RESEARCH ARTICLE

# Does small-scale irrigation have impact on household food security? Evidence from southern Tigray, Ethiopia

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**Introduction:** The livelihood of rural households in Ethiopia depends on subsistence and rain-fed oriented agriculture. However, erratic rain and prevalence of drought in the country make agricultural production a challenge. To counter this problem, use of the available water resources for irrigation development is the most promising option.

**Objective:** Therefore, this study examines the impact of small-scale irrigation on household food security in Emba Alaje district of southern Tigray zone, Tigray regional state.

**Methodology:** A multi-stage sampling technique was employed to select sample households. The study was mainly based on the primary data that were collected from 137 randomly selected rural households (67 irrigation users and 70 non-users) from 2 kebelle of the district. The data were analysed using both descriptive statistics and econometric models. Descriptive statistics was used to characterize the sample of socio-economic and demographic status of households and propensity score matching techniques model were used to analyse the impacts of small-scale irrigation on specific food security outcomes.

**Results:** The Average treatment effect on treated result shows that participation in irrigation has positive impact on household's income, food availability, food variety score, household diet diversity and calorie intake.

**Conclusion:** Therefore, the study concludes that small-scale irrigation development would have positive effect on food security of beneficiary households.

**Key Words:** *Food security; Small-scale irrigation; Propensity score matching*

## INTRODUCTION

Ethiopia is among the most food insecure countries of the world where 44% of its population live below the national poverty line, and 46% of its population get below the minimum levels of dietary energy consumption compared with other sub-Saharan and developing countries World Food Programme (WFP) [1] irrigation enhances agricultural production and improves food supply and income of rural population, opens employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops [2]. Currently, the Ethiopian government gives more emphasis to small-scale irrigation as a means of achieving food self-sufficiency [3]. To address these issues, Agricultural Development Led Industrialization (ADLI) Strategy was designed in 1991 where focus was given to the expansion of small-scale irrigation, formation of cooperative societies and access to agricultural technologies to answer the food demand and bring about the socioeconomic development in the country [4]. The study area is Tigray region, one of the most drought prone regions in the country. Because of that the government of Tigray region is implementing different agricultural development program in order to achieve food security in rural households. Among these programs, irrigation development is primarily taken by the government. Since 2003, small-scale irrigation was used to promote irrigation in 0.5 million food insecure households. In this program, government organizations, international and local NGOs, micro-finance institutions, private sectors and farmers are involved at different levels with different tasks [5].

In Emba Alaje Woreda, Studies on the impact of small-scale irrigation schemes on food security status are very limited and it is not well known to what extent irrigation user households are better off than those who depend on rainfall. A few studies had been done in the area regarding on impact of irrigation on a household food security. For instance, the study of Aregawi [5] and Kinfe [6], focuses on the impact of irrigation scheme on a household food security by taking only income as proxy measure of impact of irrigation. In other word, in the study area the impact of irrigation scheme on a household food security by taking caloric intake, household diet diversity, food variety score and household food insecurity access scale as proxy measure of impact of irrigation does not well address. With this background, this study is designed to analyse the impact of small-scale irrigation on household food security in Emba Alaje woreda and through that make recommendations to improve the effectiveness of interventions.

## RESEARCH METHODOLOGY

### Sampling technique and sample size determination

This study uses both survey design and a multi stage sampling technique. Purposive sampling technique was used to select the study area (Emba Alaje district) due its implementation of small-scale irrigation scheme. Then, out of the total 21 kebelles found within the woreda, two kebeles (Ayba and Atsela) was purposively selected mainly based on the current practice and potential for irrigation, and their accessibility in terms of road. Then, to select the representative respondents from each two kebelles, lists of all farmers in the two kebelles were obtained and stratified into two: irrigation users and non- users. Finally, a total of 137 sample household (67 irrigation users and 70 non users) are selected from the list by simple random sampling procedure.

To determine the required sample size, the study was employed a formula developed by Yamane at 95% confidence level, 8.5% margin of errors because of limit of financial and difficulty to manage large sample size.

$$n = N/1 + N(e)2$$

$$n = \frac{3281}{1 + 3281(0.085)2} = \frac{3281}{1+23} = \frac{3281}{24} = 136.7 \approx 137$$

$$\text{User} = 1581 \times \frac{137}{3281} = 66.58 \approx 67$$

$$non - user = 1700 \times \frac{137}{3281} = 70.00$$

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Where:

n=sample size for the study (137)

N=total number of household head (3281)

e=margin of errors at 8.5%.

## Source of data and methods of data collection

For this study, both quantitative and qualitative data type were collected from primary and secondary sources at different levels to fulfil the research questions and objectives of the study. Semi-structured interview was employed to collect primary data on the demographic, socioeconomic, and institutional characteristics from representative sample of households that was administered by eight enumerators. In addition to the structured survey schedule, seven key informant interviews those who have more knowledge about the area, which include elders, experts from agricultural office and development agents working in the kebele were conducted by the researcher to obtain additional information on impact of small-scale irrigation on household's food security in the study area.

## Impact analysis

For analyzing the impact of small-scale irrigation on food security of farming households in the study area, Propensity Score Matching (PSM) method was used. In this study, the treated households were smallholder farm households participating in small-scale irrigation program and the control households selected for comparison purpose were farm households in the study area who do not use irrigation users on their farms.

The difference between the average outcomes of the two groups estimates that the effect of participation on small-scale irrigation. In order to adjust the estimated propensity scores combination of the three main methods of matching was used such as Nearest Neighbour, Radius, and Kernel Matching.

# RESULTS

## Impact analysis of small-scale irrigation on household food security

**Choice of matching algorithm:** Table 1 presents the estimated results of tests of matching quality based on the three performance criteria. Pseudo-$R^2$ is high before matching and is quite low after matching, this indicating that; after matching the covariates has been balanced and there are no systematic differences between the treated and control group. In addition, the p-value is significant before matching indicating that, both the treated and control groups are quite different from each other, while the p-value is non-significant after matching indicating that both are quite similar to each other, and lower mean bias support the hypothesis that both groups have the same distribution in covariates after matching.

After looking into the results, it was found that nearest, kernel and radius matching Algorithm was found to be the best estimator for the data at hand. These results show that the matching procedure is able to balance the characteristics of irrigation user and non-user households of the matched comparison groups. Therefore, the study was used the three matching Algorithm to estimate the treatment effect such as kernel, nearest neighbour and radius matching.

TABLE 1

**Balances indicators before and after matching with nearest-neighbour, kernel and radius matching**

| Matching | Ps $R^2$ | $chi^2$ | $p>chi^2$ | Mean Bias | Med Bias | Balance test | Matched sample |
|---|---|---|---|---|---|---|---|
| Before matching | 0.318 | 60.34 | 0 | 47.5 | 15.2 | 4 | 137 |
| Nearest-neighbor matching | 0.015 | 1.88 | 0.995 | 7.5 | 5.6 | 9 | 119 |
| Kernel matching | 0.016 | 2.15 | 0.989 | 6.8 | 7.1 | 9 | 119 |
| Radius matching | 0.015 | 2.05 | 0.991 | 5.9 | 5.7 | 9 | 119 |
| Stratification matching | 0.116 | 1.54 | 0.01 | 19.4 | 16 | 5 | 126 |

The quality of matching can also be assessed by visual inspection using graphs. To do so, we plotted graphs of estimated propensity scores for treatment households and control households both before and after matching for each of three matching methods (Figures 1,2). Figure 1 portrays the distribution of the household with respect to the estimated propensity scores. In case of treatment households, most of them were found in the middle part and partly in the right side of the distribution. On the other hand, most of the control households are partly found in the center and partly in the left side of the distribution. This indicated that both the treated and control groups are quite different from each other in before matching with different characteristics. But Figure 2 shows that both groups have the same distribution in covariates and more similar after matching.

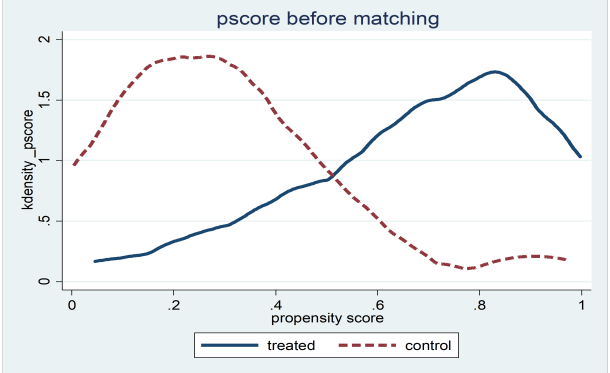


**Figure 1)** Propensity score distribution before matching

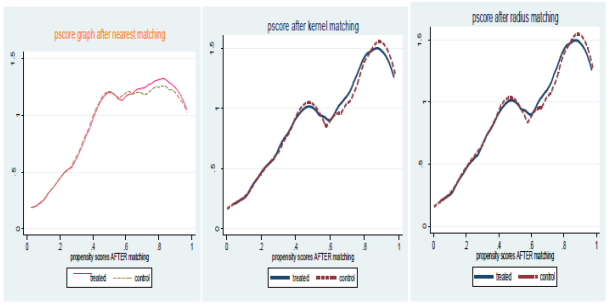


**Figure** 2) Propensity score distribution after matching

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

## Estimated average treatment effect

**Kilocalorie per person per day:** On average, participation in small-scale irrigated farming had impact on calorie intake of the participant households in small-scale irrigated farming by 1,734.56, 1,409.02 and 1,538.36 in Nearest-neighbour, Radius and Kernel matching estimators respectively. This difference was statistically significant at 1% significance level Nearest-neighbour and Radius matching methods only but in Kernel matching methods these differences in kilocalorie between treated and control groups are not statistically significant. This result is consistent with the finding of [7], the estimated average treatment effect on the treated, which is about 529 k cal is the pure effect of small-scale irrigation, and this effect is statistically significant at 5 % probability level (Table 2).

TABLE 2

Kilocalorie per person per day

| Matching method | Treated | Control | ATT | Std Err. | T |
|---|---|---|---|---|---|
| Nearest-neighbor matching | 67 | 20 | 1734.56 | 676.57 | 3.87*** |
| Radius matching | 64 | 52 | 1409.02 | 437.01 | 3.02*** |
| Kernel matching | 67 | 63 | 1538.36 | 562.912 | 1.4 |

**Note:** *** means significant at 1% significance level.

**Food availability:** Table 3 presents the PSM results on food availability. The estimation of ATT of food availability using Nearest-neighbour, Radius and Kernel matching method was 2.448, 2.261 and 2.82 matching estimators respectively. The difference was statistically significant at 1% for Nearest-neighbour, Radius and kernel matching. In the case of users, they can produce more than once a year to supplement the rain fed agriculture. The study conducted by Abonesh in eastern Showa using Heckman two stage analyses revealed that those households with access to irrigation are at better position in securing enough food than their counterparts.

TABLE 3

PSM results on food availability

| Matching method | Treated | Control | ATT | Std Err. | T |
|---|---|---|---|---|---|
| Nearest-neighbor matching | 67 | 20 | 2.448 | 0.458 | 5.342*** |
| Radius matching | 64 | 52 | 2.261 | 0.281 | 8.05*** |
| Kernel matching | 67 | 63 | 2.82 | 0.428 | 5.33*** |

**Note**: *** means significant at 1% significance level.

**Food variety score:** Table 4 presents the PSM results on food variety score. Participation in small-scale irrigation has positive and significant effect on food variety score. The estimation of ATT of food variety score using Nearest-neighbour, Radius and Kernel matching method was 5.284, 5.079 and 4.811 matching estimators respectively. The difference was statistically significant at 1% for Nearest-neighbour, Radius and kernel matching. In other words, the participation in small-scale irrigation has increased probability of households to consume different food items that are accessible across food groups.

TABLE 4

PSM results on food variety score

| Matching method | Treated | Control | ATT | Std Err. | T |
|---|---|---|---|---|---|
| Nearest-neighbor matching | 67 | 20 | 5.284 | 0.592 | 8.918*** |
| Radius matching | 64 | 52 | 5.079 | 0.475 | 10.682*** |
| Kernel matching | 67 | 63 | 4.811 | 0.459 | 10.482*** |

**Note:** *** means significant at 1% significance level respectively.

**Household food insecurity access scale:** Table 5 presents the PSM estimates on the impacts of small-scale irrigation on Household Food Insecurity Access Scale (HFIAS). Result shows that the HFIAS of irrigation user has reduced by -6.104, -5.992 and -5.937 in the case of Nearest-neighbour, Radius and Kernel matching estimators respectively. This means household scores high food insecurity access scale the household becomes more food insecurity access experienced, however, the household with low HFIAS less food insecurity access experienced.

TABLE 5

**Household food insecurity access scale**

| Matching method | Treated | control | ATT | Std Err. | T |
|---|---|---|---|---|---|
| Nearest-neighbor matching | 68 | 20 | -6.104 | 0.774 | -7.888*** |
| Radius matching | 64 | 52 | -5.992 | 0.583 | -10.274*** |
| Kernel matching | 67 | 63 | -5.937 | 0.877 | -13.361*** |

**Note:** *** means significant at 1% significance level respectively.

**Household diet diversity:** The results show that irrigation user households had a higher dietary diversity of 2.209, 2.094 and 1.844 than non-users in Nearest-neighbour, Radius and Kernel matching estimators respectively (Table 6). Again, this difference in HDD between households with irrigation and non- irrigation households is significant at 1% for all matching algorithms.

TABLE 6

**Irrigation user households on dietary diversity**

| Matching method | Treated | control | ATT | Std Err. | T |
|---|---|---|---|---|---|
| Nearest-neighbor matching | 67 | 20 | 2.209 | 0.592 | 3.72 *** |
| Radius matching | 64 | 52 | 2.094 | 0.323 | 6.484*** |
| Kernel matching | 67 | 63 | 1.844 | 0.294 | 6.268*** |

**Note:** *** means significant at 1% significance level respectively.

## DISCUSSION

According to the results, there was no significant difference in the mean age of the household heads between irrigation-user and non-irrigation user household. This indicates that, similar distribution of age between irrigation users and non-users. The t-test revealed that means difference between the two groups with regarding land holding sized is statistically significant at 1 percent significance level.

The t-test result showed that the mean comparison of the two groups with regard to livestock holding is statistically significant at 1 percent significance level. The chi-square test result ($\chi 2=12.28$) indicated that there is statistically significant relationship between the use of irrigation and access to credit at 1 percent significance level.

There was statistically significant difference at 1 percent between irrigation users and non-users in terms of the distribution of households who received training on irrigation practice.

One of the critical explanations for this is that the farm income is highly affected when the smallholder farmers are participated in small-scale irrigated farming. Because, participation in small-scale irrigated farming increases the opportunity to produce two times a year on the same farm and crop diversification, which increase annual income [8-11].

The results indicate that access to irrigation technologies significantly increased kilo calorie intake of user households and enhances food security status as compared to non-irrigation users.

This may be because non-users are producing once a year and if they run out of food before the next harvesting season, they may not have other alternative food source. Again, this difference in HFIAS between households with irrigation and non- irrigation households is significant at 1% for all matching algorithms. This thus shows that irrigation users are in a better position in consuming diversified food. This diversified consumption resulted into the diversification of production and the increased income from diversified high productivity of irrigated farm.

## CONCLUSION

Small-scale irrigation is an important driving tool in development efforts as a means of bringing household food security, reduce dependence on food aid and for economic growth. So, that this study was initiated to analyse the impact of small-scale irrigation on farm households' food security in Emba Alaje district of southern Zone, Tigray regional state with two sample kebelles.

In addition, mean difference of the outcome variables, household diet diversity, food variety score, household food insecurity access scale, household daily caloric intake and total household income, were statically significant between irrigation user and non-user households.

The result of Propensity Score Matching (PSM) indicated that access to irrigation has a significant and positive impact on household income, calorie intake, food availability, household food insecurity access scale and household diet diversity in the study area. This effect of irrigation water utilization has direct bearing on household food security. Therefore, increasing efficiency of the existing small scale irrigation schemes and designing and implementing the new schemes leads to sustainable production that could change the life of the rural poor.

## RECOMMENDATIONS

Thus, governmental and non-governmental organizations should join hands to support the development of small-scale irrigation schemes to reduce the food insecurity problem in the study area.

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## AUTHORS' CONTRIBUTION

Dr. Kebede Manjur was major adviser in this thesis and he contributes in idea generation and guidance all the time from the very beginning of proposal writing to the final thesis write up.

Dr. Gebrehiwot Woldegebrial was co-adviser in this research and he contributes in overall paper design and giving constructive suggestions.

Moges Girmay was involved in literature search, figures, development of overall research plan, study design, data collection, data analysis, data interpretation hypothesis generation and idea development, provided the validated questionnaires.

Workie Sahlu was involved in data collection, data analysis, data interpretation, supervision, data analysis and revision of the paper; and she Wrote the paper.

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