The effect of small-scale irrigation on household food security of Kindo Didaye District, Wolaita Zone, Southern Ethiopia

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Abstract

This study aimed to assess the effect of small-scale irrigation on household food security in the Kindo Didaye district. Community-based comparative cross-sectional survey was conducted at Kindo Didaye district, Wolaita zone from September 1st to 30, 2020. Data were collected by using structured questionnaires from 160 irrigation users and 163 non-users. Binary logistic regression analyses were fitted to identify factors associated with household food security. The prevalence of household food security was (87.5% Vs 66.8%, p = < 0.001) for irrigation users and irrigation nonusers, respectively. Family labor, TLU, cultivated land size, training, access to irrigation, and participation in Off-farm activities were positively associated with household food security. While the age of household head and dependency ratio negatively affected household food security.

Background

Food insecurity is the most critical public health problem in developing countries. Around the world, 690 million, or 8.9 % of the world population were unable to meet their dietary energy requirements (1). Meanwhile, there were 15.4 million people are suffering from severe food-insecure in Ethiopia (1).

Irrigation is the supply of water to crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions and even in areas where total seasonal rainfall is adequate on average; it may be poorly distributed during the year and varies from year to year (2). Irrigation is the ministering of land through the artificial application of water to ensure double cropping as well as a steady supply of water in areas where rainfall is unreliable (3). Despite, the availability of a sufficient amount of surface water and groundwater the agricultural production in Ethiopia depends mainly on precipitation(4).

There are a lot of challenges impeding the success of irrigation development are; lack of access to inputs and financing, inadequate farming skills, lack of resources for maintenance of irrigation structures, and resistance to the adoption of new technologies/crops by traditional cereal farmers, combined with Ethiopian farmers extreme risk aversion (5, 6).

Small-scale irrigation practices are a comprehensive solution to complex problems for farmers concerning soil, crops, livestock, water, nutrients, and the market (7). Henceforth, expanding small-scale irrigation schemes is one of the main intervention areas for boosting agricultural production in rural areas of the country. Even though some efforts have been underway to develop small-scale irrigation schemes; yet, Ethiopia has developed only 5% of the irrigable land (8). Furthermore, it is noted that the existing irrigation farms are operating at sub-optimal levels and many of the small-scale irrigation projects have been operating below the required economic efficiency (9, 10). Several studies have documented poverty-related benefits and costs of irrigation. Most of them indicated irrigation can increase production and productivity (11). Inversely, low access to new agricultural technologies, traditional methods of
cultivation, and low institutional support are identified as factors that keep smallholder production at subsistence level in the country (12).

Consequently, this has made the country’s agricultural-based economy extremely fragile and vulnerable to the impacts of climate variability that often leads to partial or failure of the entire harvest and subsequent food shortages and famines. The government of Ethiopia has been recently introduced and begun the implementation of policies to minimize risk through full or supplementary irrigation (13). Although the establishment of the small-scale irrigation system in the Kindo Didaye district aimed to improve the social and economic well-being of the population. But there are challenges in analyzing social or Hydrometeorological data.

Accordingly, the assessment of the role of small-scale irrigation is critical. Data are scarce on the impact of small-scale irrigation on household food security in the study area. Thus, this study aimed to assess the effect of small-scale irrigation on household food security and determinants of household food security in the Kindo Didaye District.

**Methods**

**Descriptions of the Study Area**

The Kindo Didaye District is found in Wolaita Zone, Southern Nation Nationalities, and Peoples Regional State. It is located 450 km far from Addis Ababa, the capital city of Ethiopia. There are three agro-climatic zones in the study area which are kolla (58%), Woyina Dega (37%), and Dega (5%) (Extracted from DEM, SRTM by Author, 2020) (). The annual range of temperature varies from 12.4 °C to 31.3°C. The area is characterized by a unimodal rainfall pattern. The study District has a total area of 347 sq. Km. As per CSA data of the 2007 census, the district has an estimated total population of 131582. Of these, 56,581 are male and 75,001 are female (14). The total number of households in the study area is 37,152. The district comprises 16 Kebele administrations. Only 2% of the population lived in urban areas.

Fig 1: Location map of the study area (Extracted from CSA, 2007 by the Author, 2020)

**Study Design and period**

Community based comparative cross-sectional study was conducted in the kindo didaye district from September 1st to 30th, 2020.

**Sampling size and sampling Procedure**

The sample size of households for the study was identified by using the simplified formula provided by (15), statistically estimated at 95% confidence level, the degree of variability = 0.05.
Whereas;

\[ n = \frac{N}{1 + N(e)^2} \]

Whereas;

\[ n = \frac{1.688}{1 + 1.688(0.05)^2} = 323 \]

Where \( n \) is the sample size, \( N \) is the population size (total household size), and \( e \) is the level of precision.

A two-stage stage sampling procedure was followed to select the respondent household for the study. In the first stage, three kebeles were selected randomly from those kebeles which have small-scale irrigation access. In the second stage, in the three selected sample Kebeles, households were ratified into two strata, 160 irrigation users and 163 non-users, from which sampled households were randomly selected. The calculated sample size was proportionally allocated for each Kebeles.

**Data Types and Sources**

Both primary and secondary data sources were used. The data were collected by administering pre-tested structured questionnaires. The questionnaires were designed and pre-tested before starting the actual data collection. The data collection tool includes socio-demographic, socio-economic characteristics, institutional aspect, food security status, in both groups of the households, the household characteristics (age, educational level, and farming experience), and total land size.

**Data Collection Techniques**

A structured questionnaire was developed from the literature to include all necessary information to the objectives of the study. The household survey included personal information, household resources, production and income issues related to irrigation practice, and food security. The questionnaire was prepared in English and later translated into the local language (Wolaytegna) so that the respondents can easily understand the questions. Three enumerators, one for each kebele, were employed based on their ability of local language and culture, and experiences in data collection. The one-day training was provided to the enumerators on the procedure to follow while interviewing respondents and deep discussion was also held to make the questionnaire clear. Supervision was made by the investigator in addition to any data collected during the detailed questionnaire survey administration process.

**Data Analysis**
Data were entered to EpiData version 3.1 and exported to Stata version 14 software for analysis. Descriptive statistics including proportions, frequency, charts, mean, and standard deviation was employed to describe the quantitative data. As inferential statistics, chi-square was used to identify the associations between categorical variables, and an independent t-test was also used to compare mean differences. Logistic regression was fitted to identify factors associated with food security. The goodness-of-fit of the final model was checked Hosmer-Lemeshow (p-value =0.820) it was met the assumption of logistic regression. An adjusted odds ratio with their 95% confidence intervals (CI) was calculated and the statistical significance was accepted at the 5% level of significance (p < 0.05).

**Study variables**

**Dependent variable**

Household food insecurity was measured by a modified form of a simple equation termed as Household Food Balance Model. The dependent variable was coded as the following: Household food security status (0= food insecure, 1= food secure). A modified form of a simple equation termed as Household Food Balance Model was used to measure the sample household food security.

**Independent variables**

Household Size; Sex of Household Head; Educational Level of Household Head; Age of Household Head in years; dependency ratio; Irrigation use; Access to the extension service (household head received training regularly during the last 1 year); Livestock owners; cultivated land size; Distance to the market; Credit used by the household; Involvement of the household members in off-frame activity and developmental agent contact

**Measurements of variables**

A modified form of a simple equation termed as Household Food Balance Model, originally adapted by (16) from the FAO Regional Food Balance Model and thenceforth used by different researchers in this field (17) was used to calculate the per capita food available which is

\[ NGA = GP + GB + FA + GG - (HL + GU + GS + GV) \]

Where,

NGA= Net grain available/year/household

GP= Total grain produced/year/household

GB= Total grain bought/year/household
FA= Quantity of food aid obtained/year/household
GG= Total grain obtained through gift or remittance/year/household
HL= post-harvest losses/year
GU=Quantity of grain reserved for seed/year/household
GS=Amount of grain sold/year/household
GV=Grain given to others within a year (17).

The net grain available by sample households’ calorie content was computed using the calorie conversion table (18). Household members were also converted to their adult equivalent. Then, the amounts of total calories available by each sample household were computed and divided by 365 days to get per day calorie available for the household. This figure was divided into the Adult Equivalent (AE) of respective households, which finally was given the number of calories available per AE for each sampled household. Hence, households whose caloric consumption is greater than or equal to 2100 kcal/day/AEU were categorized as food security. While households whose caloric consumption is less than 2100 kcal/day/AEU were categorized as food insecure (19). To quantify the livestock numbers of various species as a single figure that expresses the total amount of livestock present, the Tropical Livestock Unit (TLU) was used. The Tropical Livestock Unit is a common unit used to describe livestock numbers of various species as a single figure that expresses the total amount of livestock present irrespective of the specific composition. A tropical livestock unit (TLU) is equivalent to 250 kilograms of live weight and refers to the total livestock ownership of the household head. Each livestock of a household was changed to its equivalent TLU using conversion factors (1 cattle = 1 TLU; 1 goat = 0.15 TLU; 1 horse = 1 TLU; 1 mule = 1.15 TLU; 1 donkey = 0.65 TLU; and 1 poultry = 0.005 TLU) (20)

Ethical consideration

Ethical clearance was obtained from Hawassa University, college of agriculture, and submitted to the agriculture office and the Administrative of Kindo didaye district for their permission and support. Then, permission was obtained from each kebele administration office. Respondents were fully informed about the purpose of the study and gave verbal consent. Confidentiality of the information was assured by all the data collectors and investigators.

Results And Discussion

Socio-demographic characteristics

A total of 323 household heads participated in the study, which yields a 100% response rate. The vast majority of a household is headed by males (94.4%). It was determined that nearly half of the
respondents, 156 (48.3%) were in the age group of 41–55 years and the little number, 2 (0.62%) were in age 18–25 years. The mean age of participants was (43.6 ± 9.1) and the minimum age was 24 years with a range of 70 years (24, 70). Regarding education status approximately a third (29.1%) of the participant were illiterate. The mean household size of the sample population was 5.02 ± 1.59. Out of the total population, 361 were children below the age of 15 years and age group of greater than 64 years, 959 were within the age group of 15–64. The dependency ratio was 37.6 percent, which indicates that for 100 persons in the productive age group there were about 38 dependents (Table 1)

| Variables                | Category          | Frequency | Percent |
|--------------------------|-------------------|-----------|---------|
| Sex                      | Female            | 18        | 5.6     |
|                          | Male              | 305       | 94.4    |
| Age in years             | 18–25             | 2         | 0.62    |
|                          | 26–40             | 137       | 42.41   |
|                          | 41–55             | 156       | 48.3    |
|                          | > 55              | 28        | 8.67    |
| Mean age                 | 43.6 ± 9.1        |           |         |
| Educational status       | Illiterate        | 90        | 29.1    |
|                          | Read and write    | 20        | 6.19    |
|                          | 1–4 grade         | 74        | 22.91   |
|                          | 5–8 grade         | 86        | 26.63   |
|                          | 9–12 grade        | 38        | 11.76   |
|                          | College and above | 11        | 3.41    |
| Family size              | < 7               | 284       | 87.9    |
|                          | >= 7              | 39        | 12.1    |
| Mean dependency ratio    | 37.6 ± 2.5        |           |         |

**Table 1**
Socio-demographic characteristics of households in Kindo didaye district, Southern Ethiopia, 2021.

**Household economic indicators**

A quarter of the household has a farmland size of 0.6–1.5 hectares. The mean cultivated landholding size for food secure and insecure households was 0.77 and 0.53 ha with a standard deviation of 0.68 and 0.38 ha (p = 0.0025), respectively. More than half (55.4%) of households possessed less than 2.5 TLU. The mean livestock holding for food secure and insecure households was 2.67 and 1.87 in TLU (p =
0.0003), respectively. Also, the mean distance from a food-secure household’s residence to the main market was 3.31 km and it was 3.22 km for insecure households showing no statistically significant difference between the two groups (p = 0.604). About half (49.54%) of households had access to irrigation and over a third of households had off-farm income from various other employment activities. Regarding access credit, 31.1% of farmers have reported that they have got credit access and 31.3 percent were not used farm inputs (Table 2).
Table 2
Household economic characteristics and access to agricultural extension services

| Variables                        | Category | Frequency | Percent |
|----------------------------------|----------|-----------|---------|
| Land ownership                   | < 0.26   | 69        | 21.36   |
|                                  | 0.26–0.5 | 131       | 40.56   |
|                                  | 0.6–1.5  | 79        | 24.46   |
|                                  | 1.51-2   | 25        | 7.74    |
|                                  | 2+       | 19        | 5.88    |
| Access to irrigation             | user     | 160       | 49.54   |
|                                  | Nonusers | 163       | 50.46   |
| TLU                              | < 2.5    | 179       | 55.4    |
|                                  | ≥ 2.5    | 144       | 44.6    |
| Off-farm activities              | Yes      | 116       | 35.9    |
|                                  | No       | 207       | 64.1    |
| Access to credit                 | Yes      | 103       | 31.1    |
|                                  | No       | 220       | 68.9    |
| Training                         | Yes      | 148       | 45.82   |
|                                  | No       | 175       | 54.18   |
| Extension services               | Yes      | 257       | 79.6    |
|                                  | No       | 66        | 20.4    |
| Farm inputs                      | Yes      | 222       | 68.7    |
|                                  | No       | 101       | 31.3    |
| Anyone sick in your family       | Yes      | 43        | 13.3    |
|                                  | No       | 280       | 86.7    |
| Distance to the market           | < 3.5    | 225       | 69.7    |
|                                  | ≥ 3.5    | 98        | 30.3    |

Household food security status

The prevalence household food security was 87.5% (95% CI: 82.3%, 9.26%) and 66.8%(95%CI; 59.6%, 74%) for irrigation users and nonusers, respectively. The overall prevalence of food security was to be found at 77% (95%CI; 72%, 81%) (Fig. 2).
Factors associated with households’ food security

The logit model was employed to estimate the effects of the hypostasized independent variables on the food security status of households. Eight significant variables were identified out of the hypothesized fourteen variables by estimating a logit model. Family labor, TLU, cultivated land size, training, access to irrigation, and participation in nonfarm activities significantly and positively affected household food security. Whereas the age of household head and dependency ratio significantly and negatively affected household food security.

Age of household head was significantly and negatively associated with household food security at a p-value of 0.001. The negative relationship implies that older age household heads have less chance to be food secured than younger ones. This finding is similar to other studies (21, 22), this is possible because older household heads were less productive and they lead their life by remittance and gifts. They could not participate in other income-generating activities. On the other hand, older households have a large number of families and their resources were distributed among their members. This implies that, with the increase in the age of the respondents by one year the likely probability of becoming food secure decreased by 7.4%, holding other variables of the model constant.

Household size per adult equivalent was significantly and positively associated with food security at p-value< 0.016. This indicates that as the household size increases by one adult equivalent the household food security status increased by 37%. This is consistent with other studies (23–25), family size in adult equivalents indicates the sample household’s average family labor force for agricultural production and other income-generating activities. This is consistent with other studies (23, 24), family size in adult equivalents indicates the sample household’s average family labor force for agricultural production and other income-generating activities.

Households with a large labor force were food secure more than households with a small labor force. Large household family size in adult equivalent means a larger amount of labor available to the household. Since households with higher family labor can perform various agricultural activities without labor shortage. Inversely, in other studies households having a larger family size were more likely food insecure (21, 26, 27). Large family size tends to exert more pressure on food consumption than the labor it contributes to production.

Access to irrigation is positively and significantly associated with household food security at a significance level of 5%. Irrigation user households were by factors 2.03 times more likely to be food secure compared to irrigation non-users, holding other variables constant. This is in agreement with (24, 28, 29), irrigation enables households to grow food crops more than once a year, hence increased the production, income, and food availability of the household. Thus, it overcomes food insufficiency in dry or food shortage circumstances and normal seasons.
At a significance level of 5%, TLU is positively associated with household food security. After controlling for other variables, the odds of food security increased by 27% as the household TLU increased by one unit. This finding is comparable with (30–32), livestock possession positively affects food security. According to this study, lacking livestock is one of the fundamental determinants of food insecurity in the study area (30, 31), livestock possession positively affects food security. According to this study, lacking livestock is one of the fundamental determinants of food insecurity in the study area.

Table 3
Logistic regression model for household food security at Kindo Didaye district Wolaita zone, southern Ethiopia, 2020

| Variables  | Odds Ratio | Std. Err. | z    | P > z   | [95% Conf. Interval] |
|-----------|------------|-----------|------|---------|---------------------|
| ACCIRRG   | 2.039066   | .733443   | 1.98 | 0.048   | 1.00753             |
|           |            |           |      |         | 4.126717            |
| HEADAGE   | .9260577   | .0181317  | -3.92| 0.000   | .8911934            |
|           |            |           |      |         | .9622859            |
| SEXHEAD   | 1.088334   | .7074026  | 0.13 | 0.896   | .3044333            |
|           |            |           |      |         | 3.890737            |
| EDUCATA   | 1.149927   | .1245695  | 1.29 | 0.197   | .9299534            |
|           |            |           |      |         | 1.421934            |
| HHSIZEAE  | 1.374566   | .1812517  | 2.41 | 0.016   | 1.061513            |
|           |            |           |      |         | 1.779942            |
| CULTLAND  | 1.950365   | .6047963  | 2.15 | 0.031   | 1.062095            |
|           |            |           |      |         | 3.581528            |
| DISMARKE  | 1.06746    | .1368309  | 0.51 | 0.611   | .8303121            |
|           |            |           |      |         | 1.37234             |
| TLU       | 1.275366   | .1255423  | 2.47 | 0.013   | 1.051588            |
|           |            |           |      |         | 1.546763            |
| ACREDIT   | 1.248737   | .437996   | 0.63 | 0.527   | .6279295            |
|           |            |           |      |         | 2.48331             |
| TRASER    | 2.158841   | .746767   | 2.22 | 0.026   | 1.095925            |
|           |            |           |      |         | 4.25266             |
| DA_contact| 1.028578   | .127311   | 0.23 | 0.820   | .8070137            |
|           |            |           |      |         | 1.310973            |
| NONFARM   | 2.697897   | 1.098873  | 2.44 | 0.015   | 1.214297            |
|           |            |           |      |         | 5.994125            |
| DEPRATIO  | .40445     | .1403242  | -2.61| 0.009   | .204899             |
|           |            |           |      |         | .7983436            |

DA = frequency of developmental agent contacts

A significance level of 5% dependency ratio negatively affected household food security. The negative relation of dependency ratio of the household indicates that keeping other variables constant, the odds ratio in favor of food security decreases by 60% as the dependence ratio of household increase by one person. This result is similar to other studies (24, 33, 34), if the households have more dependent labor forces, they have less chance to have food security than the households who have economically inactive (≤ 15 and ≥ 65 years). In a household productive age groups are higher than the nonproductive age groups, the probability of the household being food secure would be high.

Cultivated land size owned by households positively associated household food security at a significant level of 5%. The land size of households increased by 1 hectare, the probability of food security was
increased by a factor of 1.95, other variables in the model were kept constant. This finding is similar to other studies (7, 32, 35), this could be land size owned is a proxy to wealth status, and households with large land size were expected to have diversified the quantity and type of crop produced, which may, in turn, lead to increased consumption and household food security.

Participation in nonfarm activities positively affected household food security at a significance level of 5%. This indicates that households who participate in the nonfarm activities were 2.69 times more likely to be food secured compared to non-participating households. This finding is consistent with (7, 23, 36). Since the money that they earn from nonfarm activity would increase the household’s liquidity to make on-farm investments or increase its income to purchase food and, thereby, improve household food security.

The head households who had received training were 2.1 times more likely food secured than those who had not received training. This is in agreement with (23, 30), agricultural extension-focused training regularly is believed to have better skill and knowledge on irrigation practices which encourages them to participate in it. Irrigation needs continuous training because there is continuous production by using irrigation, which needs more regular training than rain-fed agriculture.

Conclusion

About four in five households’ food security. Factors likes: family labor, cultivated land size, access to irrigation, training, TLU, and non-farm activity were positively associated with household food security. While the age of household head and dependency ratio were negatively associated with household food security. Therefore, the government should give attention during planning development strategies of food security through scaleup small-scale irrigation of agricultural production to households in poverty reduction and to improve their food security. Furthermore, the farmers should be supported in the provision of modern agricultural technologies and inputs focusing to increase production status on their piece of cultivated land to be able to get more yields per unit area.

Declarations

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Authors’ contributions

All authors have made substantial intellectual contributions to the conception and design of the study, and the acquisition, analysis, and interpretation of data. They have also been involved in drafting the manuscript, approved the final manuscript, and agreed to be accountable for all aspects of this work.
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Abbreviations

Kcal
Kilocalorie
Km
Kilometer
AEU
Adult equivalent unit
TLU
Tropical Livestock unit, MoARD: Ministry of Agriculture and Rural Development
ETB
Ethiopian Birr
FAO
Food and Agricultural Organization
WHO
World Health Organization
UN
United Nations
CSA
Central Statistical Agency
HHs
Households.

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Figures

Figure 1

Location map of the study area (Extracted from CSA, 2007 by the Author, 2020)
Figure 2

Household food security status at kindo didaye district, Wolaita zone, southern Ethiopia 2021