded that irrigation can be an indispensable technological intervention to increase household income.

The study conducted by (Girma, 2011) in Ethiopia has revealed that irrigation has a paramount impact on the livelihood of users in the sense that an increase in income by diversifying their production, which in turn enabled them to build up their assets, buy more food and non-food household items, educate their children, and reinvest in further increasing their production by buying farm inputs or livestock.

According to Bernard, 2012, irrigation has potential to increase farm income in the sense that the income obtained has also enabled plot holders to acquire assets such as livestock, scotch carts and wheelbarrows that enabled plot holders to diversify their livelihoods through getting animal manure, meat and milk and the sale of dried vegetables all year round.

Abraham et *al*., 2013 has revealed that irrigation use has contributed towards improving farm income of households. The study indicates that the average farm income of the user and non-users was 18602.16 Birr and 3975.459 Birr respectively.

Study conducted in Ethiopia by Adunga*et al*.,2014 found that irrigation use has a positive impact on households earning from the crop, and livestock in the sense that irrigation allows a greater area of land to be used for crops and asset ownership increases with access to irrigation.

A study conducted by Dereje and Desale, 2016 in Ethiopia has concluded that the application of SSI improved the annual income of irrigator households with a standard deviation of 1534.32 compared to non-irrigators who have a standard deviation of 1838.

4. Methodology of the study

The cross-sectional research design is used where mixed approach of both quantitative and qualitative methods of data collection were employed and the study has two sample groups (irrigation user and non-user groups). In this case, investment in small scale irrigation by relevant households was the influences and change in income patterns and activities were the observable consequences which have been studied. It is experimental in the sense that it has compared the treatment of farmers who practiced irrigation with those that of farmers who do not. Both qualitative and quantitative data were collected from primary and secondary data sources. The primary data were collected from the respondent of the irrigation user and non-irrigation user by using Questionnaires, key informant interview , Focus group techniques. In addition to this, secondary data were gathered from different research paper, applicable books, internet, published and unpublished document from woreda's irrigation development authority works.A multistage sampling technique was followed to select the respondent household for the study. The sample size of 299 was determined by using formula developed by Yamene, 1967 and Rose, S *et al*,.2015 at a precision level of 5%.

To address the objectives of the study, Propensity Score Matching (PSM) model using STATA software versions 14 was used to examine the impact of small scale irrigation scheme on household income and poverty reduction. Twelve independent variables were assumed to affect participation in irrigation use and outcome (farm income) variable are included.The dependent variable of this study was participation in the small-scale irrigation use is a dummy variable that takes a value of 1 for those households who are user of small scale irrigation and 0, other wise. It was hypothesized that use of irrigation has positive impact on farm income of household as outcome variable.The proposed fourteen independent variables in the study are as:- Sex of household head , Age of household head, Education level, Family size , Land size , Access to extension service , Size of livestock holding , Access to credit , Distance from farm water point , Training on irrigation technology , Slope of land , Access of media , Distance from the nearest market ,and Total livestock ownership. This work consists of the participation equation model and the outcome equation model . The participation equation is regressed using a binary logistic regression model.

5. Result and Discussion

Econometric analysis includes estimation of propensity score, matching algorithms, balancing test, average treatment effect results, common support region and sensitivity analysis respectively to attain the objective of the study.

5.1 Estimation of Propensity Score matching

Both Variance Inflation (VI) factor for continuous explanatory variables and Contingency Coefficient (CC) for discrete explanatory variables indicate that there is no multi-collinearity problem between independent variables of the study. The likelihood ratio chi^2 value of 202.26 was found statistically significant at 1% significance level. This implies that, the model was statistically significant. Moreover, the small value of Pseudo-R^2 (0.493) indicates that there was no systematic difference in the distribution of covariates between irrigation scheme users and non-users in the study area. Therefore, all explanatory variables were used in the impact analysis

procedure. The Table 1 has revealed that ten variables were found to be statistical significant while the rest two variables were not significant in explaining the variations in the household's probability of participation in irrigation use (dependent variable). Based on this gender, age, family size, farm size, sloppy of cultivated land, distance from farm to market place, access to credit, access to irrigation training, access contact of development agent and livestock ownership were the variables identified by logistic regression model that influence households' probability of participation in irrigation use.

Table 1: Household's Probability of Participation in Small Scale Irrigation Use

Logistic regression N =299

LR $chi^2(12)$=191.08

Prob>chi^2 =0.00

Log likelihood= -110.2 Pseudo R^2=0.4656

Status of Irri.	Coefficient	Marginal effect	Std. Err.	Z	p-value
GEN	1.841276	.33406	.812188	3.47	0.001***
AGE	-.0620985	-.0146883	.024147	-2.34	0.019**
EDUC	-.1312181	.0060386	.2116629	-0.12	0.905
FMSIZ	.2358139	.0557777	.1685777	1.75	0.080*
OFFINCO	-.3556835	-.0845807	.2710338	-0.95	0.344
LANDSIZE	3.676346	.8695769	23.19011	5.92	0.000***
SLOPLAND	.8064236	.1907457	.4658691	3.65	0.000***
DISTMRKT	-.2693733	-.0637157	.1148539	-1.74	0.083*
CREDTACC	1.731382	.4080018	1.981379	4.70	0.000***
CONTDA	.2439796	.0577092	.1502905	2.01	0.044**
IRRTRAIN	2.078656	.4360615	3.271026	5.13	0.000***
Tlu	-.1652961	-.0401018	0.0574614	-2.50	0.013**
-cons	-9.219289	.002471	.0023606	-3.59	0.000***

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

Source: Research Survey data result (2019).

It was found from Table1 that, gender, slope of land, access to credit, land holding size and participation in irrigation use related training affect households' probability of participation use positively and significantly at 1% significance level.

Gender is dummy variable with 1 as male and 0 as female household head respectively. It is statistically significant at 1% level of significance. With regard to the gender of the house hold head male are 33percent more likely to participate in small-scale irrigation scheme, other things remain constant, as compared to their counterparts. The probable reason is due to cultural biases where female-headed households have limited resource access and males have more exposure to other social and economic activities.

As the hectare of farm land size increases by one hectare the probability of small-scale irrigation scheme use increases by 86% of marginal effect, being other things remain constant at their mean

value. It means that it increases and improves the productivity and production of yields. It is one of the main factors affecting use of irrigation technologies to increase agricultural production.
Households with farm size are 5.57% more likely to participant in small scale irrigation scheme than their counter parts.
Households with access to irrigation training are 43% more likely to participant in small scale irrigation scheme than their counter parts.
The access to credit is 40% more likely to participate in irrigation activities than their counter parts.
It was found that farm land size with slope to flat be 19% as marginal effect, being other things remain constant at their mean value.
A positive relation between Development agent contact and irrigation use is due to the fact that as DA contact indicates more probability of participation in irrigation by 5.7% marginal effect, households who get more extension service are more likely to participate in irrigation user than households with no DA's contact of their counterparts.
As age of the household head decreases by one year the probability of irrigation uses increases by 1.2 percent of marginal effect, other things remain constant at their mean value.
The relationship of livestock (TLU) and household income status are negatively at 5% significance level by 4.01 percent as marginal effect.
As the distance in kilometre of the access to small scale irrigation increases the probability of access to nearest market place decreases by 6.3 %, other things remain constant at their mean value.The negative effect indicates that the farther the market place is from a household's residence the lower the likelihood of participation in irrigation use.
5.2. The distribution of the propensity score for each household included in irrigation user and non-user groups was computed based on the above participation model to identify the existence of a common support region. Figure1 depicts the distribution of the irrigation user and non-user households with respect to the estimated propensity scores. The figure shows that most of the irrigation user households were found in the middle and partly in the right and left side while most of non-user households were found in the left side of the distribution. The figure also shows that there is a wide area in which the propensity score of both the irrigation user and non-user households are similar.

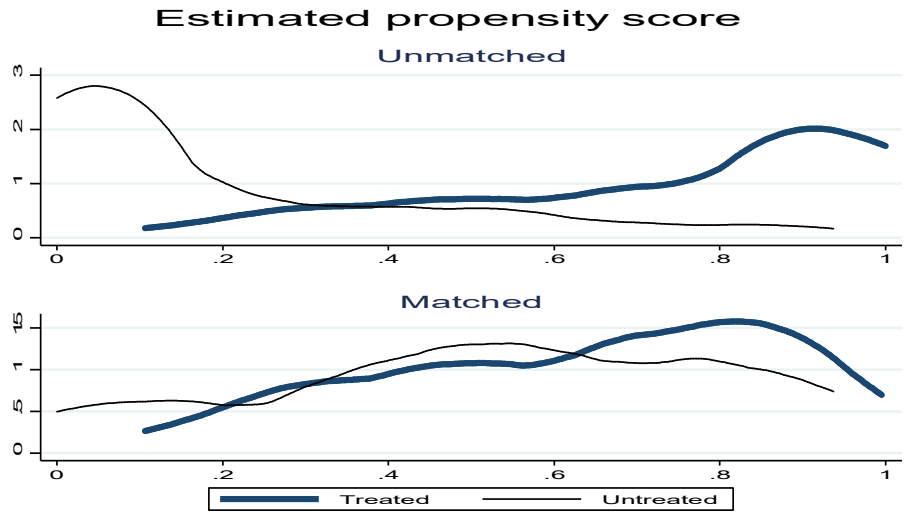

Figure1:Kernel Densities of Propensity Scores of Irrigation Users and Non-Users

Source:Research Survey result (2019)

5.3. Identifying Common Support Region

The common support region for the estimated propensity score is constructed based on the summary statistics of irrigation users and non-users. Discarding observation whose propensity score is outside common support region is the final task. As shown in the Table2, the propensity score vary between 0.3511254 - 1.311847 for irrigation users with mean score of 0.766 , whereas the score varies between 0.2476353 - 1.348291 for non-user with mean score of 0.843. The common support then lies between 0.3511254 - 1.348291. This means that household whose propensity score is less than minimum (0.3511254) and larger than maximum (1.348291) are not considered for matching purpose.

Table2: Distribution of Estimated Propensity Score of Households

Group	Observation	Mean	Std. Dev.	Min	Max
Irrigation User	132	0.7575758	0.1946749	0.3511254	1.311847
Non- User	167	0.8383234	0.2217657	0.2476353	1.348291
All sample	299	0.8026756	0.2137024	0.2476353	1.348291

Source:Research Survey result (2019)

Figure 2 below shows the distribution of propensity score and common support region. The bottom halves of the histogram shows the propensity score distribution of irrigation non user households and the upper halves shows the propensity score distribution of irrigation non user households. The green colored (treated off support) and red colour (treated on support) indicates the observations in the irrigation user and non-user group that have a suitable comparison respectively whereas the blue colour (untreated) indicates the observations in the irrigation user and non-user group that do not have a suitable comparison respectively.

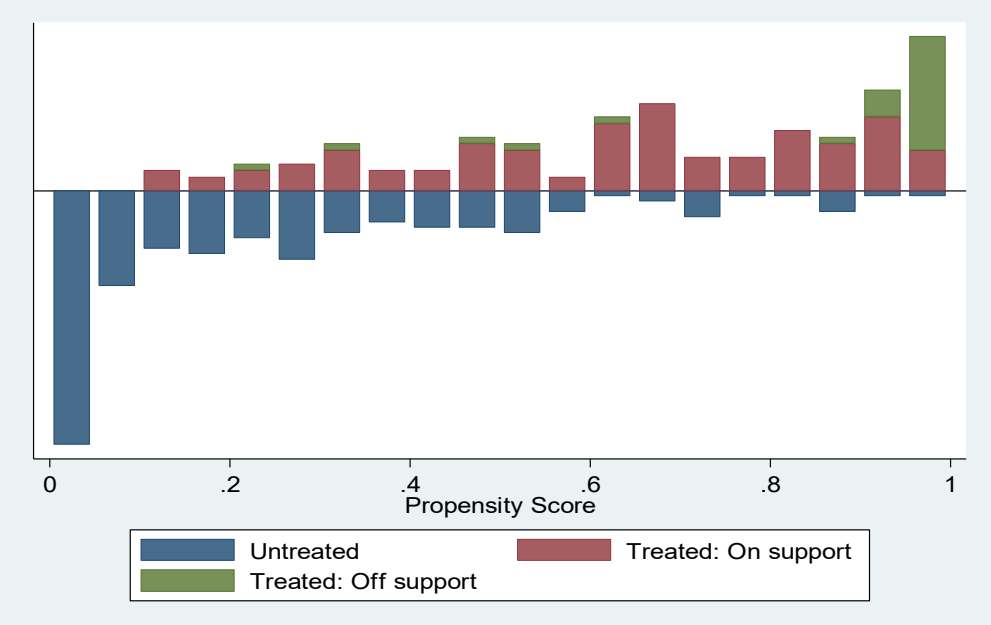

Figure2: Propensity Score Distribution and Common Support Region for Propensity Score

Source: Research Survey result (2019)

Following identification of common support region, alternative matching estimators (algorithms) were tried in matching irrigation user with non-user households in common support region. The common matching algorithms used in propensity score matching include: nearest neighbour matching, radius matching and kernel matching. These matching methods use different means of matching the irrigation participators to the control group to determine the average effect of certain program participation. The final choice of matching algorithm was guided by three criteria namely equal mean test (balancing test), Pseudo R^2 and size of matched sample (see table3). Matching algorithm which balances all covariate variables of groups resulting in insignificant mean differences between small scale irrigation users and non-users , bear low Pseudo R^2 value for which large sample size is preferable.

The simultaneous test of the matching algorithm, balancing test, mean bias, the number of matched observations (sample size) , the number of balanced covariates and the value of the pseudo R^2 for best nearest neighbour matching are 5.79, 19, 210, 12 and 0.098; for radius matching are 5.79, 13, 248, 12 and 0.098; for kernel matching are 5.79, 9.4, 248, 12 and 0.056, respectively. Based on this value of the test, the matching algorithm with the lowest mean bias, lowest pseudo R^2, approximately equal number of matched observation and equal number of balanced covariates compared to other matching algorithm consist 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.

Table3: Test on Propensity Score Matching Algorithm

Matching Algorithm	Balancing test*	Mean bias	Performance criteria		
			Pseudo-R^2	No of balanced covariates	Matched sample size
Nearest Neighbor	5.79	19	0.098	12	210
Radius matching	5.79	13	0.098	12	248
Kernel matching	5.79	9.4	0.056	12	248

Source: Own Evaluation from Research Survey Data Result (2019)

5.4. Testing Balance of Propensity Score and Covariates (check with its analysis)

After selecting best performing matching algorithm which satisfies prior identified performance criteria, balance of propensity score and covariate variables was checked by the selected matching algorithm as kernel matching with band width of 0.25 in the case. Balance is treated using a t-test to compare the mean that are statistically similar in the treatment and comparison groups. It also provides a way to help comparing propensity score techniques, using the covariate balance test as the criterion for selecting between techniques. Table 4 below shows that the standard bias difference between identified explanatory variables before matching was in the range of 57.4% - 98.4 % in absolute value. But after matching, the remaining standardized error differences between explanatory variables stand between 2.5 % - 21.2 % in absolute value. This shows that

the matching estimator selected based on the criteria able to reduce maximum bias from 98.4% to 21.2%. The main intention of estimating propensity score is not to get a precise prediction of selection into treatment rather to balance the distributions of relevant variables in both groups. Therefore, the selected matching algorithm as Kernel matching with bandwidth of 0.25 has created a covariate balance between irrigation user and non-userhouseholds, which is important to conduct impact analysis.

Table 4: Propensity Score and Covariate Balance Test (check with its analysis)

Variable	Unmatched / Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
gen	U	.93182	.79641	40.2		3.36	0.001	.
	M	.89888	.89888	0.0	100.0	0.00	1.000	.
age	U	39.924	40.898	-13.1		-1.11	0.269	0.63*
	M	39.326	40.202	-11.8	10.0	-0.87	0.387	1.12
educ	U	1.7045	1.7006	0.5		0.04	0.966	1.10
	M	1.6742	1.9775	-37.6	-7586.8	-2.50	0.013	1.31
ofinco	U	.50758	.66467	-32.2		-2.77	0.006	.
	M	.5618	.52809	6.9	78.5	0.45	0.654	.
totalfsiz	U	5.6136	4.9042	47.4		4.19	0.000	2.82*
	M	5.2472	5.1348	7.5	84.2	0.54	0.592	2.88*
landsiz	U	1.4557	1.0139	106.2		9.33	0.000	2.30*
	M	1.291	1.2017	21.5	79.8	1.88	0.062	1.15
slopland	U	3.2348	2.7485	57.1		4.84	0.000	0.63*
	M	3.1573	3.2697	-13.2	76.9	-0.93	0.352	0.90
distmrkt	U	7.0561	7.4605	-31.8		-2.77	0.006	1.71*
	M	7.2258	6.9685	20.2	36.4	1.48	0.141	1.24
accesscredit	U	.59091	.28743	64.0		5.52	0.000	.
	M	.49438	.59551	-21.3	66.7	-1.35	0.177	.
irritrainaccss	U	.83333	.43114	91.5		7.73	0.000	.
	M	.77528	.7191	12.8	86.0	0.86	0.391	.
contDA	U	2.2727	1.7485	34.2		2.88	0.004	0.48*
	M	2.2022	2.6966	-32.3	5.7	-2.41	0.017	0.71
tlu	U	4.0027	4.3538	-12.2		-1.09	0.279	3.29*
	M	4.07	3.6501	14.6	-19.6	1.01	0.316	3.20*

Note: U-Unmatched, M- Matched

Source: Research Survey result (2019)

As indicated in Table 5 below, the value of pseudo-R^2 was very low. This low pseudo-R^2 value and the insignificant likelihood ratio test indicate that irrigation user households and non-user households had the same distribution in the covariates after matching. These results indicate that the matching procedure is able to balance the characteristics in the treated and the matched comparison groups. Hence, these results can be used to assess the impact of irrigation among groups of households having similar observed characteristics. This enables to compare observed outcomes for irrigation participant with those of a non-participant group sharing a common support region.

Table 5: Chi-square Test for the Joint Significance of Variables

Sample	Pseudo-R2	LR chi^2	p>chi^2
Unmatched	0.498	204.43	0.000
Matched	0.079	19.4	0.079

Source: Computation from Research survey data, 2019

Consequently, all of the above tests propose that the matching algorithm chosen was relatively best for the data of this study. Therefore, it was promising to proceed to estimate the average treatment effect on the treated (ATT) for the sample households. From the result of testing for balance of the covariates between the treated and comparison group, it is found 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 are satisfied.

5.5. Impact of Small Scale Irrigation Use Scheme on Household Farm Income

In this section, the study provides the evidence as to whether or not the irrigation use has brought significant changes on household farm income. Following the estimation of propensity score, the implementation of a matching algorithm and the achievement of balance, the intervention impact may be estimated by averaging the difference in outcome between each treated unit of its neighbour of neighbours from the constructed comparison groups.The impact estimation of ATT on the treated participation of small scale irrigation scheme for this study was conducted using kernel matching.The estimation results are shown in the table 6 that provides a supportive evidence of statistically significant effect of irrigation use on farm income of household measured in Ethiopian birr. As briefly indicated on table 6 , it has been found that, on average, participation in small scale irrigation use has increased annual household farm income by 5439.05 birr for user households as compared to non-user households which is significant at 1% level.The information obtained from key informant interview also supports this finding that in the study area irrigation allows farmers most of the time to produce two or three times per year and earns more where they are aggressively working on vegetables and cereal production, even sometime good opportunity is seen in seedling production in consultation with experts specially, coffee and fruit seedling production.

Table 6: Average Treatment Effect on the Treated (ATT)

Outcome variable	Mean income of irrigation users	Mean income of irrigation non-users	Mean Difference	t-stat
Farm income	19993.1818	14554.1317	5439.05008	5.79***
ATT	19397.5309	16127.4047	1321.75124	2.47**

*** means significant at 1% significance level

Source: Own Research Survey Result (2019)

5.6. Sensitivity Analysis

The basic question to be answered here is whether the finding about treatment effects may be affected by unobserved factors (hidden bias) or not. Based on this, sensitivity analysis was conducted for outcome variable (farm income and physical asset). The results show that impact estimates (ATT) of this study for each outcome variables were insensitive to unobserved selection bias.

6. Summary, conclusion and recommendations.

6.1. Summary and conclusions.

The primary data for this study were collected from a total of 299 households comprising 132 irrigation users' and167 non-user households using structured questionnaire. The study used Econometric model known as Propensity Score Matching Model to analyse the impact of small scale irrigation use on farm income and asset building of sampled irrigation user households.

Twelve variables were hypothesized that determine households' probability of participation in

irrigation use. Ten of them were found to be significant variables determining households' probability of participation in irrigation use while the rest two variables were not significant in determining the probability of participation. Based on this gender, age, family size,land size, distance from market place to farm, slope of land, credit access,contact with development agent, participation in irrigation use related training and livestock ownership were the variables identified by logistic regression model that influence households' probability of participation in irrigation use.

Among four matching algorithms, Kernel matching with band width of 0.25 was found to be best estimator for the impact.The study has found that participation in irrigation use has increased annual household farm income by 5439.05 birr for participant households than non-participant households which was significant at 1% level. From this one can conclude that irrigation has positive and significant impact on annual farm income of the rural households.

6.2.Recommendations.

Based on the findings of this study, the following recommendations were forwarded. The empirical result reveals that irrigation has statistically significant and positive impact on annual farm income which motivates non-participant households to participate and earn more income. Therefore, the researcher recommends the following points.

- The study also revealed that farm distance from irrigation water source was found to be the hindrance for participation in irrigation with significant effect. 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.
- 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.
- The concerned body should emphasize on capacity building like training, experience of visit to model sites and field days are also required to scale the technologies.
- Agricultural and Natural resource development office particularly agricultural extension department should create awareness on the benefit of mass media in relating it with the irrigation use.
- As the age was negatively related with intensity of participation in irrigation, 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.
- Agricultural and Natural resource development office and NGOs organizations working on irrigation should provide training on crop diversification, appropriate crop disease and pest management and other appropriate agronomic practice like on application of water based on the water demand of the crop, slope and soil type.
- Agricultural and Natural resource development office in collaboration with other sector should timely supply enough amount of improved vegetable seeds
- 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 Loka Abaya Woreda.
- 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 of coming

because of market distance and access problem that discourages participation and intensity of participation in irrigation.

- As road distance was found to be a barrier for participation in small-scale irrigation in the study area, road infrastructure and transportation facility should be improved to enable farmers easily to transport products to the market.
- The NGOs or the local administrators should substitute the traditional system of irrigation (flood irrigation) with modern and efficient type of irrigation methods.

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