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# Impact of small-scale irrigation on household food security: evidence from Ethiopia

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**Abstract**

**Background:** Adamitulu Jido Komoblcha is one of the districts located in lowland areas of the Oromia region with irrigation potentials of 14,000 hectares out of which only 2568 hectares are under small-scale irrigation practices. Though there are a lot of households using irrigation in the study area, the impact that it has brought on the food security of the household is not yet well studied in the area. Several related studies reviewed lack appropriate impact evaluation methods in studying the impact of small-scale irrigation on food security that may result in overestimation or underestimation of the impact. To this end, the main motivation behind this study was to examine whether small-scale irrigation in the study area is creating positive change on household food security or not using the propensity score matching approach.

**Methodology:** Both primary and secondary data were collected and used in the study. The primary data were collected from randomly selected 94 irrigation users and 100 non-user households from February to March 2018. Secondary data were collected from a review of different works of literature. Both descriptive statistics and econometric models were applied to analyze the data using Stata software version 13. The study applied the propensity score matching (PSM) model to analyze the impact of small-scale irrigation on food security. In analyzing the impact of small scale irrigation on food security, we have used calorie intake, crop harvest and consumption both from own production and bought from the sale of the crop harvest produced through irrigation as an indicator of food security.

**Result:** The study has found that participation in irrigation is positively determined by age, education, land size, access to extension service, and participation in off or non-farm activities. In contrast to this, participation in irrigation is negatively determined by distance from farm plot to water source and distance from the main market. The results of the nearest neighbor and caliper matching estimators show that participation in small-scale irrigation increased the daily calorie intake of the small-scale irrigation users by 643.76 kcal over non-user households. Similarly, it increased their daily calorie intake to 596.43 kcal and 591.74 kcal, respectively, with radius and kernel matching estimators. The result further indicted that irrigation had positive impact on crop production, consumption and revenue generation which all together indicated improvement in food security. The sensitivity analysis test shows that impact results estimated by this study were insensitive to unobserved selection bias which shows it is a real impact of the irrigation.

**Conclusion:** It was concluded that irrigation has a positive and significant impact on household food security. Concerned bodies that working on small-scale irrigation development therefore should continue investment in irrigation

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activities for poverty reduction strategies and scale-up irrigation interventions to the other areas where there is potentially irrigable land.

**Keywords:** Small-scale irrigation, Impact, Food security, Propensity score matching

## Background

Around the world, over 307 million hectares were prepared for the water system, of which 304 million hectares were for the full control water system and 261 million hectares were equipped for full control and irrigated [1]. Irrigation-based agriculture plays an essential role for global food security and for the welfare of a large share of the world's population, as it provides about 40% of the global crop production [2]. Moreover, it has a substantial impact on global water resources, and currently about 70% of humanity's demand for fresh water originate from irrigation [3]. At the World Food Summit in 1996, the Food and Agriculture Organization (FAO) estimated that 60 percent of the extra food required must in the future come from irrigated agriculture. The International Commission on Irrigation and Drainage (ICID) also estimated that current food production would have to double within the next 25 years. To meet the food demand and reduce poverty, over time, the area irrigated by groundwater has increased in importance around the world. Groundwater development has been growing at an exceptional rate in recent decades. More reliable water delivery and declining extraction costs due to advances in technology and, in many instances, government subsidies for power and pump installation have encourages private investment in tube wells. For example, in India and Northern China, the area irrigated by groundwater rose from about 25 percent in the 1960s to well over 50 percent in the 1990s. The Source of irrigation water varies widely between countries depending on the hydrogeological and climatic conditions and historical development of irrigation. Responses to a recent ICID questionnaire of irrigation practices show that, among the major countries, India has over 50 percent of its area irrigated from groundwater, followed by the USA (43 percent), China (27 percent), and Pakistan (25 percent). That percentage can reach as much as 80 percent in developed countries [4].

As an agricultural intensification method, irrigation could play a dominant role in increasing agricultural production and productivity. Because of this, it has been continued to be a special concern and one of the focus areas of policymakers and planners. In Sub-Saharan Africa, there are varied water endowments where 40 million hectares of its land are suitable for irrigation [5] and irrigation development represents the most important interface between water and land resources [6]. In the last three decades, sub-Saharan Africa has witnessed increased public and scholar's interest in the use of small-scale irrigation in general and small dams in particular [7].

Ethiopia is gifted with various water resources with 12 rivers, 22 natural and artificial lakes and groundwater. Water potential of the country varies from 2.6 to 13.5 billion $m^3$ per year, which makes an average of 1575 $m^3$ of physically available water per person per year [8]. Furthermore, Ethiopia has at least 5.3 million hectares of irrigation potential in which 3.7 million hectares from gravity-fed surface water, 1.1 million hectares from groundwater and 0.5 million hectares from rainwater harvesting [9]. Though there is a huge irrigation potential in the country, majority of its population are still directly or indirectly engaged in irregular rainfall-dependent agriculture [10]. To use this irrigation potential effectively, the development policy of the country, regional states and non-governmental organizations are promoting small-scale irrigation scheme development so as to increase and stabilize food production in the country [11].

In Ethiopia, the central role of irrigated agriculture within the context of poverty reduction efforts is well understood as it increases the production of agricultural raw materials, exploit land and reduce dependence on rain-based agriculture [12]. Use of small-scale irrigation has a great importance to produce more during rainfall shortage periods. It can contribute to overall livelihood improvement of the rural population through increased income, food security, social needs fulfillment and poverty reduction [13, 14]. As a result, irrigated agriculture currently is a priority in the agricultural transformation and food security strategy of the Ethiopia government [11].

Adamitulu Jido Komoblcha is one of the districts located in lowland areas of Oromia region with irrigation potentials of 14,000 hectares. The district is endowed with four major rivers that include Bulbula, Jido, Hora Kalio and Gogessa as well as Lake Ziway for small-scale irrigation schemes that cover a total of 612 ha of land [15].

There are different studies that show a positive impact of small-scale irrigation on food security. A study conducted by [16] in Malawi shows that more than 70% of all the adopters were food insecure before adoption of the irrigation but their food security has significantly improved because of irrigation practice. A study conducted by [17] in Swaziland concluded that irrigation has positive impact on food security. Moreover, [18–23] and [13] have found that irrigation has a positive impact on household food security. However, the main gap of these studies is the lack of appropriate impact evaluation methods that may deal with the selection bias issue since irrigation participation is not random. Ignoring this may result in underestimate or overestimate of impacts of irrigation on food security of the households. It is obvious that food security is a cumulative effect of socio-economic, demographic and institutional factors, not merely irrigation. Studying impact without controlling the possible effect of these factors may lead to biased result and conclusion. Therefore, in this study we applied propensity matching method to control the effect of these factors to examine relatively the true impact of small-scale irrigation on food security of households.

## Research methodology

### Description of the study area

This study was conducted in Adamitulu Jido Komoblcha, district located about 167 km to the south of Addis Ababa, capital of Ethiopia. Geographically, it is located between 7004‟N to 7037 ‟North latitude and 38032 ‟E to 39004‟E longitude. The district covers an area of 1403.3 km$^2$. Altitude of the district varies between 1500 and 2328 m above sea level with annual average rainfall 759.7 mm and average temperature of 24 ℃ [15]. According to the district Finance and Economic Development Office [24], the district has total population of 179,840; out of which 51.76% is male and 48.24% is female. The total households of the district are 26,982 in which 20,137 are headed by male and 6845 are headed by female. Like other parts of Ethiopia, the main economic activity of the district is agriculture where 94% of its populations earn their livelihood from it, while the rest depend on off-farm activities such as petty trade, formal employment and casual wage works. The district is suitable for crop production, livestock rearing and fishery development. In the district, maize, haricot bean, *teff*, wheat, barley and sorghum are grown under rain-fed condition while vegetables such as tomato, onion, green beans and cabbage are grown using irrigation. Cattle, sheep, goat, horse, donkey, mule and poultry are the main livestock reared in the district [15]. A map indicating the study area location is presented in Fig. 1.

### Sampling technique

Multi-stage sampling procedures were used to select sample respondents. First, Adami Tulu Jido Kombolcha district was selected purposively because of its potential for irrigation. Secondly, two *kebeles* namely Bochesa and Dodicha were selected randomly from the seven irrigation potential *kebeles*. Following this, households were stratified into irrigation user and non-user categories. Cochran formula [25] was used to determine the sample size considering 95% confidence level ($z = 1.96$), 45% estimated proportion of an attribute in the population (p) and 7% level of precision (E) from 1084 total households. Thirdly, 94 irrigation users and 100 non-user households were selected randomly based on probability proportion to sample size:

$$n_0 = \frac{(Z_{\alpha/2})^2 pq}{E^2} = \frac{(1.96)^2 (0.45)(0.55)}{(0.07)^2} = 194,$$

where $n_0$ is the sample size, $z$ is the selected critical value of desired confidence level, $p$ is degree of variability in the population, $q = 1 - p$ and $E$ is the desired level of precision. In social science survey, a commonly used margin of error is 10% of the expected average value [26]. According to [27], in determining sample size 3%, 5%, 7% and 10% of margin of error are accepted. Bartlett [28] argue that 5% of margin of error is acceptable in determining sample size. Others further argue that an acceptable margin of error used by survey researchers falls between 4 and 8% at the 95% confidence level [29]. However, for this study, considering available resource to manage the study we used 7% precision level to determine the sample size.

### Data source and methods of collection

In this study, we collected both primary and secondary data from different sources. Sample respondents were primary data source for this study. To collect primary data from the respondents, we developed questionnaires focusing on socio-economy, demographic, institutional characteristics and food consumption condition of the respondents. The questionnaire was prepared in a way they measure objective of the study. Following, we selected four enumerators and provided training on the questionnaire and general data collection mechanisms for 2 days. After the training, actual data collection was undertaken by those enumerators with the supervision of authors to solve any problems that arise during the process of data collection. Secondary data were collected from review of different documents which include research works, books, office reports, journal articles written by different scholars.

### Methods of data analysis

In this study, we employed both descriptive statistics and econometric models. Descriptive analysis was undertaken using t-test and χ2. T-test was employed to compare mean differences between irrigation users and non-users across continuous variables and χ2 test

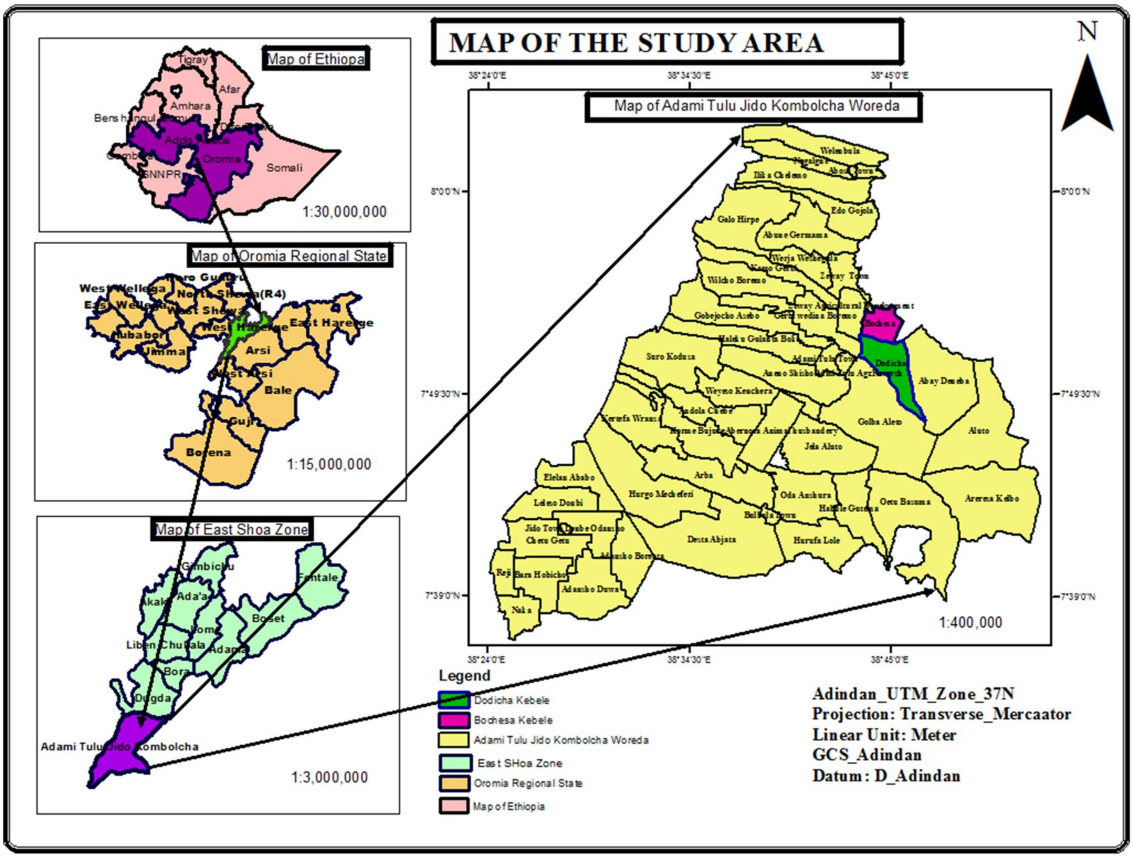

**Fig. 1** Map of the study area [15]

was employed to test the difference between the groups across categorical variables. Propensity score matching model (PSM) analysis was applied to analyze impact of small-scale irrigation on food security.

### Propensity score matching (PSM)

PSM is conditional probability that farmers adopt a new technology, given pre-adoption characteristics [30]. The method of matching has achieved popularity more recently as a tool of impact evaluation. In the implementation process, matching is done by constructing a comparison group of individuals with observable characteristics similar to those of the treated [31]. There are five steps involved in implementing the PSM that includes estimation of the propensity scores, matching treatment and control groups, checking common support condition, testing the matching quality and sensitivity analysis [32]. However, for the simplicity and clear presentation, we have merged the steps and presented them as follows.

### Estimating the propensity score

Propensity score is the probability of participation in a given intervention determined based on pre-intervention characteristics. When estimating the propensity score, two choices have to be made. The first one concerns the model to be used for the estimation, and the second one the variables to be included in this model [32]. Regarding the model choice several studies aimed at assessing impact analysis apply a probit/logit model to determine propensity score [33]. According to [34], employing probit or logit model leads to similar results when estimating propensity score of an individual's being adopter or non-adopter. However, due to its simplicity, this study applied logit model to estimate the propensity score of the sampled households. The model takes a value 1 for irrigation users and 0 for non-users. The mathematical formulation of logit model is specified as follows:

$$P_i = \left(y_i = 1/x\right) = 1/\left(1 + e^{(\beta_0+\beta_1 x_i)}\right). \tag{1}$$

This equation can be written as:

$$\mathrm{Pi} = \frac{1}{1 + \mathrm{e}^{-Z_i}}, \tag{2}$$

where Pi is the probability of using irrigation and e represents the base of natural logarithm and *Zi* is the function of explanatory variables (x)

*Pi* = 1/ (1 + *e zi)* is the probability of not using irrigation

Then, the odds ratio in favor of using irrigation is given by $\frac{P_i}{1-P_i}$*b* y taking the natural log of the equation we get the following:

Li = ln[$\frac{P_i}{1-P_i}$] = Z with the error term incorporated, the logit model will have the following form:

$$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots \beta_n x_n + U, \tag{3}$$

where × 1, × 2, × 3 ....xn are the explanatory variables of the model, β0 is the intercept β1, β2, β3...... βn are the coefficients to be estimated in the model and U is the error term. Regarding variable choice, we selected 13 independent variables used to determine the propensity score of the households (Table 1).

### Matching irrigation users with non-users and checking common support region

In this study, we applied the most commonly used nearest neighbor, kernel, radius and caliper matching algorisms to match irrigation users with non-users [35]. After that common support region was identified to delete all observations which lie outside this region [32].

### Testing the matching quality and identifying the impact

A suitable indicator to assess the distance in marginal distributions of the X variables is the standardized bias (SB) suggested by [36]. It is used to quantify the bias between treated and control groups. Mathematically estimation of the impact of small-scale irrigation to a given outcome (Y) is specified as:

$$\mathrm{tATT} = \mathrm{Yi}(\mathrm{Di} = 1) - (\mathrm{Di} = 0), \tag{4}$$

where τi is treatment effect (effect due to participation in irrigation), Yi is the outcome on household i, Di is whether household i has got the treatment or not (i.e., whether a household participated in irrigation or not).

Two treatment effects are most frequently estimated in empirical studies [32]. The first one is the (population) average treatment effect (ATE) which is simply the difference of the expected outcomes:

$$\Delta\mathrm{YATE} = \mathrm{E}(\Delta\mathrm{Y}) = \mathrm{E}(\mathrm{Y1}) - \mathrm{E}(\mathrm{Y0}). \tag{5}$$

**Table 1 Description of variables used in the logit model and their descriptive statistics**

| Variable code | Variable description | Irrigation users ($n$ = 94) | | Irrigation non-users ($n$ = 100) | | Total household ($n$ = 194) | | t-test (Chi$^2$) |
|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | |
| SEXHHD | Sex of the household head (1 if household head is male, 0 otherwise) | 85.11 | 14.89 | 90 | 10 | 87.63 | 12.37 | 1.07 |
| EDULEV | Education of the household head in schooling years | 4.26 | 2.36 | 3.56 | 2.17 | 3.9 | 2.29 | 2.16** |
| AGEHHD | Age of the household head in year | 38.54 | 8.21 | 35.98 | 7.56 | 37.2 | 7.96 | 2.26** |
| HHFEX | Farming experience of the household head in years | 15.18 | 7.52 | 12.92 | 7.63 | 14.01 | 7.65 | 2.07** |
| FAMSIZE | Number of people resending in the household | 5.38 | 2.75 | 4.27 | 1.83 | 4.8 | 2.38 | 3.33*** |
| DEPNDRTO | Dependency ratio in number | 2.07 | 1.2 | 2.14 | 1.43 | 2.11 | 1.32 | 0.33 |
| TOCLAND | Total land owned by respondents in hectares | 2.1 | 0.88 | 1.56 | 0.7 | 1.82 | 0.83 | 4.77*** |
| LIVSTO | Total livestock owned by respondents in Tropical Livestock Unit | 6.48 | 4.09 | 4.58 | 2.62 | 5.5 | 3.54 | 3.85*** |
| NEAWAT | Distance from water point to the farming plot in km | 1.09 | 0.53 | 1.46 | 4.5 | 1.28 | 0.84 | 3.05*** |
| DIMAR | Distance to the main market in km | 6.02 | 2.23 | 6.48 | 2.7 | 6.26 | 2.49 | 1.28 |
| ACCEXT | Access to extension service (1 if household head received training regularly during the last 1 year prior to the survey time, 0 otherwise) | 78.72 | 21.28 | 49 | 51 | 63.4 | 36.6 | 18.4*** |
| ACCRED | Access to credit (1 if household head received credit from formal lending institutions during the last 1 year prior to the survey time, 0 otherwise) | 53.19 | 46.81 | 28 | 72 | 40.21 | 59.79 | 12.79*** |
| NONFRMA | Total amount of annual non/off-farm income of the household in Ethiopian birr | 1673.72 | 2321.85 | 713.7 | 1633.8 | 1178.86 | 2049.01 | 3.34*** |

** $p < 0.05$; ***, $p < 0.01$

This measure answers the question what would be the effect if households in the population were randomly assigned to treatment. But this estimate might not be of importance to policy makers because it includes the effect for which the intervention was never intended. Therefore, the most important evaluation parameter is the so-called average treatment effect on the treated (ATT), which concentrates solely on the effects on those for whom the program/interventions are actually introduced.

In the sense that this parameter focuses directly on those households who participated, it determines the realized impact of small-scale irrigation usage and helping to decide whether participation on irrigation is successful or not.

It is given by the following formula:

$$\mathrm{tATT} = \mathrm{E}(\mathrm{t}/\mathrm{D} = 1) = \mathrm{E}(\mathrm{Y1}/\mathrm{D} = 1) - \mathrm{E}(\mathrm{Y0}/\mathrm{D} = 1). \tag{6}$$

This answers the question, how much did households participating in irrigation benefit compared to what they would have experienced without participating. Data on E (Y1/D = 1) are available from irrigation users. An evaluator's classic problem is to find E (Y0/D = 1). So the difference between E (Y1/D = 1)−E (Y0/D = 1) cannot be observed for the same household. The possible solution is to use the mean outcome of the comparison individuals, E (Y0/D = 0), as a substitute to the counterfactual mean for those being treated, E (Y0/D = 1) after correcting the difference between user and non-user households arising from selection effect. Thus, by rearranging, and subtracting E (Y0/D = 0) from both sides of equation, one can get the following specification for ATT:

$$\begin{aligned}&\mathrm{E}(\mathrm{Y1}/\mathrm{D} = 1) - \mathrm{E}(\mathrm{Y0}/\mathrm{D} = 0)\\ &\quad = \mathrm{tATT} + \mathrm{E}(\mathrm{Y0}/\mathrm{D} = 1)\ \mathrm{E}(\mathrm{Y0}/\mathrm{D} = 0).\end{aligned} \tag{7}$$

### Sensitivity analysis

This section presents the last implementation step of the PSM conducted to check how the finding of this study is free from hidden bias. The basic question to be answered here is whether inference about treatment effects may be altered by unobserved factors [37]. The estimation of treatment effects with matching estimators is based on the unconfoundedness or selection on observables assumption. However, if there are unobserved variables which affect assignment into treatment and the outcome variable simultaneously, a 'hidden bias' might arise [38]. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, the problem can be addressed by sensitivity analysis [37]. In order to check for unobservable biases, using Rosenbaum Bounding approach sensitivity analysis was performed on the computed outcome variables with respect to deviation from the conditional independence assumption [32].

### Literature review on food security and its measurements

According to Maxwell [40], the concept of food security revolves around three major paradigms. The first paradigm conceptualizes food security from the global and the national to the household and the individual level, the second paradigm shift was from a food first perspective to a livelihood perspective, and the third one is from objective indicators to subjective perception. The concept of food security has been changing from period to period. During 1950s to 1970s, the focus was on national-level, supply-side availability of sufficient food to feed a growing population [41]. In the early 1980s, focus turned increasingly to the demand side of food security, to individuals' capacities to access food in order to feed themselves. More recently, further emphasize is given to the utilization of foods through proper nutrition, preparation, and feeding practices, and the stability of these conditions over time [42]. Among growing concepts of food security, the prevailing definition agreed upon at the 1996 World Food Summit, is that food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life [43]. This can further be explained as achieving food security requires that the aggregate availability of physical supplies of food is sufficient, that households have adequate access to these food supplies through their own production, through the market or through other sources, and that the utilization of these food supplies is appropriate to meet the specific dietary needs of individuals [44]. Hence, availability, access, utilization, and stability are now widely accepted as the four pillars of food security [45].

Given these multidimensional nature of food security, the two notable issues in food security studies needing attention are measurement of food security and econometric model used for analysis [46]. The issue related with econometric model was explained in the methodology part as a result here we will focus only on the measurement approach. Indicators to measure food security have been proposed over decades: from narrow measurement on specific variables to complex indexes aimed at synthesizing the multiple dimensions that characterize food security [45–48]. Several classifications have been adopted to organize the indicators. First, indicators of food security may synthesize information at different levels (global, national, household, and/or individual); second, indicators may be oriented to one or more dimensions of the food security (availability, access, utilization, and stability); third, they can be distinguished in static and dynamic indicators; fourth, they may privilege a particular type of information [47]. To date, no food security measure satisfies four pillars of food security. As a result, global community has relied heavily on proxy measures that attend to one, two or perhaps three of these axioms [45]. However, a combination of measures and indicators is needed to fully reflect the complex reality of food security in any given context [49]. According to Awoke [50] food security can be measured in different ways depending on the purpose and scope of the study. For instance, the food security can be measured by household survey food consumption data, caloric intake, dietary diversity, household food insecurity access scale, food adequacy question and the like. When we come to our case, our focus is on the impact of small irrigation on food security at households. Considering the scope of the study, we measure food security using calorie intake. Furthermore, we also addressed availability component of food security in surveying food produced through irrigation, access component through additional food items bought from the sale of surplus production. As to stability, irrigation is believed to guarantee food security through multiple production regardless of shortage of rainfall throughout year. In the study area, farmers able to produce enough food during dry seasons in sustainable basis for their consumption and sale for additional income.

As indicated above, we used calorie intake as a proxy of food security which has been widely used by different authors as a measure of food security. It is one of the most direct indicators related to food security of the household [51, 52]. This method has two principal advantages. It produces the most accurate measures of individual caloric intake and therefore the most accurate measure of food security status of an individual. Second, because the data are collected on an individual basis, it is possible to determine whether food security status differs within the household [53]. There are several studies that have used calorie intake as a measure of food security. A study conducted by [54] considered amount of calorie intake to categorize households as either food secure or insecure in examining the main determinants of food security of the households. Gebremichael [55] in his study considered calorie intake as a measure of food security in examining the impact of Mai Nugus irrigation scheme on household food security. Similarly, [11] also measured food security in terms of calorie intake in impact analysis of small-scale irrigation schemes on household food security in Ethiopia. Another study conducted in Nigeria [56] employed daily calorie intake as a measure of food security in examining determinants of food security among households. In assessing the food security status of households, Weldearegay and Tedla [57] grouped households into three categories based on their calorie availability/adult equivalent/day: food secure ($\geq$ 2100 kcal/adult equivalent/day), moderately food insecure ($\geq$ 1050 to < 2100 kcal/adult equivalent/day) and severely food insecure (< 1050 kcal/adult equivalent/day).

Following the suggestion of FAO, WHO and UN [58], in this study, food security was measured based on calorie requirement, according to age and sex of household members. Accordingly, household calorie availability was computed from each food item consumed over the last 7 days before the survey time. Ethiopian Health and Nutrition Research Institute (EHNRI) conversion factor for kilocalories per kilogram of different food types was considered to calculate the calorie intake of households [59]. The net weekly calorie availability was divided by seven to obtain the household daily calorie intake. Then the family size of each household was converted into adult equivalent considering age and sex of each family member in the household. The daily net calorie consumption of the household was divided by the adult equivalent to obtain the daily calorie availability per adult equivalent of the household.

## Results and discussion

### Descriptive characteristics of the respondents

The result of descriptive statistics presented in Table 1 shows that there was significant difference between irrigation users and non-users in their education, age, farming experience, family size, land holding, livestock holding, distance from water point to the farming plot, access to extension service, access to credit and non/off-farm income. However, no significant difference was observed between two groups in their sex, distance to the main market and dependency ratio. The mean age of the total respondents was 37.2 years. The mean age of irrigation users was 38.54 years and the mean age of irrigation non-users was 35.98 years implying relatively older households participate in the small-scale irrigation practices than the younger ones. The result of t-test shows that there was statistically significant mean difference between irrigation user and non-user household in their age at 5% significance level. The mean schooling year of the entire sample was 3.9 years. The average schooling year of irrigation users and non-users was 4.26 and 3.56 years, respectively. A significant difference between two groups indicates that irrigation users are better off in terms of educational attainment than non-user households. Average farming experience of irrigation users was 15.18 years with standard deviation of 7.52 years as compared with the average farming experience of non-users (12.92 years). The difference was statistically significant at 5% significance level. This shows that irrigation users have relatively more experience in farming activities than their counterparts which may result from their age difference. The average family size of sample household was 4.8. On average, about 5.38 individuals live in households who practice small-scale irrigation against 4.27 individuals in non-user households which implies family labor demand of irrigation activities is higher than rain-fed agriculture. The mean family size comparison between the two groups revealed that there was statistically significant difference between two groups at 1% significant level. The mean land holding size of irrigation user and non-user household was 2.1 and 1.56 ha with standard deviation of 0.8 and 0.7 ha, respectively. The difference was statistically significant at 1% significance level. This shows that irrigation users have relatively large land than non-user groups. The mean livestock holding of irrigation user and non-user household was 6.48 and 4.58 in TLU, respectively. The difference was statistically significant at 1% significant level which implies irrigation users owned relatively more number of livestock than non-user households. The study revealed that the mean distance from irrigation user respondents' residence to the main market was 6.02 km and it was 6.48 km for non-user households showing no statistically significant difference between the two groups. The mean dependency ratio of irrigation user and non-user sample household was 2.07 and 2.14 which also shows insignificant difference between the two groups. The mean distance from water point to the farming plot was relatively lower for irrigation user households (1.09 km) than non-user households (1.46 km) which is significant at 1% significance level. This shows that distance is affecting non-user households not to participate in small-scale irrigation activities. The average annual off/non-farm income was larger for irrigation user household (1673.72 ETB) than for non-user households (713.7 ETB) with statistically significant difference at 1% significance level. This may indicate from the income obtained from irrigation activities respondents able to diversify their source of income to off/ non-farm earning also.

The result of descriptive statistics presented on Table 1 shows that 85.11% of irrigation user households were male headed implying irrigation activities are mainly dominated by male headed households. The Chi-square test result shows that, there was no statistically significant difference in sex distribution between irrigation user and non-user households. The result of the study also indicates that about 53.19% of irrigation users obtained credit in the past one year as compared with 28% of irrigation user. The Chi-square test shows that there was significant difference between irrigation user and non-user in accessing credit services at less than 1% significance level. This indicates that irrigation activities need finance to carry out irrigation farming like purchasing farm inputs, and hiring labor, transportation and others. In the study area it was found that majority (78.72%) of irrigation users attended extension-based training regularly while only 49% of non-users attend the training in regular base. The result of Chi-square analysis shows that there is statistically significant difference between the two groups in attending extension focused training at 1% significance level. This difference may show that irrigation needs continuous training because there is continuous production by using irrigation, which needs regular training than rain-fed agriculture.

### Econometric model analysis result

This section presents econometric model analysis result followed to analyze the impact of small-scale irrigation on household food security. The procedures of the PSM model with its result are presented as follows: -

### Determining the propensity score of households

Here binary logistic regression model was applied to determine the propensity score of the sampled households using all the hypothesized variables that were assumed to determine household's decision to use small-scale irrigation. The result presented in Table 2 shows that age, education, land, distance from water point to the farming plot, market distance, access to extension service, and non/off-farm income were the major variables determining households' participation in irrigation use.

The survey result output presented in Table 2 shows that education positively determines participation in

**Table 2 Logit model output of household's probability of participation in irrigation use**

| Variables | Coefficient | Std. Err | *Z* | *p*-value |
|---|---|---|---|---|
| SEXHHD | −0.52 | 0.49 | −0.94 | 0.345 |
| EDULEV | 0.15 | 0.08 | 1.87 | 0.062* |
| AGEHHD | 0.04 | 0.03 | 1.76 | 0.078* |
| HHFEX | 0.02 | 0.03 | 0.86 | 0.391 |
| FAMSIZE | 0.06 | 0.09 | 0.74 | 0.461 |
| DEPNDRTO | −0.03 | 0.19 | −0.21 | 0.832 |
| TOCLAND | 0.57 | 0.27 | 2.23 | 0.026** |
| LIVSTO | 0.02 | 0.07 | 0.38 | 0.703 |
| NEAWAT | −0.42 | 0.34 | −1.96 | 0.050** |
| DIMAR | −0.14 | 0.11 | −1.82 | 0.068* |
| ACCEXT | 1.24 | 0.52 | 2.96 | 0.003*** |
| ACCRED | 0.52 | 0.50 | 1.33 | 0.184 |
| NONFRMA | 0.00 | 0.00 | 2.37 | 0.018** |

LR $\text{Chi}^2$ (13) = 65.76, Prob > $\text{Chi}^2$ = 0.000, pseudo-$R^2$ = 0.2447, log likelihood −101.49855

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

irrigation use at 10% significance level. This is because education increases adoption rate of irrigation related technologies and application of these technologies effectively at farm plot level. A previous research finding of several studies shows a positive influence of education on irrigation adoption. Woldemariam and Gecho [60] found that better educated farmers have better chance to use irrigation because education equips individuals with the necessary knowledge of how to make living. Literate individuals are very ambitious to get information and use it. As agriculture is a dynamic occupation, the conservation practices and agricultural production technologies are always coming up with better knowledge. So, if the household head is literate, he/she will be very prone to accept extension services and irrigation use. Similarly, [61, 62] and [63] are in agreement with this finding.

It was found that age positively and significantly determine decision to participate in small-scale irrigation practices at 10% significance level. This indicate that as the age of the farmers increase their farming experience increase and they will be capable to manage their farm effectively including irrigation activities. This finding is consistence with [64] that shows positive relationship between age and participation in small-scale irrigation activities. According to this study, older farmers might possess richer farming experience that could be easily harnessed for improved irrigation activity.

Land and amount of income earned from non/off-farm activities are positively determine participation in irrigation at 5% significant level. A positive relationship between land and irrigation participation shows that in the study area most of farmers having small land size participate in cultivating perennial cash crop and not participate in irrigation activities as their land is already occupied with cash crops. There are several studies that shows the positive association between land size and irrigation participation [65, 66] and [67]). Furthermore, a positive relationship between irrigation use and non/off-farm income is that irrigation by its nature needs a finance to purchase farm equipment and hire labor. This is consistence with [68, 69] and [13].

Access to extension services determines irrigation participation positively and significantly at 1% significance level. This shows that farmers who follow agricultural extension focused training regularly are believed to have better skill and knowledge on irrigation practices which encourages them to participate in it. This is in agreement with [70] and [71]. Moreover, the result of logistic regression shows that distance from water point to the farming plot and distance to the main market place negatively determine participation in irrigation use at 5% and 10% statistically significance level, respectively. This shows when market place is too far from respondent's residence it takes their time and needs more cost to transport farm inputs and sell their produce which discourages them from participating in irrigation activities. This is consistent with [72]. A negative relationship between participation in small-scale irrigation activities and distance from water point to the farming plot shows that when water point is far from the place where crop cultivation takes place, it exerts additional cost for farmers to transport water from far distance for irrigation purpose that may not be feasible for farmers which consequently discourage them not to take part in irrigation activities. A study conducted by [60] is similar with this result justifying that when the farm is far from main irrigation canals, it needs high labor, financial and time costs to construct sub-canals towards individual farm and minimize the chances to use irrigation water.

Figure 2 shows propensity score distribution and common support region for propensity score estimation. The upper half shows the propensity score distribution of irrigation user and the bottom halves of histogram shows the propensity score distribution of non-user households. The green colored (treated on support) and pink colored (untreated on support) indicates the observation in the irrigation user and non-user that have suitable for comparison, respectively, while the yellow colored (treated off support) and blue colored (untreated off support) indicates the observation in the irrigation user and non-user that were not suitable for comparison, respectively.

### Matching irrigation user with non-user household and determining common support region

To match irrigation user with non-user households, we applied four most widely used matching estimators like nearest neighbor, caliper, radius and kernel estimators. As shown in Table 3, we try to match irrigation users with non-users in common support region. Accordingly, 65 households from user group and 84 households from non-user groups behave similar characteristics and matched. As a result of this, 45 households (29 from irrigation user and 16 households) from non-user were discarded from the study in impact assessment procedure.

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

Irrigation can contribute to food security in multiple ways. According to Domènech [73], irrigation can improve the amount of food available to the household through two main channels. The amount and diversity of homegrown food can improve as a result of having access to irrigation water, and households may be able to purchase more food as a result of having more income from the sale of irrigated products. Further, Liptona [74] emphasizes that irrigation boosts farm output through three main ways. Firstly, irrigation improves

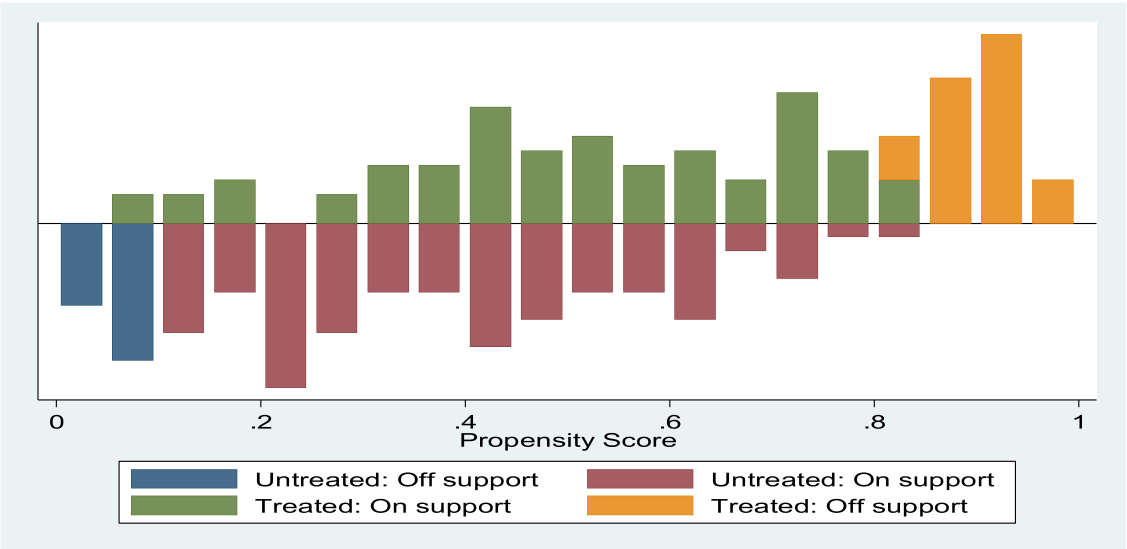

**Fig. 2** Propensity score distribution and common support region

yields through reduced crop loss due to erratic, unreliable, or insufficient rainwater supply. Secondly, irrigation allows for the possibility of multiple cropping, and so an increase in annual output. Thirdly, irrigation allows a greater area of land to be used for crops in areas where rain-fed production is impossible or marginal. Hence, irrigation adoption is a means for smallholder farmers to participate in multiple production year rounds which helps to increase yield and improve their food security regardless of season. It is also a means to produce a variety of crops for own consumption, sell to generate revenue, and also to buy other food items for consumption which all together have implications on food security.

Following this argument, to capture the real impact of irrigation on food security and show a clear impact pathway, we considered different outcomes including crops consumed from own production, additional food items bought and consumed from the revenue generated with the sale of crops produced. Besides, the calorie intake of the household was also considered as the other indicator of food security by this study. Therefore, taking the multidimensional impact of irrigation technology on food security in to consideration, we tried to survey the major crops growing with irrigation, annual crop production, consumption, sale, revenue generated, and additional food items bought from the revenue generated. To draw inference on the impact of small-scale irrigation on food security, considering these outcomes in addition to the calorie intake was found to be an important aspect. In doing this, as we have no baseline data on the status of the respondents before the adoption of small-scale irrigation, we applied PSM to match adopters with non-adopters having similar characteristics in terms of irrigation adoption determinants. Based on the purpose of the model, non-adopters is assumed to represent the pre-irrigation use status of the adopter households with respect to independent and outcome variables after matching, the only difference would be irrigation use. That is why 45 households (29 from irrigation user and 16 households from non-user) were discarded from the study in impact assessment procedure and analysis was made for only the matched sample (65 households from user group and 84 households from non-user group).

Based on this, comparison of adopters and non-adopters was made with respect to annual production, consumption, revenue generation and additional food items bought and consumed with the revenue generated and their calorie intake. We have applied the most common four matching algorisms (nearest neighbor radius, caliper and kernel) to analyze the impact of irrigation on food security.

It was found that the type of crops majorly grown and consumed in the study area includes onion, tomato, pepper, cabbage, maize, wheat, and bean. The result of this study shows that irrigation users produced more crop than non-users across all the matching estimators (Table 3). The difference was statistically significant at a 1% significance level. The implication of this is that irrigation helps adopter households to produce more crop for consumption as well as sell for additional income generation.

**Table 3 Impact of irrigation use on crop production**

| Matching algorisms | Outcome (kg) | Irrigation users | | Irrigation non-users | | ATT difference | *t*-value | *p*-value |
|---|---|---|---|---|---|---|---|---|
| | | Matched sample | ATT | Matched sample | ATT | | | |
| Nearest Neighbor | Onion | 65 | 985.26 | 84 | 210.66 | 774.6 | 15.46 | 0.00*** |
| | Tomato | 65 | 3743.3 | 84 | 512.95 | 3230.35 | 12.6 | 0.00*** |
| | Pepper | 65 | 1740.41 | 84 | 26.15 | 1714.26 | 10.74 | 0.00*** |
| | Cabbage | 65 | 3387.36 | 84 | 60.6 | 3326.76 | 9.50 | 0.00*** |
| | Maize | 65 | 3468.46 | 84 | 372.30 | 3096.15 | 12.26 | 0.00*** |
| | Wheat | 65 | 1142.90 | 84 | 230.49 | 912.41 | 21.26 | 0.00*** |
| | Beans | 65 | 1094.12 | 84 | 243.24 | 850.87 | 21.8 | 0.00*** |
| Radius | Onion | 65 | 985.26 | 84 | 230.56 | 754.7 | 15.34 | 0.00*** |
| | Tomato | 65 | 3743.3 | 84 | 556.85 | 3186.45 | 14.22 | 0.00*** |
| | Pepper | 65 | 1740.41 | 84 | 74.38 | 1666.03 | 10.59 | 0.00*** |
| | Cabbage | 65 | 3387.36 | 84 | 151.15 | 3236.21 | 9.41 | 0.00*** |
| | Maize | 65 | 3468.46 | 84 | 426.32 | 3042.13 | 12.27 | 0.00*** |
| | Wheat | 65 | 1142.90 | 84 | 241.69 | 901.21 | 21.47 | 0.00*** |
| | Beans | 65 | 1094.12 | 84 | 254.16 | 839.95 | 22.14 | 0.00*** |
| Caliper | Onion | 65 | 985.26 | 84 | 210.66 | 774.6 | 15.46 | 0.00*** |
| | Tomato | 65 | 3743.3 | 84 | 512.95 | 3230.35 | 12.60 | 0.00*** |
| | Pepper | 65 | 1740.41 | 84 | 26.15 | 1714.26 | 10.74 | 0.00*** |
| | Cabbage | 65 | 3387.36 | 84 | 60.6 | 3326.76 | 9.50 | 0.00*** |
| | Maize | 65 | 3468.46 | 84 | 372.30 | 3096.15 | 12.26 | 0.00*** |
| | Wheat | 65 | 1142.90 | 84 | 230.49 | 912.415 | 21.26 | 0.00*** |
| | Beans | 65 | 1094.12 | 84 | 243.24 | 850.87 | 21.80 | 0.00*** |
| Kernel | Onion | 65 | 985.26 | 84 | 229.9 | 755.363 | 15.33 | 0.00*** |
| | Tomato | 65 | 3743.30 | 84 | 562.03 | 3181.27 | 14.18 | 0.00*** |
| | pepper | 65 | 1740.41 | 84 | 72.30 | 1668.11 | 10.6 | 0.00*** |
| | Cabbage | 65 | 3387.36 | 84 | 150.10 | 3237.26 | 9.41 | 0.00*** |
| | Maize | 65 | 3468.46 | 84 | 424.3 | 3044.06 | 12.28 | 0.00*** |
| | Wheat | 65 | 1142.90 | 84 | 241.31 | 901.59 | 21.47 | 0.00*** |
| | Beans | 65 | 1094.12 | 84 | 254 | 840.11 | 22.13 | 0.00*** |

$^{***}$ $p < 0.01$

The result of the nearest neighbor and caliper matching algorism shows that the annual onion consumption of irrigation users was 498.68 kg more than that of non-users. Similarly, irrigation brought a positive impact on tomato consumption of the irrigation user households. It was found that the use of irrigation increased annual tomato consumption to 1831.56 kg. On the other hand, irrigation use significantly increased pepper, cabbage, maize, wheat, and haricot bean consumption across all the applied matching algorism (Table 4). This shows that irrigation increase consumption of these crop harvest which fills the food gap they had before irrigation use.

Moreover, it was found that respondents also sell surplus crop production to generate revenue for their livelihood including buying additional food items. An increase in agricultural productivity as a result of irrigation adoption can lead to increased food availability either for own consumption or for marketing and income generation purposes. Irrigation can therefore be an important source of income since smallholder irrigation systems are frequently used to grow vegetables, fruits, and other cash crops that are usually marketable and highly profitable [73]. It was found that the mean annual income generated by irrigation users was found to be 102213.79 birr across all matching algorisms. Whereas the maximum mean annual income generated by the non-users was found to be 9820.47 birr with radius matching algorism. The output of the PSM shows that surplus crop production helped households to generate more 94553.74 birr than non-users with nearest neighbor matching algorism (Table 5). It was depicted that surplus production of crops due to irrigation helps households to generate revue for their livelihood as well as to buy food items needed to complement the food requirements in addition

**Table 4 Impact of irrigation use on consumption**

| Matching algorisms | Outcome (kg) | Irrigation users | | Irrigation users | | ATT difference | *t*-value | *p*-value |
|---|---|---|---|---|---|---|---|---|
| | | Matched sample | ATT | Matched sample | ATT | | | |
| Nearest Neighbor | Onion | 65 | 672.67 | 84 | 173.98 | 498.68 | 16.05 | $0.00^{***}$ |
| | Tomato | 65 | 2262.13 | 84 | 430.56 | 1831.56 | 9.67 | $0.00^{***}$ |
| | Pepper | 65 | 87.14 | 84 | 1.38 | 85.75 | 10.77 | $0.00^{***}$ |
| | Cabbage | 65 | 508.32 | 84 | 9.15 | 499.17 | 9.51 | $0.00^{***}$ |
| | Maize | 65 | 867.11 | 84 | 93.07 | 774.03 | 12.26 | $0.00^{***}$ |
| | Wheat | 65 | 735.65 | 84 | 119.33 | 616.32 | 10.45 | $0.00^{***}$ |
| | Beans | 65 | 930 | 84 | 206.75 | 723.25 | 21.8 | $0.00^{***}$ |
| Radius | Onion | 65 | 672.67 | 84 | 188.87 | 483.79 | 15.27 | $0.00^{***}$ |
| | Tomato | 65 | 2262.13 | 84 | 443.58 | 1818.54 | 11.56 | $0.00^{***}$ |
| | Pepper | 65 | 87.14 | 84 | 4.72 | 82.41 | 10.44 | $0.00^{***}$ |
| | Cabbage | 65 | 508.32 | 84 | 23.32 | 485 | 9.41 | $0.00^{***}$ |
| | Maize | 65 | 867.11 | 84 | 106.58 | 760.53 | 12.27 | $0.00^{***}$ |
| | Wheat | 65 | 735.65 | 84 | 115.93 | 619.72 | 10.76 | $0.00^{***}$ |
| | Beans | 65 | 930 | 84 | 216 | 713.96 | 22.14 | $0.00^{***}$ |
| Caliper | Onion | 65 | 672.67 | 84 | 173.98 | 498.68 | 16.05 | $0.00^{***}$ |
| | Tomato | 65 | 2262.13 | 84 | 430.56 | 1831.56 | 9.67 | $0.00^{***}$ |
| | Pepper | 65 | 87.14 | 84 | 1.38 | 85.75 | 10.77 | $0.00^{***}$ |
| | Cabbage | 65 | 508.32 | 84 | 9.15 | 499.17 | 9.51 | $0.00^{***}$ |
| | Maize | 65 | 867.11 | 84 | 93.07 | 774.03 | 12.26 | $0.00^{***}$ |
| | Wheat | 65 | 735.65 | 84 | 119.33 | 616.32 | 10.45 | $0.00^{***}$ |
| | Beans | 65 | 930 | 84 | 206.75 | 723.25 | 21.8 | $0.00^{***}$ |
| Kernel | Onion | 65 | 672.67 | 84 | 188.38 | 484.28 | 15.25 | $0.00^{***}$ |
| | Tomato | 65 | 2262.13 | 84 | 448.46 | 1813.67 | 11.51 | $0.00^{***}$ |
| | Pepper | 65 | 87.14 | 84 | 4.54 | 82.59 | 10.46 | $0.00^{***}$ |
| | Cabbage | 65 | 508.32 | 84 | 23.12 | 485.19 | 9.41 | $0.00^{***}$ |
| | Maize | 65 | 867.11 | 84 | 106.09 | 761.01 | 22.13 | $0.00^{***}$ |
| | Wheat | 65 | 735.65 | 84 | 115.43 | 620.22 | 10.76 | $0.00^{***}$ |
| | Beans | 65 | 930.0 | 84 | 215.90 | 714.09 | 22.13 | $0.00^{***}$ |

$^{***}$ $p < 0.01$

to what they produce. This finding is consistence with different studies. A study conducted by Mangisoni [16] in Malawi shows positive impact of irrigation use on income. This study found that a net farm income earned by irrigation users was US$770 compared to US$131 earned by non-users. In Gambia, Von Braun [75] also found that cultivation of rice through irrigation system increased the real income of farmers by 13%. A study conducted by Christian [76] on analysis of the impact of smallholder irrigation schemes on the choice of rural livelihood strategy and household food security in Eastern Cape Province used both the nearest neighbor and kernel matching methods point to identify the impact of irrigation on income shows the fact that irrigation access has a positive impact on total farm income. Based on this study, the nearest neighbor matching method indicated that irrigator received high farm income R2044.01 and non-irrigating farmers R622.12. The study concluded that these positive results indicate that participating on irrigation helps to improve farm incomes of households and is significant at 5% level. The survey result depicts that with the revenue generated from sale of surplus crop production irrigation users are able to buy foods rich in calorie. The major food items bought by irrigation users include meat, barley, chicken, yogurt, and avocado and egg. This study is consistence with Olney [77] which conclude that in comparison to the control group, the irrigation use increased household consumption of micronutrient-rich foods such as dark green leafy vegetables and yellow or orange fruits, eggs.

The impact analysis result obtained using nearest neighbor and caliper matching estimator shows that irrigation increased the daily per capita caloric intake of user households by 643.76 kilocalories than non-user

**Table 5 Impact of irrigation use on revenue**

| Matching estimator | Irrigation users | | Irrigation non-users | | ATT difference (Birr) | *t*-value | *p*-value |
|---|---|---|---|---|---|---|---|
| | Matched sample | ATT (Birr) | Matched sample | ATT (Birr) | | | |
| Nearest Neighbor | 65 | 102213.79 | 84 | 7660.05 | 94553.74 | 13.26 | 0.00*** |
| Radius | 65 | 102213.79 | 84 | 9820.47 | 92393.32 | 13.22 | 0.00*** |
| Caliper | 65 | 102213.79 | 84 | 7660.05 | 94553.74 | 13.26 | 0.00*** |
| Kernel | 65 | 102213.79 | 84 | 9773.26 | 92440.53 | 13.23 | 0.00*** |

*** $p < 0.01$

**Table 6 Impact of irrigation use on calorie intake**

| Matching estimator | Irrigation users | | Irrigation non-users | | ATT difference (Kcal) | *t*-value | *p*-value |
|---|---|---|---|---|---|---|---|
| | Matched sample | ATT (Kcal) | Matched sample | ATT (Kcal) | | | |
| Nearest neighbor | 65 | 2501.54 | 84 | 1857.78 | 643.76 | 4.08 | 0.000*** |
| Radius | 65 | 2501.54 | 84 | 1905.1 | 596.43 | 4.34 | 0.000*** |
| Caliper | 65 | 2501.54 | 84 | 1857.78 | 643.76 | 4.08 | 0.000*** |
| Kernel | 65 | 2501.54 | 84 | 1909.8 | 591.74 | 4.3 | 0.000*** |

*** $p < 0.01$

households. This difference was statistically significant at 1% significance level. On the other hand, because of irrigation daily calorie intake of beneficiary households increased to 596.43 kcal and 591.74 kcal, respectively, with radius and kernel matching estimators (Table 6). The difference in calorie intake is because of the large contribution in calories by the meat, barley, chicken, yogurt, and avocado and egg consumption in addition to the consumption of onion, tomato, pepper, cabbage, maize, wheat and haricot bean. From this, it is easy to conclude that the use of irrigation has a positive impact on food security through consumption of own crop harvest, buy more calorie rich food with the revenue generated from surplus production. As irrigation use enables households to produce more than two times in a year it helps them to ensure their food security regardless of the season. Several studies are consistent with the finding of this study. A study conducted by [78] on the impact of irrigation technology use on crop yield, crop income and household food security in Nigeria using propensity score matching approach indicated that irrigation technology use is positively related to household food security. Another study conducted by [64] in Ghana on irrigation access and per capita consumption expenditure in farm households shows that irrigation access has a positive impact on household consumption expenditure per capita. Empirical analysis of a study conducted by [31] focusing on impact of irrigation water scarcity on rural household food security and income in Pakistan indicated that farmers with a water scarcity are food insecure. Dillon [79] found that irrigation significantly and positively increases caloric intakes for households with access to irrigation. According to the study because of irrigation, the daily caloric intake increased by 1836 cal for irrigators. Moreover, [80] in Malawi applied propensity score matching approach to measure the impact of irrigation on food security to correct for sample selection bias arising from the non-random selection of participants into the irrigation scheme and has found that access to irrigation facilities results into increase the daily per capita caloric intake by 10% for irrigation users compared to non-users. The empirical analysis of a study conducted by [81] in Nepal shows food security is more pronounced for those farmers who irrigation for homestead vegetable cultivation. Moreover, Desta and Almaz [82], Haile [83], Alemu [90], Tizita, [84], Abdissa,et,al [11] and Tesfaw [85], Burney [86], FAO [87], Upadhyay [88], Kabunga [89], found that irrigation adoption can significantly and positively contribute food security improvement.

**Table 7 Result of sensitivity analysis using Rosenbaum bounding approach**

| Outcomes | $e\gamma = 1$ | $e\gamma = 1.5$ | $e\gamma = 2$ | $e\gamma = 2.5$ |
|---|---|---|---|---|
| Calorie intake | 0.00001 | 0.00178 | 0.020784 | 0.082618 |

## Sensitivity analysis

Sensitivity analysis was conducted to check to what extent the study was free from bias resulting from unobservable variable. The first column of Table 7 shows outcome variable which bear statistical difference between irrigation user and non-user households while the rest of the values which corresponds to each row of the significant outcome variables are p-critical values (or the upper bound of Wilcoxon significance level -Sig+) at different critical value of γ eγ. The results show that inference for the impact of irrigation use does not change, even though the participant and non-participant households were allowed to differ in their odds of being treated up eγ = 2.5 in terms of unobserved covariates. That means for the outcome variable estimated, at various level of critical value of eγ, the p- critical values are significant which further indicate that the study has considered important covariates that affected both participation and outcome variables. Thus, it is possible to conclude that impact estimates (ATT) of this study for the outcome variables was insensitive to unobserved selection bias.

## Conclusion

This study analyzed the impact of small-scale irrigation on household food security in Adami Tulu Jido Kombolcha district. In this study, we utilized both primary and secondary data. We followed propensity score matching model (PSM) approach to analyze the impact of small-scale irrigation on the food security to fill the gap studies conducted in this field of study. We examined the impact of small-scale irrigation on food security through using the most common matching algorisms including nearest neighbor, caliper, radius and kernel matching estimators. The results of nearest neighbor and caliper matching estimators shows that participation in small-scale irrigation increased daily calorie intake of the small-scale irrigation users by 643.76 kcal over non-user households. Furthermore, the impact of small-scale irrigation was found to be positive in radius and kernel matching estimators. It was further also found that in the study area irrigation use had positive impact on crop production, consumption and revenue generation which helped households to buy calorie rich foods for their household. The sensitivity analysis test showed that impact results estimated by this study were insensitive to unobserved selection bias and it is a real impact of irrigation. Based on this result, we concluded that irrigation has positive and significant impact on household food security across all the matching estimators. Concerned bodies that working on small-scale irrigation development therefore should continue investment in irrigation activities for poverty reduction strategies and scale-up irrigation interventions to the other areas where there is potential irrigable land.

### Abbreviations

Kcal: Kilo calorie; PSM: Propensity score matching; ATT: Average treatment effect on the treated; ATE: Average treatment effect; Km: Kilometer; MoARD: Ministry of Agriculture and Rural Development; ETB: Ethiopian Birr; FAO: Food and Agricultural Organization; WHO: World Health Organization; UN: United Nations.

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### Authors' contributions

YJ: contributed to research proposal writing, data collection and supervision. AA: contributed data analysis and article writing. WT: contributed data interpretation. All authors read and approved the final manuscript.

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### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on request.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

We declare that we do not have competing interests.

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