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Impacts of Rain-Water-Harvesting and Socio Economic Factors on Household Food Security and Income in Moisture Stress Areas of Eastern Hararghe, Ethiopia

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***Abstract*: Rain-water-harvesting is one of the means by which agricultural production can be increased to meet the growing food demands in all regions. The study evaluated the impact of rain-water-harvesting irrigation on household food security and income in Eastern Hararghe, Ethiopia. Both primary and secondary data were collected for the study. Primary data were collected from 190 sample households using questionnaire prepared during june15-july20/2014. The study implemented logistic regression model and propensity score matching. Logistic regression estimation revealed that age of household head, education level, number of livestock in tropical livestock unit (TLU), size of land holding, distance between home and farmers training center and labor force the member significantly affected the participation decision of household in rain-water-harvesting. Propensity score matching method was applied to analyze the impact of the rain-water-harvesting ponds on the household food security and farm income. In matching processes, kernel matching with band width of 0.5 was found to be the best matching algorithm. This method was checked for covariate balancing with a standardized bias, t-test, and joint significance level tests. Propensity score matching method results also revealed that household participated in rain-water-harvesting practice have got 1089 Kilocalorie per adult equivalent per day (AE/day) of food, 140Ethiopian Birr (ETB) higher food expenditure/AE/year and 2072 ETB more farm income than those household that were not participated in rain-water-harvesting practice.**

***Keywords*: Rain-water-harvesting, food security, propensity score matching, logistic regression.**

I. INTRODUCTION

Ethiopia has a total population of 73.9 million and the rural population, which is predominantly dependent on agriculture, accounts for about 85 percent of the total (CSA, 2007). Ethiopia is among the low income countries of the world and ranks among the lowest for most human development indicators (World Bank 2010). The Ethiopian economy is highly vulnerable to droughts and adverse terms of trade by virtue of its dependence on primary commodities and rain-fed agriculture. Thus the country's growth performance is highly correlated with weather conditions. A 1% change in average annual rainfall is associated with a change of 0.3% in real GDP in the following year (Mwanakatwe and Barrow 2010).

Ethiopia is an agrarian country where around 95% of the country's agricultural output is produced by smallholder farmers (MoARD, 2010). The contribution of agriculture to national GDP (50%), employment (85%), export earnings (90%), and supply of industrial raw materials (70%) has remained high (World Bank, 2010). Although the country is endowed with three main resources namely land, water and labor for production, agriculture in the country is mostly small- scale, rainfall dependent, traditional and of subsistent nature with limited access to technology and institutional support services.

Rainwater harvesting and its application to achieving higher crop yields encourages farmers to add value and diversify their enterprises. Rainwater harvesting created new/additional sources of water and helped in the provision and regulation of the water supply systems. Poor management of rainwater in rain fed systems generates excessive runoff and floods, causing soil erosion and poor yields. When rainwater harvesting at the household or community level enables rainfed farms to access a source of supplementary irrigation, the economic security also improves.

Rainwater harvesting is a technique used for collection and storage of rainwater from catchments areas (Kun et al., 2004). The rain water harvesting techniques usually found in Asia and Africa originate from practices employed by ancient civilizations within these regions and these still serve as a major source of water supply in rural areas (Theib and Ahmed, 2006). Rainwater harvesting can be a very good option for the rural areas which are suffering from water scarcity (Nissen, 1982). The harvesting of rainwater in a particular region is highly dependent upon the amount and intensity of rainfall and some other factors like catchment area and type of catchment surface (Pacey and Cullis, 1989).

II. STATEMENTS OF THE PROBLEM

Due to population increase, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources. One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, rainfall is lost almost completely through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Thus, there is need for appropriate interventions to address the prevailing constraints using suitable technologies for improved and sustainable agricultural production.

To mitigate the erratic nature of rain-fall in the arid and semi-arid parts of the country, which threatens the lives of millions of people, a national food security strategy based on the development and implementation of rainwater harvesting technologies either at a village or household level was adopted after 1991. The Federal Government had allocated a budget for food security programs in the regions, an amount equal to ETB 100 million and ETB one billion during the 2002 and 2003 fiscal years, respectively. Of the total budget, most of it was used by regional states for the construction of rainwater harvesting technologies including household ponds, in collaboration with the Federal Ministry of Agriculture and Rural Development (Rami, 2003).

The main weakness of many studies is that they do not explicitly point to a causal effect of agricultural technology adoption on farm household wellbeing, or, in other words, they fail to establish an adequate and identify the true causality of change. Indeed, in order to assess the impact of rain water harvesting technology on household income generation and food secuirity, the researcher should be able to assess what the situation would be like if the water harvesting technology had not been adopted, *i.e*., the counterfactual situation. If not, that can lead to misleading policy implications, as at the household level many other factors may have changed along with technology. So this study was supported by propensity score matching method to establish counterfactual situation in impact analysis.

Generally, this study was conducted in Gursum district, which is one of the 19 districts of Eastern Hareghe zone. This district is one of the woredas in which rain water harvesting has been practiced. However, there was no adequate study to analyze extent to which, these harvested water are contributing towards household food security and income generation in the area. This means to see whether farm households use or practicing rain water harvesting for irrigation are better off than those who depend on rainfall only and whether there exists variability in food calorie and farm income generation among farmers, under the current situation in the area. Thus, it is important to know the impact of rain-water-harvesting for irrigation on household income generating and food security for household in the area.

Objectives of the Study

1. To assess determinants of participation in rain water harvesting practice in area

2. To analysis impacts of rain water harvesting on households income and food security

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III. METHODOLOGY

Sampling and Sampling technique

Eastern Hararghe zone is one of the 17 zones of the Oromia National Regional State. It is located in the eastern part of the country. It divided into 19 districts and Harar is the capital town of the zone and is located at the distance of 525 kms from Addis Ababa. The agro climatic range of Zone includes lowland (*kolla*, 30-40%), midland (*weyna dega*, 35-45%) and highland areas (*dega*, 15-20%), with lowest elevations at around 1,000 m a.s.l, culminating at 3,405 m, at the top of Gara Muleta mountain.

The study was conducted in gursum woreda of of Eatern Hararghe, which is purposively selected due to availability of potential rain-water-harvesting practice. The climate of the area is characterized by warm and dry weather with relatively low precipitation. It receives a bimodal type of rainfall, *Belg* and *Maher* rain. Agriculture is the major source of livelihood of the community. However, its productivity is dependent on the rain-fed agriculture. The farming system is subsistence type dominated by smallholder farmers. Sorghum and maize crops take the largest proportion of crop production. Total rural kebeles that are practicing water harvesting and using for irrigation purpose was identified. Out of the 39 rural *kebeles* that are found in the Gursum district, two rural *kebeles(muyadin and harashi)* were randamly selected. *Muyadin and Harashi kebeles have* 720 and 304 plastic pvc to harvest rain-water respectively. To select sample respondents from two *kebeles*, first the household heads in the both *kebeles* ware identified and stratified into two strata: farmer harvesting rain water and non-harvesters. Then the sample from each stratum was selected randomly using simple random sampling technique. Since the number of household heads in the two groups were proportional, equal number of sample was drawn from each group, *i.e.*, 95 household heads was selected from each group. Total of 190 respondents were interviewed using questionnaire prepared for this purpose during june15-july20/2014.

Data Analysis Techniques

Based on the objectives of study, both descriptive statistics and econometric models was employed to analyze qualitative and quantitative data. Besides estimating propensity score in water harvested impact analysis, logistic regression was also used for analyzing the factor determining participation in rain water harvesting practice. From econometric model, logistic regression model was applied to estimate propensity score in matching method (PSM) that was used for impact evaluation. To analysis factor determining participation in rain-water-harvesting pond for irrigation purpose, logistic model was applied. To do so, dependant variable used to analysis the factor was dichotomous variable, 'rain water pond user' represented by "1"and "0 for non-user in the model.

$$P_i = \frac{1}{1+e^{-z_i}} = \frac{e^{z_i}}{1+e^{z_i}} \qquad (1)$$

Where, P_i = is the probability of being Rain pond-user for the i^{th} farmer and it ranges from 0-1.

e^{zi} = stands for the irrational number e to the power of Z_i.

Z_i = a function of n-explanatory variables which is also expressed as:

$Z_i=b_0+b_1X_1+b_2X_2+\ldots+b_nX_n$, Where, X_1, $X_2\ldots$ X_n are explanatory variables (2)

Impact Evaluation Methods using Propensity Score Matching (PSM) Method

A logistic model is used to estimate propensity scores using a composite of pre-participation characteristics of the sampled households (Rosenbaum and Robin, 1983) and matching is then performed using propensity scores of each observation. To analyze the factor affecting rain-water-harvesting for irrigation, dependent variable is dichotomous in nature and represents the observed rain-water-harvesting ponds. It was represented in the model as rain-water-harvst user (RWH) =1 for a household that use pond to harvest rain water and non-user =0 for a household that do not use pond to harvest rain water.

The impact of rain-water-harvesting for irrigation on food security and income is the difference in households' mean calorie intake and total farm income of the participation and non-participation in the rain-water-harvesting. Thus, the fundamental problem of such an impact evaluation is a missing data problem. Hence, this study applies a propensity score matching technique, which is a widely applied impact evaluation instrument in the absence of baseline survey data for impact evaluation. According to Caliendo and Kopeinig (2005), estimation of the propensity scores, choosing a matching algorism, checking on common support condition and testing the matching quality are step in implementing PSM. Imposing a common support condition ensures that any combination of characteristics observed in the participant group can also be observed among the non-participant group (Bryson *et al*., 2002). The common support region is the area which contains the minimum and maximum propensity scores of treatment and control group households, respectively.

For any rain-water-harvesting household, there should be non-harvesting household with closest propensity score as the match. To accomplish the match, the nearest neighbor (equal weights version) was tested. The nearest neighbor method simply identifies for each household the closest twin in the opposite irrigation access status. Caliper matching which means that an individual from the comparison (non-participant) group was also tested as a matching partner for a treated individual that lies within a given caliper (propensity score range) and is closest in terms of propensity score and kernel matching estimators was also tested. However, for this specific study kernel matching was used to evaluate impact of rain-water-harvesting on households' food security, farm income and food expenditure. This is matching method whereby all treated units are matched with a weighted average of all controls with weights which are inversely proportional to the distance between the propensity scores of treated and controls Becker and Ichino (2002) Venetoklis (2004). It then computes an estimate of the rain-water-harvesting effect as the average difference in households' outcome variable between each pair of matched households. The impact of rain-water-harvesting for an individual i, noted δ_i, is defined as the difference between the potential outcome in case of rain-water-harvesting and the potential outcome in absence using PSM.

$$\delta_i = Y_{1i} - Y_{0i} \qquad (3)$$

In general, an evaluation seeks to estimate the mean impact of the rain-water-harvesting is obtained by averaging the impact across all the individuals in the population. This parameter is known as Average Treatment Effect or ATE:

$$ATE = E(\delta) = E(Y_1 - Y_0) \qquad (4)$$

where $E(.)$ represents the average (or expected value). Another quantity of interest is the Average Treatment Effect on the Treated or ATT, which measures the impact of the treatment on those individuals who participated:

$$ATT = E(Y_1 - Y_0 \mid D = 1) \qquad (5)$$

Finally, the Average Treatment Effect on the Untreated (ATU) measures the impact that the treatment would have had on those who did not participate:

$$ATU = E(Y_1 - Y_0 \mid D = 0) \qquad (6)$$

The problem is that, not all of these parameters are observable, since they depend on counterfactual outcomes. For instance, using the fact that the average of a difference is the difference of the averages, the ATT can be rewritten as:

$$ATT = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1) \qquad (7)$$

The second term, $E(Y_0 \mid D = 1)$ is the average outcome that the treated individuals would have obtained in absence of treatment, which is not observed. However, we do observe the term $E(Y_0 \mid D = 0)$ that is, the value of Y_0 for the untreated individuals.

$$ATT = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 0)$$

In this step of analyzing impacts of rain-water-harvesting on food security using propensity score matching, the most knowledgeable person in the household was asked a set of questions regarding food prepared for meals over specific period of time specifically 7 days. It requires listing out food types on questionnaire and distinguishing unambiguously between the amounts of food purchased, prepared for consumption and the amount food served. As stated earlier, the impact of the rain-water-harvesting on household food security was measured using physical consumption of food. To do so, households were asked to report the kind and amount of food items consumed by their families in the last weeks preceding the survey. Converting the data into calories adjusted for household age and sex composition involved a series of steps.

IV. RESULTS AND DISCUSSION

Households' Demographic and Socio-economic Characteristics

As mentioned in the methodology parts the descriptive parts of the analysis is used to describe characteristics of the sample respondent. Table 1 shows descriptive statistics results of sample household based on participation in rain-water-harvesting using ponds. Family size is useful for formulating various development plans and for monitoring and evaluating their implementation. In the study area, the average family size was 5.5. The t-test shows that there is no significant difference in family size between the rain water harvesting users and non-user households (Table 1). The average cultivated land of all sample respondents was 1.3ha. On average participant household have 1.5 ha while non-participants have 1.2ha. There is a significant difference in their size land holding. The survey results showed that mean difference between rain water pond user and non-user was found to be significant at 1% significant level based on land holding of household.

Table 1: Socio-economic characteristics of sample households and access to rain water ponds

Variables	All sample HH(n=190)		Rain-water pond user HH(N=95)		Non-user HH(N=95)		Mean difference	t-value
	Mean	Std	Mean	Std	Mean	Std		
Age of HH	35.5	7.4	37.3	8.7	33.8	5.2	-3.4	-3.3***
Market dista	10.5	3.1	10.4	3.1	10.6	3.1	0.2	0.4
Labor force	3.9	1.3	4.1	1.2	3.6	1.3	-0.5	-2.7***
Extension cont.	24.4	11.7	25.7	11.9	23.2	11.5	2.5	-1.5*
Extension dista	1.8	1.4	1.4	1.4	2.2	1.3	0.8	0.8

Own estimation result. *** and * means significant at the 1%, and 10% probability levels, respectively

Livestock is very important asset in farm household. In this study, the average livestock holding of household is 1.5 in TLU. On average participant household have 1.9 while that of non-participant in rain water harvesting is 1.2 in TLU. Participant households have larger livestock compared to non-participant households. The survey result revealed that, the mean difference between rain water harvest-user and non-user household was significant at 1% level of significance based livestock holding in tropical livestock unit. Similarly, rain water harvesting participants have more number of extension contact days compared to non-participants. The average number of days participants visited by extension workers in the year is 24.4time and that of non-participant is 23.2times in the year. The result showed that, the mean difference between numbers of times participants visited by extension workers and nun-participants were also found to be significant at 10% significance level.

Table 2: comparison of outcome variable between rain-water-harvesting user and non-user

	Rain water pond user		Non-user		Mean difference	t-value
	Mean	std	Mean	std		
K.calorie/AE/day	3316.5	2162.5	2289.9	1961.0	1026.5	3.4***
Food expen./AE/yr	770.6	545.2	622.5	364.1	148.1	2.2**
Total farm income/yr	5042.6	2843	2962.2	2353.3	-2080.4	-5.5***

Source: own survey computed result.*** and ** mean significant at 1% and 5% probability level respectively.

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Descriptive statistics results of sample households presented in Table 2 based on measure of food security (i.e. their calorie intake), annual households' food expenditure and total farm income in ETB. The survey results show that on average participant households and non-participant households had calorie intake of 3317 and 2290 calories, respectively. This means, households that participated in rain-water-harvesting are better off in calorie intake than that of non-participant. Annual households' food expenditure of participants and non-participants is around 771 and 623 respectively. Similarly, total farm income of participant and non-participants households is around 5043 and 2962ETB respectively. There are statistical mean differences between both groups of households all outcome variables. However, this descriptive result cannot tell us whether the observed difference is exclusively because of the participation in rain-water-harvesting activities. It is not possible to attribute the difference in all mentioned outcome variables of the two groups exclusively to the treatment, as comparisons are not yet restricted to households who have similar characteristics. Further analyses were performed using propensity score matching techniques to address this issue.

Results of Econometric Model

Determinants of participation in rain water harvesting pond for irrigation

The pseudo- R^2 indicates how well the regressors explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo- R^2 should be fairly low (Caliendo and Kopeinig, 2005).

Table 3: Logistic regression results for determinants of participation in rain-water- harvesting

RAINPOND	Coef.	Odd ratio	Std. Err.	z
Age of HH	0.0374	1.03	0.018	2.11**
Sex of HH	0.3087	1.63	0.23	1.34
HH education	0.1552	1.32	0.038	4.12***
Family size	-0.0166	0.97	0.072	-0.23
Market dista.	-0.0235	0.96	0.04	-0.59
Farm size	0.6976	3.37	0.229	3.05***
Livestock	0.6705	3.17	0.154	4.35***
Labor force	0.1607	1.33	0.093	1.73*
Extnsion cont.	0.0081	1.01	0.01	0.86
Exten. Dista	-0.3819	0.51	0.091	-4.18***
_cons	-3.9394		0.991	-3.98

Number of obs	=	190	Prob > chi2	=	0.00
LR chi2(10)	=	97.42	log likelihood	=	-82.99
			Pseudo R^2	=	0.369

*Source: Own estimation result. *** and ** means significant at the 1%, and 5% probability levels, respectively*

It was found that participation in rain-water-harvesting is significantly influenced by six explanatory variables. Age of household head, Level of formal education, , size of land holding, size of livestock in TLU, labor force in family member and distance from farmers training center are significant variables which affect the participation of the household in rain-water-harvesting ponds and its utilization. Age of household head shows positive relation with participation in rain water harvesting practice. This implies that an increase in age of household head increases participation in rain water harvesting practice and the likelihood for household to become food secure. This is possible because older farmers have better experience in farming; try to learn more from past and use better planning than the younger ones. As the age of household head increase the probability of household participation in rain-water-harvesting increase. The interpretation of the odds ratio also implies that if other factors are held constant, the odds ratio in favor of rain water harvesting practice increase by a factor of 1.03 as age of household head increase by one year (Table 3). Access to higher formal year of schooling has positive relationship with household participation in rain-water-harvesting.

Similarly, size of land holding has positive effect on household participation in rain water harvesting practice. As the size of land holding area increases the probability of being an participant in rain water harvesting increase. This is because of the fact that the size of landholding is a surrogate for a host of factors including wealth and capacity to bear risk due to larger farms. Larger farms are associated with greater wealth and availability of capital, which increases the probability of purchasing farm inputs and plastic material that is used to harvest rain-water. The interpretation of the odds ratio also implies that if other factors are held constant, the odds ratio in favor of participating in rain water harvesting increases by factor of 3.37 as size of landholding increase by one unit (ha). Tesfaye (2006) and Molla (2005) too reached to similar conclusion with regard to size of land holding variable and participation in rain-water harvesting technology.

Similarly, households that have home nearer to farmers training center were more likely to be included in the rain-water-harvesting practice. This variable found to be positively related with the participation rain-water-harvesting and using for irrigation. This implies that household that have residence far from farmers training center have not updated information regarding with new agricultural technology and training. As the distance between farmers home and farmers training center increase the probability of household participation in rain-water-harvesting decrease. The interpretation of the odds ratio also implies that if other factors are held constant, the odds ratio in favor of harvesting-rain-water and using for irrigation purpose decreases by a factor of 0.51 as distance between home and farmers training center increase by one kilometer (Table 3).

Households who have larger number of livestock in tropical livestock unit were more likely to be included in the rain-water-harvesting and utilization. These variable is found to influence participation of household in rain-water-harvesting positively and significantly. The implication of the result was that livestock are an important source of cash in rural areas to allow purchase of farm inputs that can be used when rain water is harvested used for irrigation purpose. Farmers who have large number of livestock might consider their asset base as a mechanism of insuring any risk associated with the use of harvested rain water for agriculture. Given this potential contribution of livestock to sustainable household food supply and cash generation, they encourage adoption of new technology. The odds ratio of 3.17 implies that, other things kept constant, the odds ratio in favor of harvesting rain water and using for irrigation increases by a factor of 3.17 for each increase in TLU for livestock (Table 3). This implies that livestock holding has an influence on the adoption of new technologies in different areas. This finding is consistent with previous result of Abonesh (2006).

Rain-water-harvesting require large number of labor force in rural area. Households that have larger number of working group members were more likely to be included rain-water-harvesting. As it is reveled from estimation of the logit regression analysis indicate that, participation in rain-water-harvesting technology has a positive and statistically significant association with use of higher labor, most likely due to the higher level of labor requirement during construction of rain water harvesting pond and watering activities involved. The interpretation of the odds ratio also implies that if other factors are held constant, the odds ratio in favor of participating in rain water harvesting increases by factor of 1.3 as number working family member increase by one person.

Impact Estimation

Results of propensity scores matching

The logistic regression model was used to estimate propensity score matching for participant and non-participants households in rain-water-harvesting. The dependent variable in this model is a binary variable indicating whether the household was a participant in the rain-water-harvesting or not. The model was estimated with STATA 11.2 computing software using the propensity scores matching algorithm developed by Leuven and Sianesi (2003). Results presented in Table 3 shows the estimated model appears to perform well for the intended matching exercise. The pseudo-R^2 value is 0.369. A low pseudo-R^2 value shows that participant households do not have much distinct characteristics overall and as such finding a good match between treated and non-treated households becomes simple.

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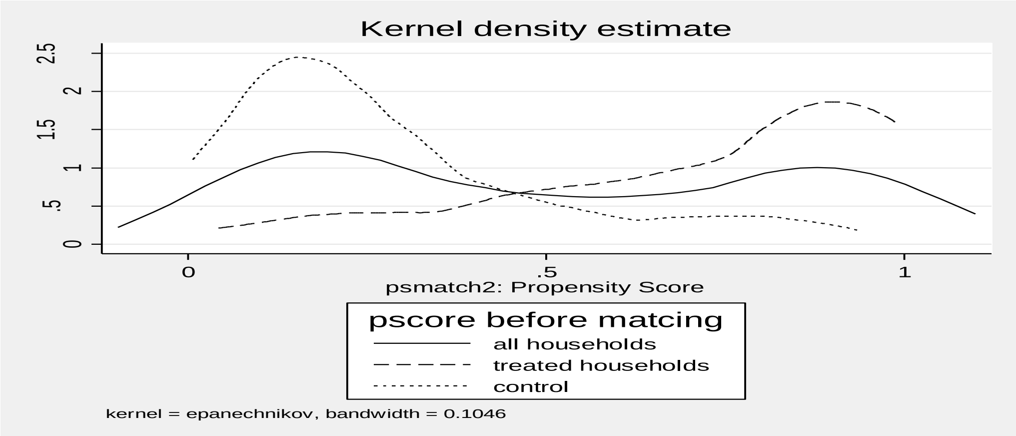

Figure 1: Kernel density of propensity score distribution

Figure 1 portrays the distribution of the household with respect to the estimated propensity scores .In case of treatment households, most of them are found in the right starting from the middle of the distributed propensity. On the other hand, most of the control or non-user of harvested rain households are partly found in the center and with the most part of distribution found in the left side.

Matching participant and comparison households

Four main tasks were accomplished before matching. First, predicted values of treatment participation (propensity scores) estimated for all participated households and non-participants. Second, a common support condition was imposed on the propensity score distributions of participant household in rain-water-harvesting and non-participant household. Third, discard observations whose predicted propensity scores fall outside the range of the common support region. And finally sensitivity analysis was done in order to check the robustness of the estimation (whether the hidden bias affects the estimated ATT or not).

Imposing a common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al*., 2002). The common support region is the area which contains the minimum and maximum propensity scores of treatment and control group households, respectively. It requires deleting of all observations whose propensity scores is smaller than the minimum and larger than the maximum of treatment and control, respectively (Caliendo and Kopeinig, 2005). For this study, the common support region would lie between 0.0426386 and 0.9336423. In other words, households whose estimated propensity score is less than 0.0426386 and larger than 0.9336423are not considered for the matching exercise. As a result of this restriction, 33 households (28 participant and 5 non-participant households) were discarded.

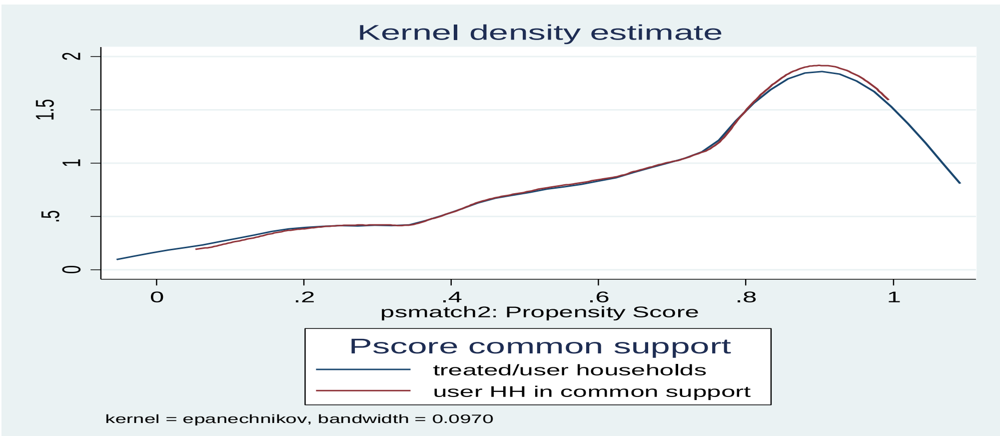

Figure 2: Kernel density of propensity scores of participant households

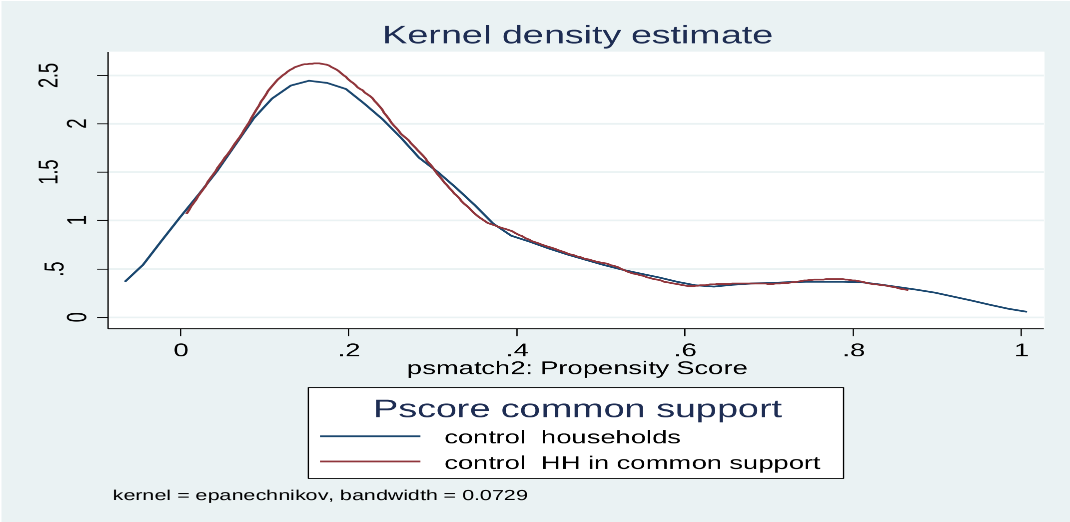

Figure 3: Kernel density of propensity scores of non-participant households

Choice of matching algorithms

Balancing test is a test conducted to know whether there is statistically significant difference in mean value of the two groups of the respondents and preferred when there is no significant difference after matched. Accordingly, matching estimators were evaluated via matching the participant and non-participant households in common support region. Therefore, a matching estimator having balanced or insignificant mean differences in all explanatory variables, bears a low pseudo- R^2 value and also the one that results in large matched sample size is preferred for matching exercise.

Table 4: Performance measures of matching estimators

Matching Estimator	Performance Criteria		
	Balancing test*	Pseudo-R^2	Matched sample size
Nearest Neighbor			
1 Neighbor	4	0.383	157
2 Neighbor	6	0.269	157
3 Neighbor	5	0.261	157
4 Neighbor	4	0.262	157
Radius Caliper			
0.1	6	0.236	157
0.25	7	0.132	157
0.5	10	0.024	157
Kernel Matching			
Band width of 0.1	5	0.249	157
Band width of 0.25	5	0.175	157
Band width of 0.5	10	0.023	157

* Number of explanatory variables with no statistically significant mean differences between the matched groups of participants and non-participants households in rain-water-harvesting

In line with the above indicators of matching quality, kernel matching with 0.5 band width is resulted in relatively low pseudo-R^2 with best balancing test (all explanatory variables insignificant) and large matched sample size as compared to other alternative matching estimators indicated in Table 4. Then it was selected as a best fit matching estimator.

Testing the balance of propensity score and covariates

After choosing the best performing matching algorithm the next step is to check the balancing of propensity score and covariate using different procedures by applying the selected matching algorithm(in our case kernel matching). As indicated earlier, the main purpose of the propensity score estimation is not to obtain a precise prediction of selection into treatment, but rather to balance the distributions of relevant variables in both groups.

Table 5: Balancing test for covariate

		Mean		%reduct		t-test	
Variable	**Sample**	**Treated**	**Control**	**%bias**	**/bias/**	**t**	**P > t**
pscore	Unmatched	0.72092	0.27908	178.3		12.29	0.000
	Matched	0.61754	0.49043	51.3	71.2	-1.97	0.051
AGEHH	Unmatched	37.242	33.832	47.4		3.27	0.001
	Matched	35.731	35.641	1.3	97.3	-0.46	0.644
SEXHH	Unmatched	0.63158	0.47368	32		2.21	0.029
	Matched	0.56716	0.56188	1.1	96.7	-0.67	0.504
EDUCHH	Unmatched	5.6526	3.8632	59.6		4.11	0.000
	Matched	5.1045	4.8911	7.1	88.1	-0.4	0.691
HHSIZE	Unmatched	5.5789	5.3263	14.7		1.02	0.311
	Matched	5.5373	5.5568	-1.1	92.3	-0.32	0.747
MARKD	Unmatched	10.417	10.579	-5.2		-0.36	0.722
	Matched	10.555	10.716	-5.1	1	-0.16	0.872
FARMSIZ	Unmatched	1.5305	1.1579	72.5		5	0.000
	Matched	1.409	1.3152	18.2	74.8	-0.59	0.559
LIVESTO	Unmatched	1.8547	1.1925	78.4		5.4	0.000
	Matched	1.5448	1.3919	18.1	76.9	-0.82	0.416
LABFOCE	Unmatched	4.1263	3.6316	39.1		2.7	0.008
	Matched	4.0597	3.827	18.4	53	-0.54	0.591
EXTCONTC	Unmatched	25.705	23.189	21.5		1.48	0.14
	Matched	24.627	24.615	0.1	99.5	-0.4	0.693
DISTFTC	Unmatched	1.4048	2.1614	-55.6		-3.83	0.000
	Matched	1.479	1.775	-21.7	60.9	0.66	0.511

Source: own survey result of PSM estimation

The mean standardized bias before and after matching are shown in the fifth columns of Table 5, while column six reports the total bias reduction obtained by the matching procedure. In the present matching models, the standardized difference in covariate before matching is in the range of 5.2% and 78% in absolute value. After matching, the remaining standardized difference of covariate for almost all covariates lies between 0.1% and 21%. In all cases, it is evident that sample differences in the unmatched data significantly exceed those in the samples of matched cases. The process of matching thus creates a high degree of covariate balance between the participant and non-participant samples that are ready to use in the estimation procedure. Similarly, t-values in Tables 5 shows that before matching almost half of chosen variables exhibited statistically significant differences while after matching all of the covariates were balanced and become statistically insignificant.

Table 6: Chi-square test for the joint significance of variables

Sample	Pseudo R^2	LR chi^2	p>chi^2
Unmatched	0.373	98.38	0.000
Matched	0.023	4.86	0.938

The low pseudo-R^2 and the insignificant likelihood ratio tests support the hypothesis that both groups have the same distribution in covariates after matching (see Table 6). These results clearly show that the matching procedure is able to balance the characteristics in the participant and the matched non-participant groups. We, therefore, used these results to evaluate the impact of rain-water-harvesting for irrigation on outcome variable among groups of households having similar observed characteristics. This allows comparing observed outcomes for participants with those of comparison groups sharing a common support.

Sianesi (2004), suggests re-estimating the propensity score on the matched sample, i.e. only on participants and matched non-participants, and comparing the pseudo-R^2s before and after matching is important. The pseudo-R^2 indicates how well the repressors explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore the pseudo-R^2 should be fairly low. The low pseudo-R^2 (compared with other pseudo-R^2's resulted using different matching estimators) and the insignificant likelihood ratio tests (indicated by the higher p-value after matching) support the hypothesis that both groups have the same distribution in covariates after matching. All of the above tests suggest that the matching algorithm we have chosen is relatively best with the data we have at hand. Thus, we can proceed to estimate ATT for households.

Estimating treatment effect on treated (ATT)

The level of, and changes in, socio-economic and demographic variables can be properly analyzed, and can serve as proxies to indicate the status and changes in food security (Von Braun *et al.*, 1992). Food security at the household level is measured by direct survey of income, expenditure and consumption and comparing it with the minimum subsistence requirement. In this regard, income and expenses are used to compute the status of food security. The minimum level of income, which is required per adult equivalent, was calculated on the basis of amount of food required by an adult person. The government of Ethiopia has set the minimum acceptable weighted average food requirement per person per day at 2100 kilo calorie (FDRE, 1996) which is estimated to be 225 kg of food (grain equivalent) per person per year. Consequently, a threshold level is set by computing the value of this amount of cereal by the existing local market price of grain.

Table 7: Average treatment effect on treated (ATT)

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
K.calorie/AE/day	ATT	3197.61	2108.51	1089.10	347.44	3.13***
Foodexpen./AE/yr	ATT	764.36	623.82	140.54	81.48	1.72*
Totalfarm income/yr	ATT	4941.43	2869.26	2072.17	491.16	4.22***

*Source: own survey result. *** & *Mean significant at 1% and 5% of probability level respectively*

In order to solve the second objective, the following impact indicators of the treatment effect have been performed using propensity score matching model. In this section, the PSM results provides evidence as to whether or not the rain-water-harvesting has brought significant changes on households' food security, farm income and annual food expenditure of households in Ethiopian Birr. The estimation result presented in Table 7 provides a supportive evidence of statistically significant effect of the rain-water-harvesting on household food security measured in calorie intake, household Farm income and food expenditure in ETB. After controlling for pre-participation differences in demographic, location and asset endowment characteristics of the rainwater pond-user and non-user households, it has been found that, on average, the participant households' have increased physical food consumption by 1089 Kilocalories. Similarly, the rain-water-harvesting has increased income of participating households by 2072 ETB and food expenditure by140ETB than that of non-participant households in rain-water-harvesting.

Sensitivity analysis

Rosenbaum (2002), proposes using Rosenbaum bounding approach in order to check the sensitivity of the estimated ATT. The basic question to be answered here is whether inference about treatment effects may be altered by unobserved factors. In order to control for unobservable biases Table 8 below shows the result of sensitivity of rain-water-harvesting impact on different outcome variables.

Table 8 presents the critical level of e^{γ} (first row), at which the causal inference of significant rain-water-harvesting impact has to be questioned. Rosenbaum bounds were calculated for rain-water-harvesting impacts that are positive and significantly different from zero. The first column of the Table shows those outcome variables which bears statistical difference between participant and non-participant households in this impact estimate .The values which corresponds to each row of the significant outcome variables are p-critical values (or the upper bound of Wilcoxon signify. level -Sig+) at different critical value of e^{γ}.

Table 8: Result of sensitivity analysis using Rosenbaum bounding approach

No	Outcomes	e^{γ}=1	e^{γ}=1.25	e^{γ}=1.5	e^{γ}=1.75	e^{γ}=2	e^{γ}=2.25	e^{γ}=2.5	e^{γ}=2.75	e^{γ}=3
1	Total farm income/AE/yr	0.00	0.000	0.000	0.000	0.000	7.80E-16	2.00E-14	2.80E-13	2.60E-12
2	Kilocalorie intake/AE/day	0.00	0.000	0.000	0.000	0.000	7.80E-16	2.00E-14	2.80E-13	2.60E-12
3	Food expend./AE/yr	0.00	0.000	0.000	0.000	0.000	7.80E-16	2.00E-14	2.80E-13	2.60E-12

* e^{γ} (gamma) - log odds of differential assignment due to unobserved factors where Wilcoxon significance level for each significant outcome variable is calculated.

Results show that the inference for the effect of the rain-water-harvesting is not changing though the participants and non participant households has been allowed to differ in their odds of being treated up to (e^{γ} = 3**)** in terms of unobserved covariates**.** That means for all outcome variables estimated, at various level of critical value of e^{γ}, the p-critical values are significant which further indicate that we have considered important covariates that affected both participation and outcome variables. We couldn't get the critical value e^{γ} where the estimated ATT is questioned even if we have set largely up to 3. Thus, we can conclude that our impact estimates (ATT) are insensitive to unobserved selection bias and are a pure effect of rain-water-harvesting.

V. RECOMMENDATION

Rain-water-harvesting for irrigation is important development effort to ensure households food security and farm income if properly implemented. Based on the empirical findings reported in this study, the following recommendations are forwarded:

Education of household head and participation in rain-water-harvesting ponds showed positive and significant relationship. The more household head educated, the higher will be the probability of educating family member and familiar with modern technology adoption and participation in rain-water-harvesting. Formal education is one of the factors that affect income of household and food security. Strengthening educational capacity of household heads and whole community leads to acceptance of important new technology and increase household income and food security. Therefore, a way of access to adult education should be designed. Similarly, a rain-water-harvesting activity is labor intensive and requires more participation of family member and community in pond construction. This variable has positive and significant relationship with participation in rain-water-harvesting activities. So, encouraging farm community work share or cooperative work in rain-water-harvesting pond preparation is very important in the study area.

Based on primary data collected from household survey, the impacts of rain-water-harvesting ponds on households food security (measured in kilocalories), annual farm income and food expenditure measured in Ethiopian Birr in the study area. The results of propensity score matching obtained from analyzed data is revealed that, household participated in rain-water-harvesting is better off in both household food security and Annual farm income compared to non-participant household in rain-water-harvesting in study area. Participant households obtained on average 1089kilocalories more compared to non-participates households in rain-water-harvesting. It is concluded that strengthening participation in rain-water-harvesting pond preparation and utilization is very important for households income generation and food security. This can be attained through training farmers and building their capacity for pond construction. Therefore, government and other development institution should increasing household participation in rain-water-harvesting for irrigation through developing water-harvesting technology, improving capacity of existing rain-ponds and asset building like rain-harvesting PVC plastic and motor pump facility.

Figure 4: Trapezoidal pond covered with pvc plastic in study area

Figure 5: Sample of cylindrical rain-water-harvesting ponds pvc plastic

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