Analyzing the impact of small-scale irrigation schemes on household food security status in Karat Zuria District of Konso Zone, Southern Ethiopia

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Abstract

Small-scale irrigation is one of the suggested panaceas for intensifying the production and productivity of crops among the rural households. This study examined the impact of small-scale irrigation schemes on household food security status at Karat Zuria Woreda of Konso Zone, southern Ethiopia. Both primary and secondary data were collected to achieve the objective of the study. Primary data were collected from 371 household heads using a two-stage sampling technique. Descriptive statistics and econometrics model approach, such as the Propensity Score Matching (PSM) model, were used. The result of the Logit model revealed that participation in small-scale irrigation was positively affected by education, training, number of oxen, use of credit, access to irrigation water, off-farm income, and negatively by the age of the household head and the distance of the plot from a water source. The result of the PSM model revealed that 64% of irrigating households were food secured based on their energy intake, while only 25% from non -user households became food secured, whereas 36% from irrigation participants and 75% of non-participants were food secure. The average food consumption of user households was 2393.99 kcal, while that of non-participants was 2095.65 Kcal. Among the findings of the study, several factors hindered households from utilizing irrigation. These factors include awareness, sharing training, and lack of startup capital. To this end, the government and concerned bodies should provide different workshops and training for the rural households. The Konso zone should subsidize agricultural inputs for the households.

Keywords: *Farm income; Food security; Propensity Score Matching; Small-scale irrigation, Household, Average treatment effect*

Introduction

Ethiopia is the fourth country with the highest number of undernourished people in the world (Gitz et al., 2016). Although Ethiopian people consume a minimum daily requirement of 2200 kcal/day/AE, more than thirty million people in the country live undernourished. The majority of the Ethiopian population lives in rural areas whose livelihood is based on subsistence agriculture, which is subject to erratic rainfall, affecting the agricultural productivity, resulting in food deficit. Agriculture is the leading economic sector, serving as a main source of income, employment, and foreign exchange. It contributes about 41% to GDP, supplies 70% row materials, and creates employment opportunities for more than 80 % of the total population of the country (Rt, 2016).

Agriculture in Ethiopia is mostly small-scale, which is heavily dependent on rainfall, traditional and subsistence farming with limited access to technology, low levels of modern input use, and low institutional support. The dependency on rain-fed agriculture, coupled with its erratic nature, is a major factor that is blamed for the poor performance of the agricultural sector and the main cause of food insecurity in the country(Gitz et al., 2016). Due to that unstable rainfall regime, the productivity and efficiency of the agricultural sector are low, leading to the severe food insecurity problem in the country (Gebrehiwot Yihdego, 2015).

To overcome this subsistence level of small holder production, the Ethiopian government has designed strong policy responses specific to Ethiopia's food security and agricultural productivity challenge through making significant investments and strides with Productive Safety net Program (PSNP) and a national strategic plan in 1991 known as Agricultural Development Led Industrialization (ADLI) which relies on the expansion of small-scale irrigation, formation of cooperative societies and access to agricultural technologies to response the food demand and bring socio-economic development in the country. Hence, small-scale irrigation is a policy priority in Ethiopia for poverty reduction in rural areas of the country and to sustain food security through the production of food grain and cereals ((IMF), 2012). Abraham et al. (2011) listed out the benefits of irrigation that includes; increase food production in arid and semi-arid regions, enhancing food production, promoting economic growth and sustainable development, creating employment opportunities, and improving the living conditions of small-scale farmers.

The study conducted by Awartani & Millis (2018) compared the productivity of farms using irrigation and that of rain-fed farms in the Tigray region and concluded that: Irrigating households in the region reported that, since the utilization of irrigation technology, we observed 20% increases in annual income due to the production of high-value cash crops

In the study area, the Konso district, people introduced small-scale irrigation as a means of reducing chronic food shortage, increasing agricultural productivity, and achieving food security at the household level and community (Hindersah et al., 2018).

The problem of food insecurity due to low production and crop loss in Ethiopia is the result of unreliable and dynamic rainfall patterns. To address this food insecurity problem as a result of variation in rainfall, irrigation utilization, and wise water control activities were taken as a key gateway. In the study area, according to the report of the Drought Mitigation Commission (DMC, 2010), there is a serious food shortage among the people of Konso. During the best times, less than 30% of the Konso population is self-sufficient in food from their own production. Farmers began to use these water sources for irrigating their farms on a traditional basis to escape the food insecurity problem. Hence, the researcher was interested in knowing whether the irrigation practices are contributing to the food security of residents and whether irrigating farmers are better off in terms of crop production and income levels as compared to non-irrigating farmers or not (Moges & Melkamu, 2020).

Despite several studies on small-scale irrigation, existing research has important limitations that this study addresses. Prior work (Aklilu, 2017; Tizita, 2017) used binary logit models and focused on determinants of participation rather than measuring the program's causal impact on household food security. Other studies (Gitz et al., 2016) reported only descriptive assessments and failed to quantify how irrigation affected treated households' livelihoods. Findings are also inconsistent across locations, for instance, (Gitz et al., 2016). Found household head age unrelated to participation in Tigray, whereas this analysis in Konso indicates a significant negative effect of age. Moreover, some local studies (Petros & Yisihak, 2017) report no significant role for assets such as oxen in participation, suggesting context-specific determinants that remain unresolved. In general, there is a gap in using robust impact evaluation methods, such as propensity score matching, that can quantify the effect of small-scale irrigation on household food security and reconcile heterogeneous findings across regions. This study fills that gap by applying propensity score matching to estimate the impact of small-scale irrigation on household income and food-security outcomes in Konso district, and by examining whether and why determinants of participation vary across contexts. This study aimed to achieve the following objectives: 1) To examine the economic impact of small-scale irrigation schemes on household food security and 2) To compare and contrast the food security status of irrigation user and non-user households in the study area.

Materials and Methods

Description of the Study Area

Konso Zone is located in the South Ethiopia regional state. Koso Zone is composed of 4 woredas and one city administration, the Karat city administration. It is located about 600 km south of Addis Ababa at 5^{o} 10'-5^{o} 40' N latitude and 37^{o} 00'-37^{o} 40' longitude.

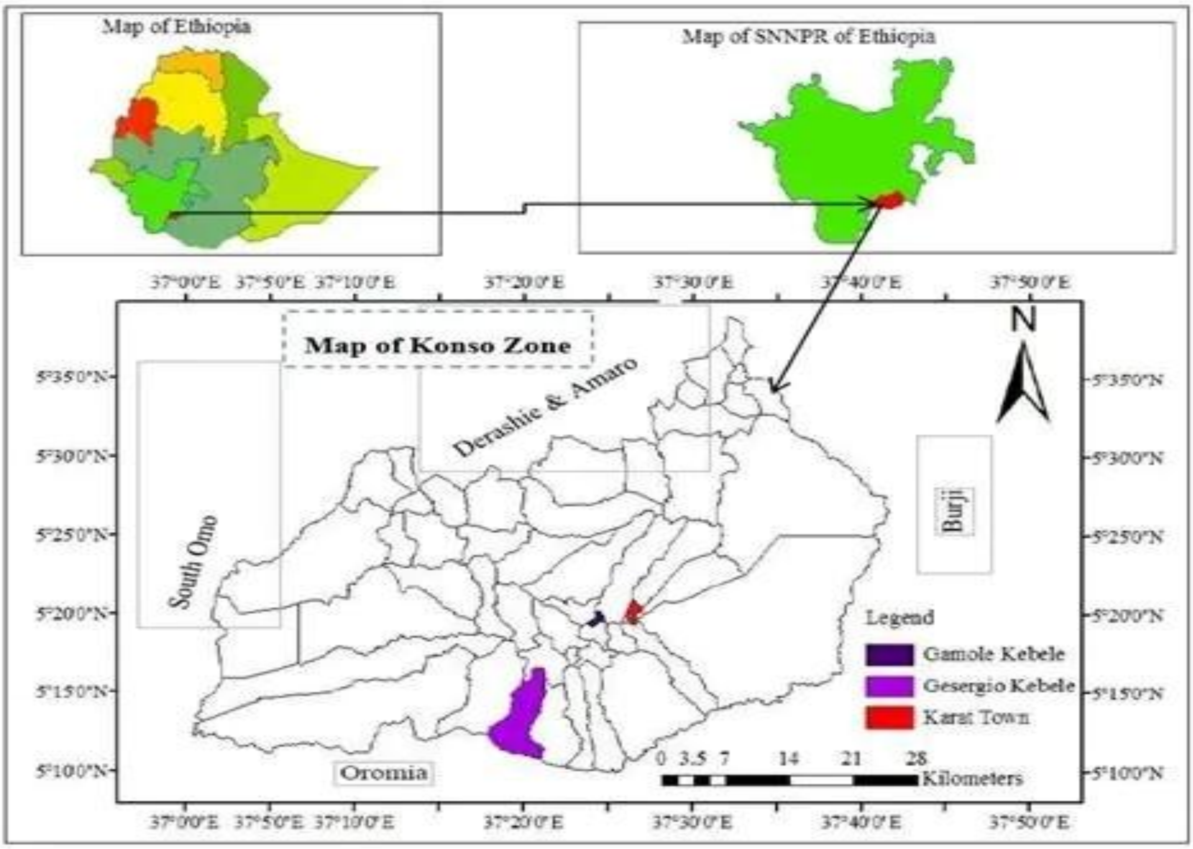

Fig 1: map of the study area, source Konso zone municipality

The total land area of Konso is 2274sqkm. Relatively the study area is located North of Borena zone in Oromia region, east of DebubOmo Zone and Alli Special Woreda, South of Derashe Special Woreda and West of Burji District (Design, 2018).

Research design

A cross-sectional research design with a mixed approach was used in the study, as it is better and more effective for obtaining information about the status or the immediate past of the case under study. It is also appropriate and suitable to use data collection tools such as questionnaires, interviews, focus group discussions (FGD), and document analyses.

Source of Data and Methods of Collection

This study employed both primary and secondary sources of data. Primary data were collected from the respondent households selected from irrigation users and non-users from those kebeles with access to irrigation water. These primary data were collected by structured close ended and open-ended questionnaires and interviews. Secondary data were gathered from different published and unpublished documents and internet sources.

Primary data were collected using questionnaires and interviews to gather information on household characteristics, farming practices, small-scale irrigation use, crop production, access to agricultural services, and challenges faced by farmers. Trained enumerators administered questionnaires from each village who were familiar with the local households and language, and for respondents who could not read and write, the enumerators conducted face-to-face interviews by reading the questions and recording their responses.

Sampling Design

The study employed a two-stage sampling after purposively selecting the four kebeles from seven kebeles with access to irrigation water resources. In the first stage, stratification between irrigator households and non-irrigators has been undertaken. Secondly, a simple random sampling technique with a proportion of their total sample size from both groups was employed. Then the probability proportional sampling technique was used to determine a sample household from each kebele. Finally, ‘’397’’ households were selected from the total number of households from four kebeles by using the Yamane (1967) formula for sample size determination: $n = \frac{N}{1+N(e)2}$

$$52687/(1+52687(0.05)2)$$

$$n = 52687/132.7175 \approx 397$$

Where n is the sample size to be drawn from the population

N, the total number of households from which sample households were selected

E, error term counted (5%)

Out of the total sample, 397 households 159 households were irrigation users, and the left 238 households were non-users of irrigation. This figure was taken based on the prevailing number of program participants and non-participants. According to Rosenbaum and Rubin (1974), the number of controlled groups must exceed the number of treated households to get matches from the treated group between the specified common support regions. Hence, 40% of total households were taken as the treatment group and 60% was controlled group.

Table 1: Household size, sample size, proportion, and sample size

Kebeles	Household size	Proportion	Sample size
Jarso	2850	2850*397/5723	≈198
Tishmale	1131	1131*397/5723	≈78
Fuchucha	414	414*397/5723	≈29
Baide	1328	1328*397/5723	≈ 92
Total	**5723**		**≈397**

Source: own computation, 2018/19

Method of Data Analysis

The data collected has been analyzed by both descriptive and econometric models. Descriptive statistics include frequency, mean, maximum, and minimum, standard errors, and standard deviations, whereas the econometric analysis was performed with PSM (propensity score matching model).

Food Security Status (Z)

In determining the food security status of the households, food quantities of the consumed food items at the household level in the study area were calculated and then converted to calories based on their composition, and the calorie values were divided by the corresponding adult equivalent values of the households to obtain comparable numbers across different-sized households. Accordingly, food secure households were those whose daily per capita calorie consumption per AE is greater than or equal to the required daily minimum calorie intake 2200kcal/day/AE, whereas those households with calorie intake less than the minimum daily requirement were considered as food insecure households (Bogale & Lemma, 2023).

Measuring the Extent of Food Insecurity

Foster J, Greer J, Thorbecke E (1984) class of poverty measure was adopted to assess the extent of food insecurity among the established food insecure sample households. The mathematical expression of the FGT index is specified as follows: $P\alpha =$

$\frac{1}{N}\sum_{i=1}^{q}[(\frac{Z-Yi}{z})]^{\alpha}$ Where, Z is the food insecurity line, Y_i is the per capita calorie intake of household i adjusted for per adult consumption equivalent, N is the total sample size, and q is the total number of food insecure households below the food insecurity line.

The parameter 'α' refers to the extent to which households are above or below the minimum daily requirement of energy. If α=0, then FGT measures the head count index, which measures the proportion of the poor population. In other words, it is the share of sample households whose food expenditure per adult equivalent falls below the food insecurity line. If α=1, then FGT refers to the mean distance that divorces the food-insecure household from the food insecurity line, commonly called the depth of food insecurity.

If α=2, then FGT measures the severity of food insecurity. It takes into account not only the distance separating the food-insecure from the food insecurity line, but also inequality among the food-insecure households.

Analytical models

The PSM (propensity score matching) model has been employed and specified as follows:

This study has two models for the participation equation and outcome equation. The first equation is the participation equation or logit equation. In this equation, participation in irrigation is the dependent variable, which is dichotomous by nature, taking the value 1 for participants and 0, otherwise.

Hence, the logit model guarantees that the estimated probabilities lie in the range 0 to 1(Rubinfeld, 2010). For that, a logit model was employed in this study. According to Gujirati (1995), the functional form of the logit model is specified as under:

$$P(Y_i = 1) = \frac{e^{Y_i}}{1 + e^{Y_i}} \dots\dots\dots\dots\dots\dots.1$$

The probability of irrigation non-users, *i.e.* $P(Y_i = 0)$ and it is given by $1 - P(Y_i = 1)$ is given as:

$$P(Y_i = 0) = \frac{1}{1 + e^{Y_i}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2$$

When the ratio of equation 1 to 2 is calculated (the probability of an event occurring to the probability of non-occurring), we get the odds ratio.

$$\frac{P(Y_i = 1)}{P(Y_i = 0)} = \frac{\frac{e^{Y_i}}{1 + e^{Y_i}}}{\frac{1}{1 + e^{Y_i}}} = e^{Y_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots 3$$

Where $P(Y_i = 1) / P(Y_i = 0)$, odds ratio in favor of irrigation users is: the ratio of the probability that the household is an irrigation user to the probability that the household is a non-user.

The logit equation can be obtained by taking the natural log of the equation

$$L_i = \ln(e^{Y_i}) = Y_i = \beta_i X_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Propensity Score Matching Model (PSM)

Propensity score matching consist of four phases most commonly: estimating the probability of participation, that is, the propensity score, for each unit in the sample; selecting a matching algorithm that is used to match beneficiaries with non-beneficiaries to construct a comparison group; checking for balance in the characteristics of the treatment and comparison groups; along with estimating the program effect and interpreting the results (Caliendo and Kopeinig, 2005). In this model, two groups (the treatment and control) of households were compared to analyze the impact of small-scale irrigation on ensuring their food security. The non-participant households were used as a comparison group to examine the impact of a small-scale irrigation scheme on participant households in the Konso district of Southern Ethiopia. The outcome variable that was used for comparison in this study is the household's farm income per adult equivalent.

The impact of the irrigation program was analyzed within the concept of the program evaluation.

An outcome equation that accounts for the value of irrigation utilization is

$$Y_i = \beta X + \delta T_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

$$Yi = \beta_0 + \delta T_i + \sum Xi\beta i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where Yi =is the outcome variable, household farm income of the i^{th} household

Ti= is a dummy variable indicating whether or not the individual participated in irrigation practice/ treatment indicator

δ= vector of unknown parameters measuring the value of participation in the program

Xi = is a vector of personal exogenous characteristics of the households

The Average treatment effect of the i^{th} household (ATE^i), the difference in the household's food production per adult equivalent, can be expressed by $Y1^i$-$Y0^i$. Where, $Y1^i$ is the food production of the i^{th} participant household, and $Y0^i$ is the food production per adult equivalent of the i^{th} non-participant household. Assuming D as household participation status in the irrigation scheme (D = 1 for participant and D = 0 for non-participant), the ATE^i in casual effect notion can be expressed by:

$$ATE^i = E(Y_1{}^i / D=1) - E(Y^i{}_0 / D=0) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where $E(Y_1^i/D=1)$ is the average food production per adult equivalent for a household with access to an irrigation scheme and $E(Y^i_0/D=0)$ is the average food production per adult equivalent for a household with no access to irrigation.

For the sample households in the study area, the average Effect of treatment on the treated ATT can be given as:

$$ATT = E(Y^i_1 - Y^i_o/D=1) = E(Y^i_1/D=1) - E(Y^i_0/D=1) \ldots\ldots 8$$

One major challenge of impact evaluation was the difficulty of simultaneously observing households' food production per adult equivalent with and without access to the irrigation scheme. In other words, the participant households could be different from the non-participants in attributes other than access to the irrigation scheme, which creates a fundamental problem of causal inference. In order to address the selection bias, it is important to note whether the two basic assumptions are satisfied or not.

Table 2: Definition of Variables, Measurement, and Expected Hypothesis

No	Independent variables	Code	Variable type	Unit of measurement	R/n with Dt
1.	Age of household head	Aghh	Continuous	Years	-
2.	Sex of household head	Sxhh	Dummy	0 and 1	+
3.	Education level of household head	Yrsch	Continuous	Grades	+
4.	Cultivated land holding	Clhh	Continuous	Hectare	+
5.	Farm distance from rivers	Dfrs	Continuous	Km	-
6.	Use of credit	Uscr	Dummy	0 and 1	+
7.	Livestock holding	Livhh	Continuous	TLU	+
8.	Total household farm income	Hhfi	Continuous	ETB	+
9.	Off-farm income	Offin	Continuous	ETB	+
10.	No of oxen owned	Noxen	Continuous	Number	+
11.	Attending training	Attr	Dummy	0 and 1	+
12.	Distance from the market	Dmkt	Continuous	Kilometer	-
13.	Access to irrigation	Acw	Dummy	0 and 1	+

Results

Measuring the Food Security Status of Households

Table 3: Food security status of the households

HHFSS	Irrigation users		Irrigation non-users		X^2
	Freq	%ge	Freq	%ge	
Food secured	96	64	55	25	
Mildly food insecure	18	12	87	39.3	
Moderately insecure	24	16	41	18.5	
Severely Insecure	12	8	38	17.2	
Total	150	100%	221	100%	18.3170***

Source: computation from own survey based on CIA World Factbook (2018), freq= frequency, %ge= percentage, HHFSS= household food insecurity status

The second objective of the study was to compare household food security between irrigation users and irrigation non-user households. Household food security was assessed, and the results are presented in Table 3 above. To this end, the study engaged the direct calorie intake method (DCI) using a seven-day recall period approach to test the dietary variation among the irrigation users and non-users. Consequently, the minimum daily-recommended amount of calories, which is 2200 kcal/day/AE, was used as a food security line. Based on this food security line, households whose daily per capita calorie intake is greater than or equal to 2200 kcal/day/AE were categorized as food secure households, and those whose calorie consumption is less than the minimum requirement were considered as food insecure households. Calorie content was obtained by dividing the total estimated household calorie intake by adult equivalent, and the daily per capita calorie was calculated by dividing the household's per capita calorie intake by seven.

The result shows that out of the total sampled households, 151 (40.7%) of households were food secure and 220 (59.3%) of households were food insecure in the study area. The majority (64%) of irrigation user households were food secure, 12% of irrigation user households were mildly food insecure, while 16% of irrigation user households were moderately food insecure, and only 8% of irrigation user households were severely food insecure. Similarly, out of total non- user households, 25% were food secure, 39.3% of non-users were mildly food insecure, while 18.5% of irrigation non-users were moderately food insecure, and 17.2% of non-users were severely food insecure. The result indicates that irrigation user households are more food secure than irrigation non-user households do. The Chi-square test shows that there is a significant difference in food security status between irrigation users and non-users at 1% level of significance. The finding reveals that the mean value of the energy available for irrigating households was estimated to be 2147.075kcal/day/AE, and for non-user households, the average calorie consumption was found to be 1949.463 Kcal/AE/day. The minimum and maximum energy available for user households were 807.816 Kcal and 2939.659Kcal, respectively. On the other hand, the minimum and maximum energy intakes for food-insecure households were 271.577 kcal and 2874.1 Kcal/day/AE, respectively. This result indicates that households participating in irrigation utilization are obtaining better calorie intake compared to those not participating in irrigation technology. The improvement in calorie consumption is attributed to increased agricultural production, higher crop diversity, and improved household income generated from irrigation activities. As a result, irrigation users are more likely to have better food availability and improved nutritional status than non-users, indicating the positive contribution of irrigation technology to household food security and livelihoods. This result goes in line with the findings of (Abadi et al., 2025).

Measuring the extent of food insecurity by the FGT method in the study area

This section tries to examine the extent of food insecurity among food-insecure sample households using the Foster-Greer-Thorbecke E (FGT) class of food insecurity measures. The result of this study shows that the head count ratio, the food insecurity gap, and the severity of food insecurity were estimated to be 59 percent, 12.9 percent, and 41.9 percent, respectively, in the study area. This implies 59 percent of the sample households cannot meet the minimum requirement recommended for a healthy and active life.

Table 4: FGT indices for food in secured households

Poverty headcount ratio	Poverty gap index	Severity index
0.590 (0.0255)	**0.129 (0.00823)**	**.0419(0.0041)**

Source: own computation from survey data, 2019

Descriptive Analysis of the Outcome Variables

Farm income per adult equivalent: In the first stage of the PSM model, participation in irrigation is the dependent variable, which is dichotomous in nature and takes the values 1 for an irrigation user and 0, otherwise. However, in the second stage, household food production per adult equivalent is the dependent variable, which is continuous and measured in ETB. It is the sum of income from crop production, livestock rearing, and off-farm activities.

Table 5: Mean comparison for impact indicators

Variable	Sample mean	Users mean	Non-users mean	Mean difference	T_value
Household's farm income	15967.5	24625.5	10090.98	-14534.5	-4.48***
Killo Calori/Day	2029.344	2147.075	1949.463	-197.638	-4.03***

Source: computation from own survey data, 2019, Hhfin = household farm income, and KCAL = kilocalorie

The result of Table 5 shows that the monthly average farm income for irrigation user households was found to be 24625.5 ETB, and for non-irrigators was 10090.98 ETB. The mean difference in household farm income between the two groups is significant at 1%. This significant variation in farm income between the two groups indicates that irrigating households were better off in terms of farm production and income levels as compared to non-irrigating farmers in the study area. Similarly, the household food security status was measured using daily calorie intake of food consumption, and then the average daily consumption for irrigating households was 2147.075kcal/day/AE, and that of non-irrigating households was 1949.463kcal/day/AE. The T-value shows that there is significant variation between the two groups, and significant at 1 percent. This implies that irrigating households were better in consumption as compared to non- irrigating households. This, in general, indicates that irrigation users generate more income from both farm (livestock and crop) and have a greater probability to diversify their consumption.

Table 6: Logistic regression

Variables	Coefficients	Z value	P value	Marginal effect
Constant	2.18	1.33	.185	2.180
Access to water	2.53	5.52	.000	.551
Number of oxen	.25	1.94	.052	.062
Attending training	.94	1.79	.073	.231
Off-farm income	.001	2.94	.003	.0004
Use of credit	.895	1.83	.067	.219
Farm distance from source of water	-.705	-6.57	.000	-.175
Cultivated land holding	-.303	-1.46	.144	-.075
Live stock holding	.069	.77	.441	.017
Educational level of households	.132	1.71	.088	.33
Sex of household head	.589	.94	.347	.141
Age of household head	-.080	-2.94	.003	-.020
Distance from market	.056	1.18	.237	.014

Source Model result 2019, ***, **, * 1, 5 &10% significance

As shown in Table 6 above, from the variables expected to affect the treatment in the irrigation scheme in the study area, access to irrigation, number of oxen owned, attending trainings provided by agricultural agents, participation in off farm and non-farm activity, access to credit, and education level of household head influenced the participation in to small scale irrigation positively and significantly. The distance of the plot from the source of water and the age of the respondents negatively and significantly affected the involvement in the utilization of irrigation water negatively and significantly.

Age of the household head (Aghh): the variable age is one of the demographic factors affecting the adoption of small-scale irrigation. It is significant at 1% level of significance and is negatively related to the use of irrigation water. This relationship indicates that, other things being equal, a one-year increase in age of the household reduces the probability of participating in small-scale irrigation by 2%. This implies that older farmers have less chance of participating in irrigation, while younger households are sensitive to newly emerging advanced technologies. This result has been achieved by several authors, like Bogale & Asnake (2023). This similar finding indicates that younger farmers in the study area usually have better exposure to education, agricultural training, and new information sources provided by development agents, non-governmental organizations, and the district agricultural office. They are more likely to attend farmers' training sessions, participate in demonstration programs, and access information about improved farming practices, including small-scale irrigation technologies.

Education level of household head: Years of schooling are positively and significantly associated with treatment in irrigation. It is significant at 10% and had the same effect as hypothesized. Other things remaining constant, the marginal effect shows that, as a household's years of schooling increase by one year, the probability of being an irrigation user increases by 33%. This indicates that educated households had higher probabilities of being treated in irrigation for their awareness regarding the issue, particularly the use of irrigation water, than non-educated households. This result has similar findings with the study conducted by Getaneh (2016), Tewdros (2013), and (Oyato et al., 2024). This gives insights that educated farmers are more capable of understanding extension messages, attending training programs, and making informed decisions regarding improved agricultural practices. Education improves managerial skills, record-keeping ability, and openness to innovation, which increases the likelihood of adopting modern technologies such as small-scale irrigation. In the study area, those farmers who have attended higher classes were sensitive to new technologies and had good awareness, confidence, and capacity to implement irrigation technologies effectively.

Distance from source of water: the variable distance from the water source has a negative relationship with the utilization of the small-scale irrigation scheme, and it is statistically significant at 1% level of significance. The marginal effect tells that, as the distance from the main source of water increases by 1 km, the probability of being an irrigator decreases by 17.5% ceteris paribus. This indicates that farmers cultivating near the main source of water have a better chance of using irrigation than those far away from the source. This result agrees with the result of the study conducted by. The possible justification for this similarity is that greater distance from the water source increases the cost, time, and labor required to transport water and maintain irrigation infrastructure such as canals, pipes, or pumps. Farmers located far from water sources may also face higher water losses due to seepage and evaporation during conveyance, as well as difficulties in regular monitoring and management of irrigation activities. In addition, distant households may have limited access to a reliable water supply, especially during dry seasons, which discourages them from investing in irrigation practices. Therefore, proximity to water sources reduces operational constraints and encourages farmers to adopt and utilize small-scale irrigation technologies.

Use of credit: Access to credit is an important variable in contributing positively to participation in small-scale irrigation. The result shows that credit use is significant at 10% and has a positive impact on irrigation adoption. This implies that households using credit are .219 times more likely to adopt irrigation than non-credit users, other things remaining constant. This is because they are covering their production costs through credit and employing additional labor, purchase improved inputs for their production. The result of this paper contradicts with studies conducted in different regions by (Unturtune, 2017) In the Andhra state of India, (Getahun, 2015) in Sidama and similar to (Yishak, 2016) in Debubomo zones. The positive and significant relationship between credit use and participation in small-scale irrigation observed in this study can contradict findings from other regions due to differences in socio-economic, cultural, and institutional conditions across locations. In the case of the Konso indigenous community, several contextual factors explain why access to credit plays a stronger role in irrigation adoption compared to other areas. The Konso community traditionally practices terrace-based agriculture and intensive land management systems that require substantial labor and input investment. As a result, access to financial resources becomes essential for purchasing improved seeds, fertilizers, irrigation equipment, and hiring labor. Empirical evidence indicates that households with access to credit are more likely to adopt irrigation because credit enables farmers to finance production inputs and agricultural technologies that would otherwise be unaffordable. The basic contradiction of this finding is that in many rural areas of Ethiopia, farmers face barriers such as a lack of collateral, high interest rates, and limited awareness of credit programs, which reduces the effectiveness of credit in supporting technology adoption(Girma, 2022).

Off-farm income: This variable has a significant impact on participating in the irrigation scheme. It is significant at 1% level of significance and positively influenced the adoption of small-scale irrigation. This implies that a one-birr increase in non-farm income leads to an increase in the probability of participating in irrigation by 0.04% ceteris paribus. Thus, households engaged in off-farm and non-farm activities earn more income and spend on necessary inputs for their irrigation utilization, and hence increase their chance to adopt new technologies. This result agrees with the result of (Bogale & Lemma, 2023)

Number of Oxen: The number of oxen owned by households is the main source of income and power in most rural areas of our country; in the study area, oxen are the engines for agricultural work, providing manure and power to crop cultivation, a used as a means of boosting crop production (Asfaw, 2010). In this result, the number of oxen has a significant impact at 10% and positively affects the treatment in irrigation. The marginal effect shows that, as the number of oxen increases by one, the probability of participating in small-scale irrigation will increase by 0.62, other things being constant. This implies that households with a large number of oxen have a greater chance of being involved in the use of irrigation water in comparison with those who have relatively a smaller number of oxen. In general, more oxen owner has more probability of using irrigation and cultivating more size of land on time. This result contradicts several studies conducted by different authors in different parts of our country. For instance, Petros and Yishak (2017) studied the determinants of small-scale irrigation in the Boloso Sore district of the Wolayta Soddo zone.

Attending training: Training is a major source of knowledge for farmers regarding improved agricultural practices, including modern cultivation techniques, use of improved seed varieties suitable for both rainy and dry seasons, proper fertilizer application, and methods to increase farm productivity (Mume et al., 2023). In this study, the training variable was found to be statistically significant at the 10% level and had a positive effect on participation in small-scale irrigation schemes. Holding other factors constant, households that received agricultural training were 0.231 times more likely to participate in small-scale irrigation compared to households that did not receive training.

This result can be explained by the fact that training enhances farmers' technical skills, awareness, and confidence in using irrigation technologies, which improves their capacity to adopt new agricultural practices and manage irrigation systems effectively. Training programs also provide information on water management, crop selection, and input utilization, which are essential for successful irrigation farming. Empirical evidence indicates that farmers who have frequent contact with extension services and participate in agricultural training programs are more likely to adopt irrigation technologies and other improved farming practices because they gain practical knowledge and technical support needed for implementation. A recent study in Eastern Oromia found that extension contact and training significantly increased farmers' adoption of small-scale irrigation practices by improving their understanding of climate risks and modern agricultural technologies(Wana & Dukamo, 2025)

Access to irrigation water: Access to irrigation water was found to have a positive and highly significant effect on households' decisions to participate in small-scale irrigation schemes at the 1% significance level. The positive coefficient indicates that the availability of reliable irrigation water strongly motivates farmers to engage in irrigation activities because it ensures a consistent water supply to their farm plots. Holding other factors constant, the marginal effect results show that households with access to irrigation water are 55% more likely to participate in small-scale irrigation than households without such access. This can be explained by the fact that reliable water access enables farmers to cultivate crops more than once per year, reduces dependence on rainfall, and increases overall agricultural productivity.

Recent empirical studies (Olkeba et al., 2025) support this finding, which shows that access to irrigation water is one of the most critical institutional and physical factors influencing irrigation adoption and agricultural production among smallholder farmers. For instance, a national-level study in Ethiopia reported that improved access to irrigation sources significantly increases the likelihood of irrigation utilization and enhances household productivity and food security outcomes. Similarly, a recent review of irrigation adoption in Ethiopia identified access to water as a key determinant that positively and significantly influences farmers' participation in irrigation and contributes to improved agricultural output and rural livelihoods. This positive relationship between irrigation water access and participation observed in this study is consistent with the findings of (Adamu Asefa & Negasa Andersa, 2023)**.** In Western Oromia and is further supported by recent evidence indicating that reliable irrigation water availability remains a fundamental requirement for expanding irrigation use and improving household productivity in rural Ethiopia

Choice of Matching Algorithm

There are different matching methods for matching between irrigation users and non-users found in the region of common support. From those different matching algorithms, the radius method was taken as the best estimator based on the qualifications designed by (Wahba & Dehejia, 2012). These basic criteria include a balancing test for balancing all covariates, which suggests that there must be an insignificant mean difference between the users and non-users after matching, a smaller pseudo R^2 is preferable to the largest, and an estimator with a large number of matched samples is the best matching estimator.

Table 7: Comparison of Different Matching Algorithms

Matching Estimators	Performance criteria		
	Balancing test	Pseudo R^2	Matched sample
Kernel Matching			
Band width 0.1	12	0.025	258
Band width 0.25	12	0.028	258
Band width 0.5	9	0.061	258
Radious Matching			
Caliper 0.1*	***12***	***0.021***	***258***
Caliper 0.25	11	0.041	258
Caliper 0.5	8	0.103	258
Nearest Neighbor Matching			
Neighbor (1)	10	0.071	258
Neighbor (2)	11	0.056	258
Neighbor (3)	12	0.040	258
Neighbor (4)	12	0.027	258

Source: Own estimation result, 2019, * refers to the selected best matching method

Based on the three qualification criteria, radius matching with caliper 0.1 was found to be the best method for matching the observations. This provides the lowest pseudo R2, a large number of matched covariates, and a large matched sample size. The following table presents the results of a comparison of different matching algorithms.

Matching Irrigation Users and Non-users

Based on the result of Table 6, the estimated propensity scores for irrigation households lie between 0.0040499and 1, with a mean of 0.836723 and a range between 3.23e-06 and .9922802 with a mean of 0.1108215 for non-participants of small-scale irrigation. Therefore, the common support region for both irrigation users and non-users falls between [.0040499, .9922802), indicating that households whose propensity score lies below 0.0040499 and above 0.9922802 were dropped and were not matched with any one of the households in the defined region. Suddenly, 47 households from the comparison group were found outside the region of common support, and no household from the treatment group lies outside the common support region. However, 150 households from the treatment and 174 from the comparison were matched with each other.

Table 8: Estimated propensity score Distribution

Table 8: Estimated propensity score Distribution

Respondents	Obs	On sup	Off sup	Mean	Min	Max
Users	150	150	0	.836723	.0040499	1
Non-users	221	174	47	.1108215	3.23e-06	.9922802
Total households	371	324	47	.4633819	.0010522	1

Source: Model result, 2019, Obs =observation, Min= minimum value, Max= maximum value, sup, support

Average Treatment Effect on Treated

This study found that small-scale irrigation has a positive and significant impact on household farm income and, hence, food security status in the study area. The results of this study demonstrate that small-scale irrigation has a positive and statistically significant impact on household farm income and, consequently, on household food security status in the study area. The empirical findings indicate that participation in small-scale irrigation programs significantly improves both economic and nutritional outcomes for rural households. The study result revealed that irrigation participation increased average household farm income by 12,013.30 Ethiopian Birr (ETB) and improved daily calorie intake by 205.19 kilocalories per adult equivalent (Kcal/AE). These indicators, farm income and calorie intake, are widely recognized in recent food security literature as reliable proxy measures for assessing household food security status, as they directly reflect households' capacity to access sufficient food and maintain adequate nutritional standards.

The improvement in income and calorie intake among irrigation users suggests that access to irrigation enhances agricultural productivity by enabling farmers to cultivate crops during dry seasons, diversify production, and reduce dependence on unreliable rainfall. Increased production leads to higher marketable surplus and income generation, which in turn improves households' purchasing power and ability to meet food and non-food needs. Furthermore, irrigation allows households to produce vegetables and other high-value crops that contribute to improved dietary diversity and nutritional intake. Therefore, the positive effect of irrigation on both income and calorie consumption indicates that small-scale irrigation plays a crucial role in strengthening rural livelihoods and reducing food insecurity.

Table 9: Average Treatment Effect on Treated (ATT)

Outcome Variables	Treated	Controls	Difference	SE	T-vale
HHFIN	23847.81	11834.50	12013.30	3507.53	3.425^{***}
FSTA	2366.04	2160.85	205.19	78.85	2.602^{***}

Source: own estimation result2019, SE= standard error, HHFIN= household farm income and FSTA= food security staus

Discussions

The study demonstrated that small-scale irrigation significantly improved household food security, income levels, and nutritional outcomes. The finding clearly indicated that participation in small-scale irrigation had a measurable and positive impact on household welfare. Irrigation users were more food secure, consumed higher daily calorie levels, and earned substantially higher monthly farm incomes compared to non-users. The study identified several key factors that influenced participation in irrigation schemes, including access to irrigation water, education level, ownership of productive assets such as oxen, participation in training programs, and access to credit services. These enabling conditions played a critical role in determining whether households could successfully adopt irrigation practices and improve their livelihoods. In the irrigation study, distance from water sources was found to negatively affect participation in irrigation, with each additional kilometer significantly reducing the likelihood that farmers would engage in irrigation activities. This finding highlights the importance of infrastructure development and service accessibility in promoting adoption of beneficial technologies.

The study showed that farmers who participated in training programs and had access to extension services were more likely to adopt irrigation and achieve higher productivity. Training enhanced farmers' knowledge and confidence in using new technologies, enabling them to maximize the benefits of irrigation systems. The findings of the study also reveals that, households that did not participate in irrigation schemes experienced lower income levels, reduced food security, and greater vulnerability to economic shocks. The study suggested that involving farmers in planning and managing irrigation schemes could improve adoption rates and sustainability. Farmers possess valuable knowledge about local environmental conditions, cropping systems, and resource constraints, and their participation helps ensure that interventions are practical and acceptable

These findings are consistent with empirical evidence from other regions of the world that highlight the significant role of irrigation in improving household welfare. For example, (Jambo et al., 2021) found that participation in small-scale irrigation schemes significantly increased farmers' crop yields, household income, and food availability, thereby reducing vulnerability to seasonal food shortages. Their study concluded that irrigation development is a key strategy for enhancing food security in semi-arid regions where rainfall variability constrains agricultural production. Similarly, Abanega, 2020 reported that the households in the Southern region of Ethiopia participating in irrigation programs had significantly higher income levels and calorie consumption compared to non-participants. The study emphasized that irrigation improves food security by stabilizing production, increasing cropping intensity, and enabling year-round farming activities.

Finally, the studies emphasize irrigation infrastructure, improving access to credit, and strengthening extension services are essential strategies for enhancing food security and rural livelihoods.

Conclusions

The study concludes that small-scale irrigation plays a decisive role in improving rural livelihoods and household food security. The results demonstrate that households participating in irrigation are significantly better off than non-users in terms of food security status, nutritional intake, and farm income. Specifically, a much higher proportion of irrigation users were food secure, consumed more daily calories, and earned more than double the monthly farm income compared to non-irrigation households, confirming the strong economic and nutritional benefits of irrigation utilization. However, despite these gains, a notable share of households still experiences food insecurity, as reflected by the food insecurity indices. The econometric analysis further shows that access to water, education, livestock ownership, training, credit services, and off-farm income positively influence participation in irrigation, while older age and greater distance from water sources reduce the likelihood of adoption, emphasizing the importance of infrastructure and institutional support in expanding irrigation and enhancing food security outcomes.

Recommendation

Despite the positive impact of irrigation on food security and income, the study identified key constraints limiting wider adoption of irrigation technologies, including limited awareness, inadequate startup capital, insufficient access to credit, and the physical distance of their plot of land from water sources. These challenges suggest the need for targeted institutional and policy interventions.

Based on the research findings, the study recommended that government agencies and relevant stakeholders strengthen agricultural extension services, expand farmers' training programs, improve rural credit access, and invest in irrigation infrastructure development.

Finally, Konso Development Association is highly recommended for subsidizing agricultural inputs and improving water access systems to enhance irrigation participation, increase agricultural productivity, and ultimately improve household food security in the study area.

Declarations

Funding: funding is not available for this paper

Ethical Approval: A committee approved the paper, and the research was conducted in accordance with the guidelines of Arba Minch University

Contribution of the author: The author conducted the study, wrote the manuscript, and approved the final draft.

Conflict of interest: There is no conflict of interest

Data availability: The necessary data are incorporated in the paper.

Acknowledgements

First, I would like to thank the Almighty God for taking care of me and keeping me alive to achieve this goal. I am highly grateful to my advisor, Dr Sisay Debebe, for his kind advice, guidance, helpful comments, and motivation to accomplish my work. Thirdly, I would like to thank Arba Minch University in general and Sawla campus in particular for providing this opportunity to conduct this paper.

References

Abadi, A., Abebe, T., Menza, M., & Syraji, Y. (2025). Impact of small-scale irrigation on the food security status of rural households in Ethiopia. *Journal of Agriculture and Food Research*, *24*(April), 102402. https://doi.org/10.1016/j.jafr.2025.102402

Abanega, A. (2020). *Impact of Small- Scale Irrigation on Smallholder Farmers' Income: The Case of Shebe Sombo District, Jimma Zone, Ethiopia*. *June*, 1–93.

Adamu Asefa, Z., & Negasa Andersa, K. (2023). Determinants of the Adoption of Small-Scale Irrigation Technology and Its Impact on Household Food Security in Ethiopia: A Review. *International Journal of Applied Agricultural Sciences*, *9*(6), 191–195. https://doi.org/10.11648/j.ijaas.20230906.13

Awartani, F., & Millis, B. (2018). Determinants of growth in micro and small enterprises: Empirical evidence from jordan. *Proceedings - 2018 IEEE 5th International Conference on Data Science and Advanced Analytics, DSAA 2018*, 614–622. https://doi.org/10.1109/DSAA.2018.00079

Bogale, G., & Asnake, H. (2023). Analysis of Factors Affecting the Academic Performance of Preparatory School Students (In Case of Sawla Secondary and Preparatory School). *Science Journal of Education*, *11*(4), 131–141. https://doi.org/10.11648/j.sjedu.20231104.13

Bogale, G., & Lemma, M. (2023). The Role of Women Participation in Income Generating Activities (in Case of Demba Gofa Woreda). *Social Sciences*, *12*(3), 94–106. https://doi.org/10.11648/j.ss.20231203.14

Design, S. (2018). *SNNPR Segen Zone Konso Woreda Delbena Small Scale Irrigation Project Delbena Watershed Management Draft Report*. 1–71.

Gebrehiwot Yihdego, A. (2015). The Impact of Small – Scale Irrigation on Income of Rural Farm Households: Evidence from Ahferom Woreda in Tigray, Ethiopia. *International Journal of Business and Economics Research*, *4*(4), 217. https://doi.org/10.11648/j.ijber.20150404.14

Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia: A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, *10*(March), 100362. https://doi.org/10.1016/j.jafr.2022.100362

Gitz, V., Meybeck, A., Lipper, L., Young, C., & Braatz, S. (2016). Climate change and food security: Risks and responses. In *Food and Agriculture Organization of the United Nations*. https://doi.org/10.1080/14767058.2017.1347921

Hindersah, R., Handyman, Z., Indriani, F. N., Suryatmana, P., & Nurlaeny, N. (2018). JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT Azotobacter population, soil nitrogen and groundnut growth in mercury-contaminated tailing inoculated with Azotobacter. *J. Degrade. Min. Land Manage*, *5*(53), 2502–2458. https://doi.org/10.15243/jdmlm

Jambo, Y., Alemu, A., & Tasew, W. (2021). Impact of small-scale irrigation on household food security: evidence from Ethiopia. *Agriculture and Food Security*, *10*(1), 1–16. https://doi.org/10.1186/s40066-021-00294-w

Moges, A., & Melkamu, M. (2020). Determinants of Rural Household Food Insecurity Status and Coping Strategies in Case of Konso Woreda, Segen Area People's Zone of Southern Ethiopia. *International Journal of Business and Economics Research*, *9*(4), 202. https://doi.org/10.11648/j.ijber.20200904.16

Mume, I. D., Mohammed, J. H., & Ogeto, M. A. (2023). Determinants of adoption of small-scale irrigation practices as adaptation strategies to climate change stresses in Kersa

District, Eastern Oromia, Ethiopia. *Discover Food*, *3*(1). https://doi.org/10.1007/s44187-023-00047-7

Olkeba, A., Aligo, A., & Seyoum, A. (2025). Determinants of differential access to irrigation practices among smallholder farmers in Ethiopia. *Discover Food*, *5*(1). https://doi.org/10.1007/s44187-025-00526-z

Oyato, M. T., Borano, G. B., & Tariku, K. A. (2024). Household food insecurity predictors and coping strategies in Basketo Special District , Southern Ethiopia : using the double hurdle model. *Cogent Social Sciences*, *10*(1). https://doi.org/10.1080/23311886.2024.2362287

Rt, A. N. R. (2016). *A nnual repo rt 2016*.

Wana, T. G., & Dukamo, T. A. (2025). Trends and sustainability of small-scale irrigation in Southern Ethiopia: exploring constraints and adoption dynamics. *BMC Agriculture*, *1*(1), 1–15. https://doi.org/10.1186/s44399-025-00013-x