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Impact of Small-Scale Irrigation on Rural Households' Food Security in Arba Minch Zuria Woreda, Southern Ethiopia

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Abstract

This study investigates the impact of small-scale irrigation on rural household food security in the Arba Minch Zuria Woreda, Southern Ethiopia. A three-stage sampling procedure was applied to select 379 households stratified by agroecology and irrigation. Data were collected through structured household surveys and complemented by key informant interviews to ensure clarity, reliability and contextual depth. Food security was assessed using two complementary indicators: daily caloric intake per adult equivalent (AE) and the Foster–Greer–Thorbecke (FGT) food insecurity index, which captures the access and utilization pillars of food security. The results indicate that 51.45% of households were food insecure, with 15.20% experiencing a food gap and 6.56% facing severe food insecurity. The binary logit model results show that education, adult equivalence, and livestock ownership significantly increased the likelihood of irrigation participation, whereas age and dependency ratio reduced it. The Endogenous Switching Regression (ESR) model revealed that irrigation users consumed, on average, 2,160.06 kcal more per AE per day, an improvement of 121.95% compared with the counterfactual scenario of non-use. These findings confirm that small-scale irrigation substantially improves household food security, highlighting the need for expanded irrigation infrastructure, technical training, and inclusive policies targeting vulnerable households.

Keywords: *Endogenous Switching Regression Model; Ethiopia; Food Security; Foster–Greer–Thorbecke Index; Small-Scale Irrigation*

1. INTRODUCTION

Food security remains a global development priority, with an estimated 735 million people suffering from chronic undernourishment in 2023 (FAO, 2023). Sub-Saharan Africa bears a disproportionate share of this burden, with over 280 million people experiencing food insecurity due to climate variability, weak infrastructure, and low agricultural productivity (African Union, 2023). The concept of food security encompasses four interrelated pillars: availability, access, utilization, and stability (FAO, 2008). In rural, rain-fed agricultural systems, these dimensions are especially vulnerable to environmental shocks, such as droughts.

In Ethiopia, agriculture is central to the national economy, accounting for over 33% of the GDP and employing nearly two-thirds of the population (World Bank, 2024). However, the sector is constrained by fragmented landholdings, traditional farming practices, limited irrigation coverage, and erratic rainfall. These structural challenges, alongside rapid population growth and environmental degradation, continue to undermine rural food security despite ongoing policy and development interventions (CSA, 2021; MoA, 2022).

Small-scale irrigation has been widely promoted to boost agricultural productivity and improve rural livelihoods. Several studies have reported positive effects of irrigation on income and poverty reduction, such as those by Abdi and Teshome (2015), Jema et al. (2013), Muez (2014), Sisay and Fekadu (2013). Others, including Abdissa et al. (2017), Alemu (2017), Asayehegn (2012), Bagson and Kuuder (2013), Deribe (2015), Issahaku (2018) and Jambo et al. (2021) have specifically emphasized irrigation’s role in improving food security. However, most of these studies rely on income or welfare indicators as proxies and do not directly assess food security using scientifically grounded nutritional benchmarks. Furthermore, few of these studies address the potential selection bias involved in household decisions to adopt irrigation, which may distort the impact estimates.

Arba Minch Zuria Woreda, located in the Gamo Zone of Southern Ethiopia, is an area with considerable irrigation potential, yet persistent food insecurity. Despite access to surface and groundwater resources, agricultural production remains largely rain dependent and vulnerable to climate variability. Although small-scale irrigation schemes have been introduced in parts of the district, their direct impact on household food security, measured in terms of access and utilization, has not been rigorously evaluated.

This study addresses these gaps by examining the impact of small-scale irrigation on household food security in the Arba Minch Zuria Woreda. An Endogenous Switching Regression (ESR) model is applied to correct for selection bias, and two key food security indicators are employed: daily caloric intake per adult equivalent and the Foster-Greer-Thorbecke (FGT) index. By providing empirical evidence of the direct nutritional benefits of irrigation, this study contributes to Ethiopia's food security strategy and the achievement of Sustainable Development Goal 2: Zero Hunger.

2. METHODOLOGY

2.1. Description of the Study Area

Arba Minch Zuria Woreda is located in the Gamo Zone of the Southern Ethiopia Regional State, approximately 275 km south of Hawassa and 505 km from Addis Ababa. It spans 168,172 hectares and lies between 5°42′–6°13′ N latitude and 37°19′–37°41′ E longitude (WARDO, 2015; Asfaw et al., 2021). The Woreda consists of 29 rural kebeles across three agro-ecological zones: Dega (14%), Weynadega (53%), and Kolla (33%).

The area receives bimodal rainfall ranging from 800 to 1,200 mm annually and experiences temperatures between 16°C and 37°C. Major rivers, including the Hare, Baso, and Kulfo, drain into Lakes Abaya and Chamo, providing considerable irrigation potential (Asfaw et al., 2021).

Agriculture is the primary livelihood, with maize, sorghum, teff, and fruits such as bananas and mangoes widely cultivated. Ox-drawn plowing and livestock rearing, particularly cattle and goat fattening, are common practices. Despite abundant water resources, agricultural production remains largely rain-fed and vulnerable to climate variability, contributing to food insecurity (Asfaw et al., 2021).

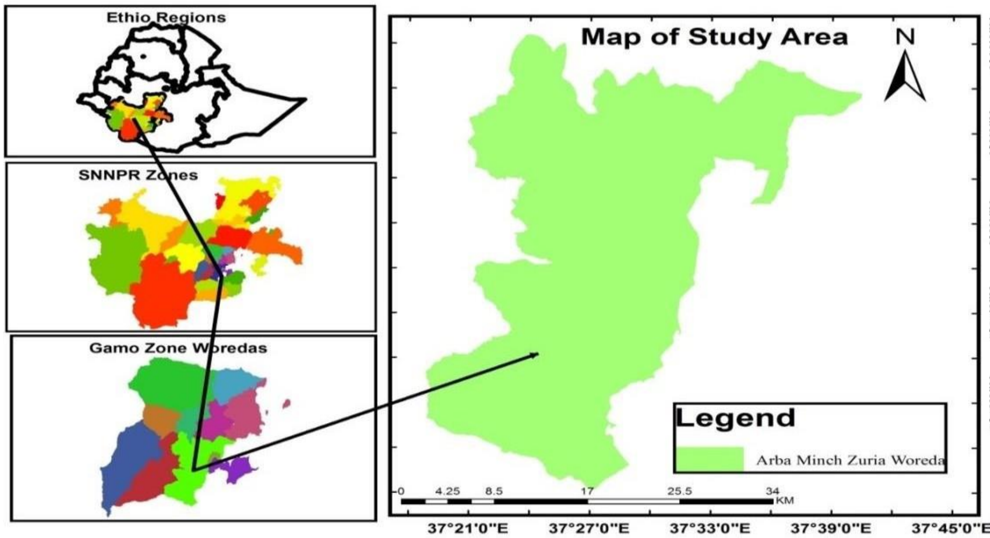

Figure 1
Location Map of the Study Area
Source: Adapted from Asfaw *et al.* (2021)

2.2. Sampling Techniques and Sample Size Determination

A three-stage sampling technique was employed to select the final respondents. The study area comprises 29 kebeles distributed across three agro-ecological zones: Dega (4 kebeles), Weynadega (15 kebeles), and Kolla (10 kebeles).

In the first stage, the kebeles were grouped by agro-ecological zones (cluster sampling). Using probability proportional to size (PPS), six kebeles were selected by simple random sampling: one from Dega, three from Weynadega, and two from the Kolla.

In the second stage, households within the selected kebeles were stratified into irrigation users and non-users to create homogeneous strata for comparison purposes.

In the third stage, 379 households were selected through simple random sampling from the strata, maintaining proportionality to the respective users (40%) and non-users (60%), reflecting their actual distribution and ensuring a robust comparison.

The sample size was determined using Cochran's (1977) formula for finite populations, considering a 95% confidence level (z = 1.96), an estimated population proportion of 50% (p = 0.5), and a 5% margin of error (e = 0.05). The total farming household population in the woreda was 27,266 (WoA, 2018). The formula used is:

$$n=\frac{z^2\dot{P}(1-\dot{P})}{e2+\left(\frac{z^2\dot{P}(1-\dot{P})}{N}\right)} \approx \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2+\left(\frac{(1.96)^2 0.5(0.5)}{27266}\right)}=379 \quad (1)$$

where n is the required sample size, z is the critical value corresponding to the 95% confidence level, p represents the estimated proportion of the population possessing the attribute of interest, q is equal to 1 minus p, e is the desired margin of error, and N is the total population size.

Table 1

Distribution of sample households for each kebele

Agro-Ecological Zone	Number of Kebeles	Sample Kebeles Selected	Total HH	Irrigation users	Sample HH (users)	Non-irrigation users	Sample HH (Non-users)
Dega	4	Laka	1229	134	9	1095	44
Weynadega	15	Genta	642	119	8	523	21
		Meyche	1625	64	4	1561	63
		Zigiti Bakole	910	45	3	865	35
		Zigiti Merche					
Kolla	10	Kolla Shelle	1428	1379	90	52	2
		Shara	2105	580	38	1525	62
Total	29	6	7939	2318	152	5621	227

Source: Survey data, 2019

2.3. Study Design and Data Collection Techniques

In this study, a cross-sectional explanatory design was employed, integrating both quantitative and qualitative approaches. Primary data were collected using a structured and pretested questionnaire administered to 379 randomly selected rural households across six kebeles.

Qualitative data were gathered through key informant interviews with district experts, focus group discussions with farmers, and field observations, which were used to triangulate and enrich quantitative findings. Additionally, secondary data from the District Agricultural Bureau supported the contextual analysis.

2.4. Methods of Data Analysis

This study used both descriptive and econometric methods to analyze the impact of small-scale irrigation on food security at the household level. Descriptive statistics, including frequencies, means, standard deviations, t-tests, and chi-square tests, were used to compare the socioeconomic characteristics of irrigation users and non-users. Furthermore, the Foster–Greer–Thorbecke (FGT) food insecurity indices, namely incidence (headcount), gap, and severity, were computed using the Distributive Analysis Statistical Package (DASP), allowing for a detailed assessment of food insecurity patterns in the study area.

For the econometric analysis, a binary logistic regression model was used to identify factors affecting participation in small-scale irrigation, while an Endogenous Switching Regression (ESR) model was employed to estimate the impact of irrigation on household food security, addressing potential selection bias. The analysis was conducted using STATA version 14, and qualitative findings from the key informant interviews were used to support the interpretation and triangulate the quantitative results.

2.4.1. Binary Logit Model Specification

A logistic regression model was employed to determine the factors affecting rural households' decisions to participate in small-scale irrigation in the study area. In this model, the dependent variable is irrigation participation, which is coded as 1 for irrigation users and 0 otherwise.

Binary logistic regression was used to estimate the determinants of irrigation participation. The key assumptions of this model include the linearity of the log-odds between the dependent variable and predictors, independence of error terms, and absence of multicollinearity among explanatory variables (Hosmer & Lemeshow, 2004). The violation of these assumptions may compromise the accuracy of the model estimates. A sufficiently large and balanced sample comprising both outcome category irrigation participants and non-participants is also essential for reliable inference. These limitations highlight areas where the results should be interpreted cautiously

(Long & Freese, 2014). Logistic regression performs well when the dependent variable is dichotomous (Gujarati 2004).

The model is defined as:

$$P(Y_i=1|X_i)=\frac{e^{Y_i}}{1+e^{Y_i}} \quad (2)$$

If we divide the probability of being an irrigation user by the probability of being a non-user, we obtain the odds ratio:

$$\frac{P_i}{1-P_i}=\frac{\frac{e^{Y_i}}{1+e^{Y_i}}}{\frac{1}{1+e^{Y_i}}}=e^{Y_i} \quad (3)$$

Taking the natural log of both sides gives the logit model:

$$\ln\left(\frac{P_i}{1-P_i}\right)=\ln e^{Y_i}=Y_i=\beta_i X_i+\varepsilon_i \quad (4)$$

where Y_i is the irrigation status of household i (1 = user, 0 = non-user), X_i is the vector of explanatory variables, and ε_i is the error term. The definitions, measurement, and expected signs of these explanatory variables are provided in Table 2.

2.4.2. Endogenous Switching Regression (ESR) Model Specification

The primary objective of this study was to examine the impact of small-scale irrigation on rural household food security. An Endogenous Switching Regression (ESR) model was employed to address potential selection bias. In the first stage (participation equation), a logit model was used to identify the factors influencing household decisions to participate in small-scale irrigation. The dependent variable, irrigation participation, is coded as 1 for users and 0 for non-users.

Following Becerril and Abdulai (2010) and Khonje et al. (2015), households' participation decisions are modeled within a random utility framework. Let A_i denote the difference between the utility from participation (U_{i1}) and non-participation (U_{i0}) in small-scale irrigation. Households will participate if the utility from irrigation exceeds that from non-participation, i.e., $U_{i1}-U_{i0}>0$. As both utilities are unobservable, the net benefit A_i is treated as a latent variable determined by observed and unobserved factors:

$$A^*_i=X_i\beta+\varepsilon_i \text{ where } A_i=\begin{cases}1 & if\ A^*_i>0\\ 0 & \text{otherwise}\end{cases} \quad (5)$$

Here, A_i is a binary variable indicating irrigation participation; X_i is a vector of socioeconomic and institutional characteristics; β is a vector of parameters to be estimated; and εi is the random error term. The relationship between irrigation participation and food security (measured by daily caloric intake per adult equivalent) is modeled as follows:

$$Y^*_i = Z_i\partial + \theta Ad_i + u_i \quad (6)$$

where Y^*_i denotes household food security, Zi is a vector of explanatory variables, Adi represents irrigation participation, δ and θ are parameters to estimate, and u_i is the error term.

The key parameter θ captures the effect of irrigation participation, assuming a random assignment (Faltermeier & Abdulai, 2009; Khonje et al., 2015). However, since households self-select irrigation use, selection bias may occur (Amare et al., 2012). Recent empirical studies (e.g., Asfaw et al., 2012; Assefa et al., 2022; Tsegaw et al., 2022; Khonje et al., 2015; Mohammed, 2019) have highlighted the role of unobserved factors in these decisions. The ESR model accounts for this bias in the following way.

For the ESR model to be valid, instruments affecting participation but not directly influencing food security are required (Shiferaw et al., 2014). Following Di Falco et al. (2011) and Khonje et al. (2015) we conducted a falsification test. The dependency ratio was used as an instrument, significantly influencing participation but not the food security outcome for non-users ($F = 2.70$; $p > 0.102$).

In the second stage, the outcome equations for irrigation users (Regime 1) and non-users (Regime 2) are estimated conditionally as follows:

Regime 1 (Irrigation Users): $Y1i = \beta 1xi + \delta s1\lambda i1 + \eta 1i \ \ if \ \ Ai = 1$ (7a)

Regime 2 (Irrigation Nonusers): $Y2i = \beta 2xi + \delta s2\lambda i2 + \eta 2i \ if \ Ai = 0$ (7b)

Here, Yi is the daily caloric intake per adult equivalent, Yi is the vector of explanatory variables, λ_1 and λ_2 are inverse Mills ratios (IMRs) computed from the first-stage equation to correct selection bias, and η is the error term.

Following Di Falco et al. (2011) and Asfaw et al. (2012) the expected outcomes are computed as:

Actual Irrigation Users: $E[Yi1Ai = 1; x] = Xi1\beta + \delta s1\lambda i1$ (8a)

Actual Nonusers: E [Yi2Ai = 0; x] = $Xi2$ β + δs2$\lambda i2$ (8b)

Counterfactual (Users as Nonusers): E [Yi2Ai = 1; x] = $Xi1$ β + δs2$\lambda i1$ (8c)

Counterfactual (Nonusers as Users): E [Yi1Ai = 0; x] = $Xi2$ β + δs1$\lambda i2$ (8d)

The Average Treatment Effect on the Treated (ATT) is:

ATT = E [$Yi1|Ai$ = 1; X] − E [$Yi2|Ai$ = 1; X] = X$i1$ β + δs1$\lambda i1$ − X $i2$β + δs2$\lambda i2$ (9)

The Average Treatment Effect on the Untreated (ATU) is:

ATU = E [Yi1Ai = 0; x] − E [Yi2Ai = 0; x] = $Xi2$ β + δs1$\lambda i2$ − $Xi2$ β + δs2$\lambda i2$ (10)

Finally, Transitional Heterogeneity (TH) can be calculated as the difference between ATT and ATU.

2.4.3. Estimation of the Outcome Variable (Food Security)

In this study, the primary outcome variable was household food security, which is a multidimensional concept encompassing availability, access, utilization, and stability, as defined by FAO (2008). However, owing to the household-level focus and data availability, this study specifically emphasized access and utilization dimensions. These were operationalized using two complementary quantitative indicators: daily caloric intake per adult equivalent (AE) and the Foster–Greer–Thorbecke (FGT) index of food insecurity.

The first indicator, daily caloric intake per AE, was used as a direct measure of food access. It was calculated based on data collected through a 7-day recall survey in which households reported the types and quantities of food items consumed. These quantities were converted into kilocalories using the Ethiopian Food Composition Tables, and household composition was adjusted to adult equivalents based on the FAO/WHO-recommended age- and sex-specific conversion factors. The resulting total caloric intake was divided by seven to obtain the daily intake and then normalized per adult equivalent (AE) to allow inter-household comparison. Following national guidelines (FDRE, 2014), households with a daily intake of less than 2,200 kcal per AE were classified as food insecure, whereas those meeting or exceeding this threshold were considered food secure.

To capture the intensity and distribution of food insecurity beyond simple classification, the second measure applied was the Foster–Greer–Thorbecke (FGT) index. This index provides three key metrics: incidence of food insecurity (headcount ratio, α = 0), depth or food gap index (α = 1), and severity of food insecurity (squared food gap index, α = 2). The FGT formula is as follows:

$$\mathbf{FGT}_{\alpha} = \frac{1}{n}\sum_{i=1}^{q}\left[\left(\frac{Z-Yi}{Z}\right)\right]^{\alpha} \quad (11)$$

In the above formula, *n* represents the total number of households in the sample, and *q* refers to the number of households classified as food insecure, meaning that their daily caloric intake per adult equivalent falls below the threshold value ($Yi < Z$). The term *Yi* denotes the daily caloric intake per adult equivalent for household *i*, and *Z* represents the established food security threshold, which in this study is set at 2,200 kilocalories per AE per day, as recommended by the Ethiopian Government (FDRE, 2014). The parameter *α* (alpha) indicates the degree of sensitivity to the depth and severity of food insecurity: when α = 0, the index captures only the incidence (headcount); when α = 1, it reflects the food insecurity gap; and when α = 2, it emphasizes the severity by giving more weight to those further below the threshold. These indices were computed using the Distributive Analysis Statistical Package (DASP), which is specifically designed for poverty and inequality analysis in STATA.

By combining these two indicators, caloric adequacy and the FGT index, this study provides a nuanced, scientifically robust, and policy-relevant evaluation of food security outcomes. These measures were used as dependent variables in both the descriptive analysis and econometric models, particularly the Endogenous Switching Regression (ESR) model, to estimate the causal impact of irrigation participation on household food security.

2.4.4. Definition and Hypotheses of Explanatory Variables

The explanatory variables used in the binary logit and ESR models were selected based on relevant economic theory and empirical studies. Table 2 provides definitions, measurement units, and expected signs.

Table 2

Summary of the Definition and Hypothesis of Explanatory Variables

List of explanatory variables	**Nature and measurement units of variables**	**Hypothesized direction of significance**	**Some of the supporting evidences**
Age of a household Head (Agehh)	Continuous (years)	Negative	Getaneh (2011); Temesgen (2017)
Sex of household head (Sexhh)	Dummy (1 if male, 0 otherwise)	Positive	Jema *et al.* (2013); Hadush (2014)
Education Level of the household head (Eduhh)	Continuous (class year)	Positive	Muez (2014); Adem (2016)
Family size of a household per adult equivalent (Famsize)	Continuous (AE)	Positive	Hadush (2014); Sikhulumile (2013)
Total livestock owned (Tlu)	Continuous (TLU)	Positive	Aboneshetal., (2008); Getaneh (2011)
Dependency ratio (Depr)	Continuous (number)	Negative	Ifa et al. (2021); Adem (2016)
Cultivated land size (Landsize)	Continuous (hectare)	Positive/ Negative	Sithole *et al.*, (2014); Abebaw *et al*., (2015)
Distance from irrigation water source (Distws)	Continuous (km)	Negative	Sikhulumile (2013)
Frequency of extension contact (Freqext)	Continuous (year)	Positive	Sinyolo *et al.*, (2014); Adem (2016)
Access to Credit (Act)	Dummy (1 if used, 0 if not)	Positive	Temesgen (2017)
Distance from the nearest market (Distmkt)	Continuous (km)	Negative	Muez (2014); Temesgen (2017)

Source; Own definition, 2019

3. RESULTS AND DISCUSSION

3.1. Descriptive Statistics Results

3.1.1. Descriptive Statistics of the Dummy Variables

As shown in Table 3, this study examined two key binary variables: the sex of the household head and access to credit. Of the 379 sampled households, 152 (40%) were irrigation users and 227

(60%) were non users. Overall, 81.27% of the households were male-headed, while 18.73% were female-headed. Among the irrigation users, 79.61% were male-headed and 20.39% were female-headed. Similarly, 82.38% of non-users were male-headed and 17.62% were female-headed households. The chi-square test showed no statistically significant difference in the sex distribution between the two groups.

Access to credit was measured as a dummy variable based on whether the household received credit from any source, formal or informal, during the previous 12 months. The overall proportion of households with credit access was 41.95%. Among irrigation users, 40.79% had access to credit, compared to 42.73% of non-users. Contrary to expectations, the chi-square test found no significant association between credit access and irrigation participation.

Table 3

Descriptive statistics of sample households (for dummy variables)

Variables	**Types**	**Irrigation users**		**Irrigation nonusers**		**Total**		**χ^2-test**
		Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	
Sex	Male	121	79.61	187	82.38	308	81.27	0.4600
	Female	31	20.39	40	17.62	71	18.73	
	Total	152	100	227	100	379	100	
Access to Credit	Credit users	62	40.79	97	42.73	159	41.95	0.1410
	Credit nonusers	90	59.21	130	57.27	220	58.05	
	Total	152	100	227	100	379	100	

Source: own survey result, 2019.

3.1.2. Descriptive Statistics Results for Continuous Variables

Descriptive statistics were used to examine the continuous variables characterizing the socioeconomic conditions of irrigation users and non-users. As shown in Table 4, the average age of household heads across the sample was 44 years, with irrigation users having a mean age of 42 years and non-users averaging 45. The difference was statistically significant at the 5% level, suggesting that younger farmers may be more inclined to participate in irrigation because of their greater physical capacity or openness to innovation. Regarding education, irrigation users attained an average of 5.36 years of schooling, while non-users averaged 2.69 years of schooling. This difference was significant at the 1% level, indicating that better-educated households are more likely to understand and adopt irrigation technology.

In terms of household size, adult equivalency was calculated using FAO/WHO-standardized conversion factors to adjust for age and sex. Irrigation users had an average adult equivalency of 5.03, compared to 4.44 for non-users, with a significant mean difference at the 1% level. This implies that households with more active labor forces are more likely to engage in irrigation practices, which often require more labor. Livestock ownership, measured in Tropical Livestock Units (TLUs), also showed a significant difference: irrigation users owned an average of 7.18 TLUs, while non-users owned 5.39 TLUs on average. This difference, significant at the 1% level, may indicate that households with greater asset endowments are better positioned to invest in irrigation.

Landholding size was another factor that varied between the groups. On average, the sample households cultivated 0.61 hectares of land. Irrigation users had a slightly larger average land size (0.68 ha) than non-users (0.57 ha), and this difference was statistically significant at the 10% level. Although not highly significant, this suggests that land size may modestly influence irrigation adoption. Finally, the frequency of agricultural extension contact differed between the two groups. The mean number of extension visits per year was 9.03 for irrigation users and 7.97 for non-users, with the difference significant at the 1% level. This finding underscores the importance of extension services in promoting irrigation participation, as frequent contact may increase farmers' exposure to new techniques and encourage their adoption.

Table 4

Descriptive Statistics of Sample Households (for Continuous Variables)

Variables	Irrigation user HH		Non-irrigation user HH		Combined		t value
	Means	**Standard Deviations**	**Means**	**Standard Deviations**	**Means**	**Standard Deviations**	
Age of HH head (years)	42.21053	9.659523	45.20264	12.57168	44.00264	11.57252	2.4838**
Education level of HH head (years of attendance)	5.361842	3.574281	2.687225	3.442828	3.759894	3.730026	-7.2996***
Adult equivalency	5.039868	1.615483	4.439868	1.512709	4.680501	1.580306	-3.6823***
Livestock holding	7.180743	4.222236	5.388586	3.262708	6.10734	3.776197	-4.6502***
Dependency ratio	0.8899285	0.841307	0.9701176	0.8046895	0.9379573	0.8194132	0.9336
Cultivated land size	0.6768092	0.5592842	0.5660793	0.5406949	0.6104881	0.5501808	-1.9272*
Distance from water source	5.178618	2.8151	5.101762	2.853432	5.132586	2.834636	-0.2584
Extension contract	9.026316	2.893124	7.969163	3.737388	8.39314	3.458913	-2.9456***
Distance from the nearest market	4.289803	3.144212	4.247797	3.041133	4.264644	3.078822	-0.1300

Note: *****, **** and ***** indicate significance at the 1%, 5%, and 10% levels, respectively

Source: Own survey results, 2019.

3.1.3. Descriptive Results of the Outcome Variable

Household food security was assessed using the daily caloric intake per adult equivalent (AE). As shown in Table 3, the average intake across all sampled households was 2,711.73 kcal, with a standard deviation of 1,917.89 kcal. Irrigation users had a significantly higher mean caloric intake of 3,931.21 kcal (SD = 2,383.20), while non-users averaged only 1,895.17 kcal (SD = 829.15). The mean difference of 2,036.04 kcal between the two groups was statistically significant at the 1% level, indicating a strong association between irrigation use and improved household calorie consumption.

The caloric adequacy method was used to classify households as food-secure or insecure. Those consuming less than the national minimum requirement of 2,200 kcal per AE per day (FDRE, 2014) were categorized as food insecure. On average, irrigation users exceeded this threshold, whereas non-users fell significantly below it.

These findings highlight a substantial disparity in food access between the two groups, suggesting that irrigation participation contributes to improved dietary intake of food. The higher caloric intake among users may reflect enhanced productivity and income from irrigated agriculture, which helps buffer households against food insecurity, particularly under conditions of climate variability. To rigorously examine the causal relationship between irrigation use and food security outcomes, the Endogenous Switching Regression (ESR) model was employed in the subsequent analysis.

Table 5

Mean caloric intake per adult equivalent of sample households

Variables	Irrigation user HH	Irrigation nonuser HH	Combined means	Mean differences	t value
Daily calorie intake per AE	3931.207	1895.166	2711.732	2036.041	-11.8513***

Source: Own survey results, 2019.

3.1.4. Food Security Status of Households in the Study Area

The food security status of households was assessed using the Foster-Greer-Thorbecke (FGT) indices, focusing on calorie-based deprivation as a proxy for the access and utilization pillars of food security. Although originally designed for income poverty analysis, the FGT framework was adapted here to capture the depth and severity of food consumption shortfalls. In this study, the terms “poverty gap” and “severity” refer specifically to calorie intake, not income deficits.

The results indicate that 51.45% (n = 195) of the sampled households were food insecure, while 48.55% (n = 184) were food secure. The average daily caloric intake per adult equivalent was 2,711.73 kcal, which is above the national minimum threshold of 2,200 kcal but below both the national average (3,127 kcal) and the SNNPRS average (3,529 kcal), based on Karale (2015). Considerable variation in intake was observed, ranging from 1,549.43 to 3,943.52 kcal, with a mean difference of 2,394.08 kcal (Figure 2). This disparity highlights the unequal distribution of food access across households and underscores the potential role of small-scale irrigation in improving food security.

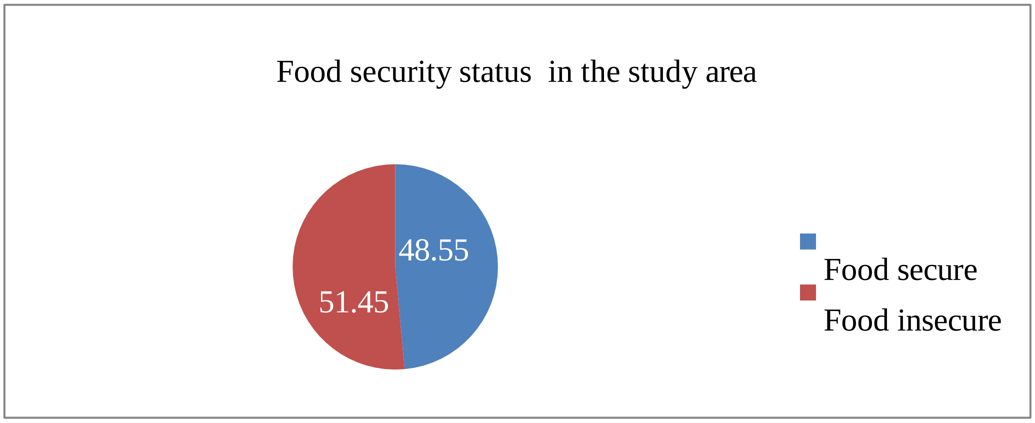

Figure 2

Food-Secured and Insecure Households in Percentages

Source: Computed from our own survey 2019

3.1.5. FGT Measures of Food Insecurity Indices in the Study Area

Food insecurity in the study area was analyzed using the Foster-Greer-Thorbecke (FGT) indices, based on the minimum dietary requirement of 2,200 kcal per adult equivalent per day. As shown in Figure 3, the headcount index (α=0) was 0.5145, indicating that 51.45% of the households were food insecure.

The food gap index (α=1) was 0.1521, suggesting that food-insecure households need, on average, a 15.21% increase in calorie intake to meet the threshold. The severity index (α=2) was 0.0656, reflecting the intensity of deprivation among the most food insecure households.

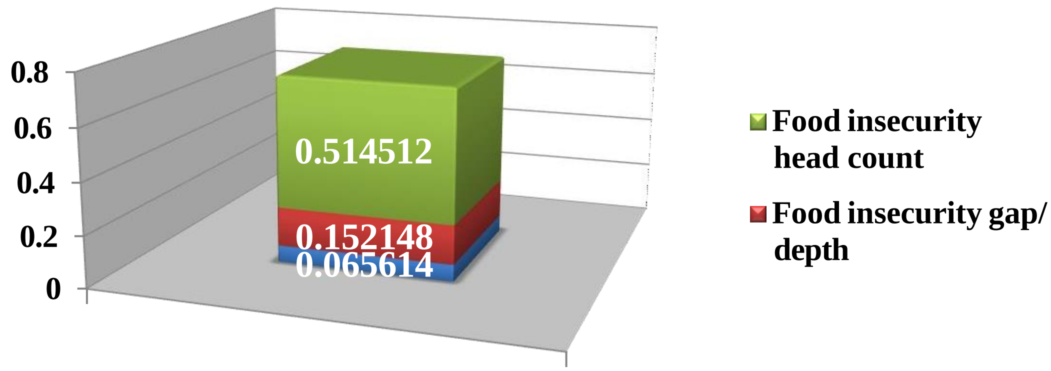

Figure 3

FGT Food Insecurity Indices of Sample Households

Source: Own survey results, 2019.

3.1.6. Food Insecurity Indices among Irrigation Users and Non-users

Food insecurity levels were assessed using the Foster–Greer–Thorbecke (FGT) indices based on data collected through a structured and pre-tested household survey. The questionnaire was piloted on 12 households to ensure its clarity, consistency, and logical flow. Expert reviews from local agricultural officers further strengthened the content validity, and trained enumerators conducted the interviews under close supervision.

Using the national threshold of 2,200 kcal per adult equivalent per day, the results show stark contrasts in food insecurity between irrigation users and non-users (Figure 4). The headcount index was 22.4% for irrigation users and 70.9% for non-users, indicating significantly higher food insecurity among non-irrigated households. The food gap index was 3.1% for users and 23.3% for non-users, whereas the severity index was also notably lower for irrigation users. These findings highlight not only a lower incidence of food insecurity among irrigation users but also less depth and inequality in calorie deprivation. Overall, the analysis underscores the crucial role of small-scale irrigation in enhancing household food security and reducing vulnerability to food shortages in the study area.

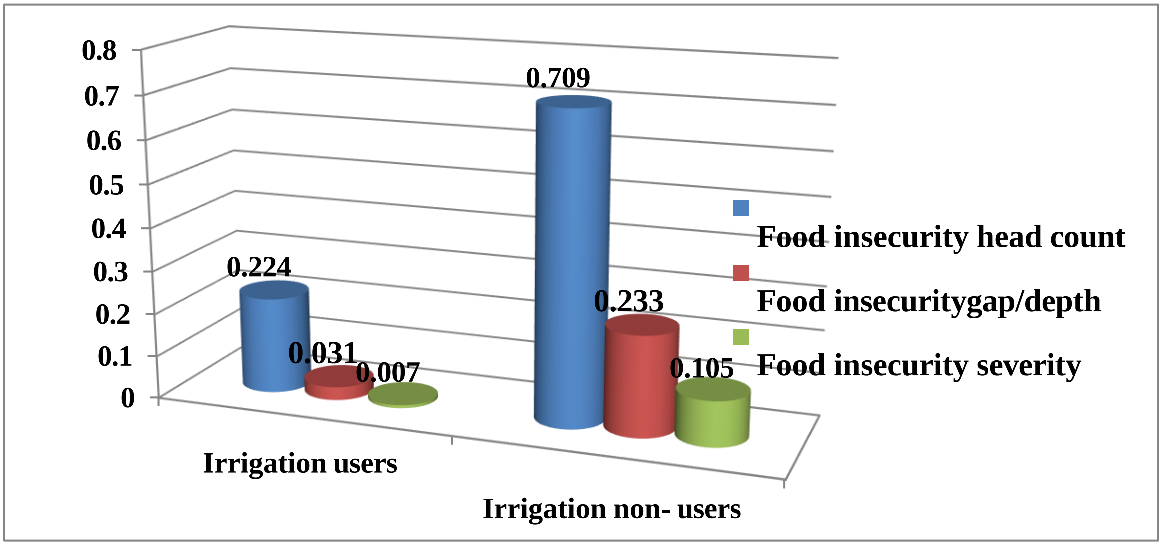

Figure 4

FGT Food Insecurity Indices Results between Irrigation users and nonusers

Source: Own survey results, 2019.

3.2. Econometric Model Results

3.2.1. Factors Affecting a Rural Household's Decision to Participate in a Small-Scale Irrigation Scheme

To investigate the determinants of rural household participation in small-scale irrigation schemes, a binary logit regression model was employed. This model estimated the likelihood of a household engaging in irrigation based on a set of socio-economic and institutional characteristics. The validity of the model specification was assessed using a link test, in accordance with the procedures outlined by Pregibon (1979) and Pettitt (1989). The p-value for the squared predicted value (hatsq) was 0.133, indicating that it was statistically insignificant. This suggests no evidence of model misspecification, affirming that the model was properly specified and that no relevant explanatory variables were omitted from the model. Furthermore, the model achieved a Pseudo R^2 value of 0.2204, implying that approximately 22.04% of the variation in household irrigation participation decisions was explained by the variables included. The overall model fit was statistically significant at the 1% level, as evidenced by the chi-square test p-value of 0.0000, confirming the collective explanatory power of the covariates (Table 6).

Of the 11 explanatory variables considered in the model, seven significantly influenced household participation in small-scale irrigation schemes. The direction and magnitude of these effects were consistent with theoretical expectations and previous empirical findings. The age of the household head emerged as a statistically significant factor at the 1% level, with a negative relationship with irrigation participation. The marginal effect indicates that a one-year increase in age reduces the probability of participating in irrigation by 1.05%. This suggests that younger household heads are more inclined to adopt irrigation practices, possibly because of their greater physical capacity, openness to innovation, and willingness to undertake labor-intensive tasks. In contrast, older farmers, who may possess greater wealth or have established coping mechanisms, tend to be less motivated to invest in long-term improvements. This result aligns with the findings of Getaneh (2011) and Temesgen (2017), who noted that older farmers are generally more reluctant to adopt new technologies.

The education level of the household head was positively and significantly associated with irrigation participation at the 1% level. An additional year of schooling increases the likelihood of participation by approximately 3.98%, holding other variables constant. Education enhances awareness, decision-making abilities, and responsiveness to new agricultural techniques. Literate farmers are more likely to access and interpret information about irrigation technologies and are better equipped to diversify their production and income streams. This finding supports prior research by Adem (2016) and Muez (2014) who emphasized education's role in promoting irrigation adoption.

Family size, measured in adult equivalence, also had a significant positive effect on irrigation participation at the 1% level of significance. The marginal effect reveals that each additional adult equivalent increases the likelihood of participation by 5.88%. Larger households typically have greater access to labor, which is crucial for managing irrigation systems and intensifying agricultural practices. These results are consistent with those of Hadush (2014) and Sikhulumile (2013), who found that irrigating households tended to have larger labor pools than non-irrigators, reflecting the labor-intensive nature of irrigated farming.

Livestock ownership, measured in Tropical Livestock Units (TLU), was another significant factor influencing irrigation participation. A one-unit increase in TLU raises the probability of participation by 2.87%, which is statistically significant at the 1% level. Livestock can serve as a financial buffer, providing households with the necessary liquidity to invest in irrigation infrastructure and their input costs. This relationship aligns with the findings of Abonesh et al. (2006) and Hadush (2014), who reported that livestock ownership positively influenced participation in micro-irrigation schemes.

The dependency ratio, which measures the proportion of dependents to working-age members within a household, was negatively associated with irrigation participation and was significant at the 5% level. A one-unit increase in the dependency ratio decreased the likelihood of participation by 5.75%. This outcome suggests that households with more dependents may face labor and financial constraints, reducing their capacity to adopt time- and labor-intensive irrigation practices. This result corroborates previous studies by Adem (2016) and Ifa et al. (2021) who found that high dependency ratios can deter household engagement in agricultural development programs due to increased household burdens.

Cultivated land size was positively associated with participation in small-scale irrigation, with statistical significance at the 5% level. An increase of one hectare in cultivated land raised the probability of irrigation participation by 8.64%. Larger landholdings offer more opportunities for crop diversification and yield maximization via irrigation. Households with larger plots are also more likely to invest in irrigation technology to enhance productivity and reduce weather-related risks. This finding is supported by Sithole et al. (2014) and Abebaw et al. (2015), who observed that landholding size significantly influenced farmers' decisions to participate in irrigation practices.

The frequency of extension contact was also a statistically significant predictor at the 5% level. The marginal effect indicates that each additional extension visit increases the probability of irrigation participation by 1.48%. Extension services play a vital role in disseminating agricultural knowledge, building farmers’ capacity, and promoting new technologies. Households with more frequent contact with extension agents are likely to be better informed about the benefits and practicalities of irrigation, thus enhancing their likelihood of participation. This result is consistent with the findings of Adem (2016) and Sinyolo et al. (2014) who emphasized the importance of regular extension support in improving technology adoption.

In addition to the quantitative findings, qualitative evidence gathered from focus group discussions and key informant interviews provided valuable insights into the behavioral and institutional dimensions of irrigation participation. Local agricultural officers and development agents consistently noted that better-educated households, those with substantial livestock holdings, and those with sufficient family labor were more likely to engage in irrigation. These observations reinforce the econometric results by illustrating how access to assets and information facilitates household decision-making about irrigation use. Conversely, older farmers and those with higher dependency ratios were viewed as more risk-averse and less inclined to adopt new agricultural practices. Such households often prioritize subsistence strategies and are less likely to invest in long-term productivity enhancements because of their limited resources and future planning horizons.

These qualitative insights not only validate the quantitative model results but also reveal contextual factors, such as trust in extension services, social norms, and access to community support, that shape household choices in complex and dynamic ways. Overall, the integration of qualitative and quantitative evidence enhanced the robustness and relevance of the study's conclusions, offering a comprehensive understanding of the drivers of rural household participation in small-scale irrigation schemes in Arba Minch Zuria Woreda.

Table 6

Logistic estimation and Marginal effect results

Variable	**Coefficient**	**Robust Std. Err.**	**Z**	**P-value**	**Marginal effect (dy/dx)**
Agehh	-0.0447633	0.0138932	-3.22	0.001***	-0.0078146
Sexhh	-0.1524677	0.2963739	-0.51	0.607	-0.0266172
Eduhh	0.2281115	0.0359878	6.34	0.000***	0.0398228
Ae	0.3372357	0.0932242	3.62	0.000***	0.0588733
Tlu	0.1645055	0.0397476	4.14	0.000***	0.0287188
Depr	-0.3292645	0.162571	-2.03	0.043**	-0.0574818
Landsize	0.4949291	0.2061181	2.40	0.016**	0.0864029
Distws	0.0055882	0.0430289	0.13	0.897	0.0009756
Freqext	0.084934	0.042106	2.02	0.044**	0.0148275
Act	-0.0920262	0.2436694	-0.38	0.706	-0.0160656
Distmkt	0.0214199	0.0409902	0.52	0.601	0.0037394
Number of observations	379	Pseudo R2	0.2204	Prob> chi2	0.0000***
Wald chi2(11) =	67.79	Log pseudolikelihood	-198.97488		

***, ** and * represent significance at 1, 5 and 10% level respectively.

Source; Own Survey result, 2019

3.2.2. Endogenous Switching Regression (ESR) Model Results

To examine the causal effect of small-scale irrigation on household food security and account for selection bias, this study employed an Endogenous Switching Regression (ESR) model. This approach enables a comparison between the actual and counterfactual outcomes for both irrigation users and non-users. Food security was measured using the daily caloric intake per adult equivalent (AE), which reflects the access and utilization dimensions more accurately than income-based proxies.

The ESR model estimated the Average Treatment Effect on the Treated (ATT) and the Average Treatment Effect on the Untreated (ATU), as shown in Table 7. The ATT indicates the difference in caloric intake between actual irrigation users and the level they would have attained without irrigation usage. The ATU estimates the expected gain in caloric intake for non-users if they adopt irrigation. Additionally, Transitional Heterogeneity (TH), the difference between ATT and ATU, assesses whether the impact of irrigation varies between groups (Lokshin, 2011).

The results showed that irrigation users had an average intake of 3,931.21 kcal per AE, compared to an estimated 1,771.14 kcal in the absence of irrigation, yielding an ATT of 2,160.06 kcal, or approximately a 122% increase. For non-users, the estimated intake with irrigation was 2,392.59 kcal, a 126% increase over their current intake. Both ATT and ATU were statistically significant at the 1% level. The significant TH value suggests non-users would benefit even more from irrigation than current users, highlighting the value of expanding irrigation access.

These findings underscore the importance of small-scale irrigation for enhancing food access. They support Ethiopia's development priorities of food security and poverty reduction through agricultural intensification. The results align with those of previous studies by Asayehegn (2012), Deribe (2015), Issahaku (2018), Molla (2017) all of which reported strong positive impacts of irrigation on household food consumption. Similarly, Jambo et al. (2021), Khonje et al. (2015), and Tsegaw et al. (2022) emphasized the value of correcting for selection bias when assessing the impact of irrigation.

This study adds to the literature by using the ESR model in the specific context of Arba Minch Zuria Woreda and employing a calorie-based food security indicator rather than income or expenditure proxies. This localized, consumption-focused analysis provides stronger policy evidence of the benefits of irrigation in food-insecure rural areas.

In conclusion, the results confirm that small-scale irrigation significantly improves dietary energy intake and plays a vital role in reducing food insecurity. The combination of rigorous econometric methods with localized data offers actionable insights for scaling up irrigation as part of broader rural development strategies in Southern Ethiopia.

Table 7

Average treatment effect of household total daily calorie intake per adult equivalent after endogenous switching regression

Outcome Variable	Categories	Decision stage		Treatment effects
		Irrigation user	Irrigation nonuser	
Daily calorie intake per adult equivalent	ATT	(a1) 3931.207	(c1) 1771.144	2160.063 ***
	ATU	(d1) 4287.751	(b1) 1895.166	2392.585***
	HE	-356.544	-124.022	-232.522***

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Sources: Own survey results, 2019

4. CONCLUSIONS AND RECOMMENDATIONS

This study examined the impact of small-scale irrigation on rural household food security in Arba Minch Zuria Woreda, Southern Ethiopia, using a combination of descriptive and econometric methods. Two core indicators, daily caloric intake per adult equivalent and the Foster–Greer–Thorbecke (FGT) index, were applied to assess the extent and depth of food insecurity among the sampled households. The findings revealed that 51.45% of households were food insecure, with a food gap of 15.2% and severity index of 6.56%. Although the average caloric intake per adult equivalent stood at 2,711.73 kcal, this aggregate figure conceals considerable disparities between irrigation users and non-users.

The binary logit model identified the key factors influencing irrigation participation. Education level, adult equivalency, and livestock holdings were positively associated with participation, whereas older age and higher dependency ratios had a negative effect. These results underscore the importance of household-level human and physical capital in adopting irrigation practices. Furthermore, the Endogenous Switching Regression (ESR) model confirmed the significant positive impact of small-scale irrigation on food security outcomes. Households using irrigation consumed, on average, 2,160.06 kilocalories more per adult equivalent per day than they would have without irrigation, equating to a 121.95% improvement. This evidence affirms that irrigation not only boosts food availability but also enhances household resilience to food insecurity.

Based on these findings, urgent and coordinated action is required from both local and national stakeholders. Local government bodies and agricultural offices should prioritize scaling up small-scale irrigation in food-insecure and non-irrigated kebeles. This requires investment in irrigation infrastructure, farmer training, and the development of equitable access strategies, especially for marginalized groups such as elderly and female-headed households. Regional irrigation authorities and the Ministry of Agriculture should support these efforts through policy frameworks that promote inclusive irrigation. Development partners and NGOs can play complementary roles by facilitating access to agricultural inputs and promoting community-level innovations. Strengthening agricultural extension services at the woreda level is also critical to ensure sustained farmer engagement and knowledge dissemination in the region. Without integrated, multi-level interventions, efforts to achieve national food security targets and Sustainable Development Goal 2 (Zero Hunger) will remain insufficient, particularly in vulnerable rural areas such as Arba Minch Zuria.

REFERENCES

Abadi, A., Duka, T. A., & Mamo, M. M. (2021). Factors Affecting Rural Households' Participation in Small-Scale Irrigation Scheme: The case of Arba Minch Zuria Woreda, Southern Ethiopia. *Ethiopian Journal of Business and Social Sciences*, *4*(2), 1-18.

Abdi, E., & Teshome, G. (2015). *The Impact of Boset-Fentalle Irrigation on the Income of Agro Pastoralist in Fentalle District of Oromia National Regional State, Ethiopia* (Doctoral dissertation, Haramaya University).

Abdi, M., & Teshome, A. (2015). The impact of small-scale irrigation on household income: The case of Kersa district, eastern Oromia, Ethiopia. *Journal of Economics and Sustainable Development*, *6*(21), 105–110.

Abdissa, F., Tesema, G., & Yirga, C. (2017). Impact analysis of small-scale irrigation schemes on household food security the case of Sibu Sire District in Western Oromia, Ethiopia. *Irrigat Drainage Sys Eng*, *6*(187), 2.

Abiyu, A., Tebeje, M., & Mekonnen, E. (2015). Determinants of small-scale irrigation utilization by smallholder farmers in rift valley basin, Wolaita zone, Ethiopia. *Journal of Natural Sciences Research*, *5*(21), 2224-3186.

African Union. (2023). *Africa regional overview of food security and nutrition*. African Union Commission and FAO.

Alemu, T. (2017). The contribution of small-scale irrigation to household food security in Ethiopia. *African Journal of Agricultural Research*, *12*(23), 1990–1998.

Amare, M., Asfaw, S., & Shiferaw, B. (2012). Welfare impacts of maize–pigeonpea intensification in Tanzania. *Agricultural Economics*, *43*(1), 27-43.

Asayehegn, K. (2012). Irrigation versus rain-fed agriculture: Driving for households' income disparity, a study from Central Tigray, Ethiopia. *Agricultural Science Research Journal*, *2*(1), 20-29.

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food policy*, *37*(3), 283-295.

Assefa, E., Ayalew, Z., & Mohammed, H. (2022). Impact of small-scale irrigation schemes on farmers livelihood, the case of Mekdela Woreda, North-East Ethiopia. *Cogent Economics & Finance*, *10*(1), 2041259.

Bagson, E., & Kuuder, C. J. W. (2013). Assessment of a smallscale irrigation scheme on household food security and leisure in Kokoligu; Ghana.

Becerril, J., & Abdulai, A. (2010). The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. *World development*, *38*(7), 1024-1035.

Belay, S., & Beyene, F. (2013). Small-scale irrigation and household income linkage: Evidence from Deder district, Ethiopia. *Afr J Agric Res*, *8*(34), 4441-4451.

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons.

CSA. (2021). *Agricultural sample survey: Report on area and production of major crops (Private peasant holdings, Meher season)*. Central Statistical Agency of Ethiopia.

CSA (Ethiopia Central Statistical Agency) & WFP (World Food Program). (2014). *Comprehensive food security and vulnerability analysis (CFSVA).*

Deribie, M. (2015). *Impact of Akaki small-scale irrigation scheme on household food security* (Doctoral dissertation, St. Mary's University).

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro- perspective from Ethiopia. *American journal of agricultural economics*, *93*(3), 829-846.

FAO. (2008). *An introduction to the basic concepts of food security*. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/al936e/al936e.pdf

FAO. (2023). *The state of food security and nutrition in the world 2023*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cc3017en

Faltermeier, L., & Abdulai, A. (2009). The impact of water conservation and intensification technologies: empirical evidence for rice farmers in Ghana. *Agricultural Economics*, *40*(3), 365-379.

FDRE, M. (2014). Growth and Transformation Plan: Annual Progress Report for FY 2012/13. *Addis Ababa, Ethiopia*.

Gujarati, D. (2004). Basic Econometrics. (4th ed.) The McGraw− Hill Companies. *Search In*.

Hadush, H. (2014). *Adoption and impact of micro irrigation on household income: the case of Eastern Tigray* (Doctoral dissertation, The Institute of Development Studies and Partner Organizations).

Haji, J., Aman, M., & Hailu, T. (2013). Impact analysis of Mede Telila small scale irrigation scheme on house poverty alleviation: Case of Gorogutu district in eastern Haratghe Oromia national regional state Ethiopia. *International Journal of Development and Economic Sustainability*, *1*(1), 15-30.

Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression*. John Wiley & Sons.

Issahaku, E. I. (2018). *Impacts of small-scale irrigation on food security and rural livelihoods empowerment in lawra municipality* (Doctoral dissertation).

Jambo, Y., Alemu, A., & Tasew, W. (2021). Impact of small-scale irrigation on household food security: evidence from Ethiopia. *Agriculture & Food Security*, *10*(1), 21.

Jema, H., Beyene, F., & Abdi, M. (2013). Impact of small-scale irrigation on household poverty: Empirical evidence from eastern Ethiopia. *International Journal of Economics and Finance*, *5*(1), 1–10.

Kalkidan, F., & Tewodros, M. (2017). Review on the role of small-scale irrigation agriculture on poverty alleviation in Ethiopia. *North Asian International Research Journal of Multidisciplinary*, *3*(6), 1-18.

Karale, K. (2015). *Household food security status and its determinants in rural Konso Woreda, Segen Area Peoples' Zone, Southern Ethiopia* (Doctoral dissertation, MSc Thesis, College of Agriculture, Hawassa University).

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. *World development*, *66*, 695-706.

Lokshin, M., & Sajaia, Z. (2011). Impact of interventions on discrete outcomes: Maximum likelihood estimation of the binary choice models with binary endogenous regressors. *The Stata Journal*, *11*(3), 368-385.

Long, J. S., & Freese, J. (2006). *Regression models for categorical dependent variables using Stata* (Vol. 7). Stata press.

Ministry of Agriculture (MoA). (2022). *National food and nutrition strategy (2022–2030).* Ministry of Agriculture, Ethiopia.

Ministry of Finance and Economic Development (MoFED). (2010). *Growth and transformation plan (GTP) 2010/11–2014/15*.

Molla, A. (2017). Impact of small-scale irrigation on farm households' food security: The case of Girana irrigation scheme in Kobo district, North Wollo zone of Amhara region, Ethiopia (Doctoral dissertation, Haromaya University).

Muez, H. A. (2014). *The impact of small-scale irrigation on rural household food security: the case of Emba Alaje woreda* (Doctoral dissertation, The Institute of Development Studies and Partner Organizations).

Pettitt, A. N. (1989). One degree of freedom for non-additivity: Applications with generalized linear models and link functions. *Biometrics*, 1153-1162.

Pregibon, D. (1979). Data Analytic Methods for Generalized Linear Models PhD thesis University of Toronto.

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food policy*, *44*, 272-284.

Sinyolo, S., Mudhara, M., & Wale, E. (2014). The impact of smallholder irrigation on household welfare: The case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa. *Water SA*, *40*(1), 145–156. https://doi.org/10.4314/wsa.v40i1.17

Sisay, D., & Fekadu, B. (2013). The impact of small-scale irrigation on household income: The case of Gomma Woreda, Jimma Zone. *Ethiopian Journal of Economics*, *22*(2), 55–78.

Sithole, N. L., Lagat, J. K., & Masuku, M. B. (2014). Factors influencing farmers participation in smallholder irrigation schemes: The case of ntfonjeni rural development area. *Journal of Economics and Sustainable Development*, *5*(22), 157-167.

Tesfaye, A., Bogale, A., Namara, R. E., & Bacha, D. (2008). The impact of small-scale irrigation on household food security: The case of Filtino and Godino irrigation schemes in Ethiopia. *Irrigation and Drainage Systems*, *22*(2), 145-158.

Tsegaw, C., Tesfaye, E., & Bizuayehu, S. (2022). Adoption of Improved Soybean Varieties and their Impact on Households' Food Security: The Case of Pawe Woreda, Western Ethiopia. *Ethiopian Economics Association (EEA)*, 219.

USAID (United States Agency for International Development). (2018). *Crop availability and market study in Ethiopia*.

Woreda Agriculture and Rural Development Office (WARDO). (2015). *Annual agricultural report* (Unpublished internal document).

World Bank. (2024). *Ethiopia economic update: Harnessing digital technologies for inclusive growth*. World Bank Group. https://www.worldbank.org/en/country/ethiopia/publication

Zemarku, Z., Abrham, M., Bojago, E., & Dado, T. B. (2022). Determinants of Small- Scale Irrigation Use for Poverty Reduction: The Case of Offa Woreda, Wolaita Zone, Southern Ethiopia. *Advances in Agriculture*, *2022*(1), 4049868.