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# Small Scale Irrigation and its Determinant Factors in Central Ethiopia: Empirical Evidences from Walmara District

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**Abstract:** *Small-scale irrigation is the feasible way by which agricultural production and productivity can be enhanced to meet the ever-growing food demand of populated countries like Ethiopia. This study was conducted to assess factors affecting farm households' participation decision in small-scale irrigation using the primary data collected from 220 sample households from Walmara district, central Ethiopia. Both descriptive and econometric data analyses were conducted to analyze the collected data. The logistic regression result revealed that the sex of the household head, size of land owned, the occurrence of crop pests during the main season, family size, and access to credit services were the variables that positively and significantly affected household participation decision in small scale irrigation, while age of the household head, number of livestock owned and distance from irrigation site were the variables that negatively and significantly affected households' participation decision in small-scale irrigation. Therefore, agricultural policy interventions that promoting the establishment of institutions that providing financial, material and technical supports to farmers are recommended.*

**Keywords:** *Determinant factors, Participation in irrigation, Logit, Walmara, Ethiopia*

## 1. INTRODUCTION

The Ethiopian economy is mainly dependent on agriculture and the sector is mainly characterized by its traditional, subsistent, and rainfed farming system, which is highly vulnerable to the adverse effects of climate variability and erratic rainfall patterns. Although remarkable efforts are being made to transform the sector from traditional, subsistent, and rain-fed to modern, technology-intensive, mechanized, irrigated, and market-oriented with full packages of post-harvest technologies, the sector is yet unable to sustain the food demands of the ever-growing population of the country.

Ethiopia is one of the poorest countries in the world, ranked 173$^{rd}$ out of 189 nations. According to UNDP (2018a), more than 22 million people were below the national poverty line during 2017. Recurrent drought, lower average land holding, higher average family size per household and low soil fertility are among the factors contributing to poverty and food insecurity status in the country. The average land holding of the country is 0.9 hectare (FAO and IFC, 2015), the average family size per household for the country is 5 persons and the average cereal productivity is 2.45 tons per hectare (CSA, 2017).

In such cases, small scale irrigation is recommended by different scholars for its contributions in increasing agricultural production and productivity, improving household income, and improving the livelihood of farm households (Tulu, 2014; Hirko et al. 2018). The research conducted by Asayehegn (2012) also proved the contribution of small-scale irrigation in improving household food security status, poverty reduction, diversification of crops grown, source of a balanced diet, improved health status, employment creation, easier access to medications, good sources of feeds for animals and good sources of asset possession. Moreover, irrigation is reported to improved food security, dietary diversity, and livelihood under climate variability and increasing population growth (Passarelli et al., 2018; Domenech, 2015; Lefore et al., 2019; Muleta et al., 2021) and it has the potential of increasing agricultural yields by more than 50%, in which the majority of increased income helping smallholder farmers (Xie et al., 2014).

Ethiopia has immense water resource that can be used to irrigate millions of hectares of land and contribute to take lives of millions out of poverty and food insecurity. According to Ayalew (2018), the water potential of the country from major rivers, lakes and groundwater is estimated to be more than 239.19 billion cubic meters, out of which 124.4 billion cubic meters from rivers, 84.79 billion cubic meters from lakes, and 30 billion cubic meters from groundwater. This water alone has the potential of irrigating about 3,800,733 hectares of land. In contrary to the potential of the country, the level of irrigation utilization is by far below the potential and almost all (97percent) of cereal production in the country is under rainfed system because of technical, physical and economic challenges (FAO and IFC, 2015).

Similarly, Walmara district has a high potential of irrigable land and irrigation water. The irrigable land potential of the district is estimated to be more than 9,055 hectares. According to the information from the district, about 7,580 hectares were cultivated under different types of irrigation. Out of the total irrigated land in the district, 828 hectares were cultivated using modern irrigation, 4,890 hectares were cultivated using traditional furrow irrigation, 1,788 hectares were cultivated using motor pump irrigation, and 74 hectares were cultivated using wells, and all the types of irrigation are serving more than 2,163 households living in the district. There are different streams and rivers serving for irrigation purposes in the district. Holeta river is the main that is being raised in the long irrigation history of the district in both traditional and modern irrigation.

Therefore, understanding factors affecting household decision to participate in small-scale irrigation and its implication on household food security status is critically important. So, this study was designed with the objective to give valuable information for better policy intervention.

## 2. RESEARCH METHODOLOGY

### 2.1. Description of the Study Area

The study was conducted in Walmara district, central Ethiopia. The district is found at 34 kilometres to the west of Addis Ababa and lies between 8°50'-9°15' N and 38°25'-38°45' E. The area of the district is 65,605 hectares, out of which 61 percent classified as highland and 39 percent as mid-highland. The altitude of the district is between 2060 and 3380 meters, and the mean is 2400 meters. The annual rain of the district ranges from 795 to 1300 millimetres, with a mean of 144 millimetres. Moreover, the annual temperature of the district ranges from 6 ºc to 24ºc, and the mean is 14 ºc. According to CSA (2019), the population projection of Walmara district was 112,498 (56,200 male and 56,298 feminine).

### 2.2. Description of irrigation schemes in the district

Walmara district is among the surplus producing, and the districts with high irrigation potential of the Oromia region and selected to be one of the agricultural growths and transformation program two (AGP II) districts. Therefore, the construction of modern irrigation schemes in different peasant associations of the district is being undertaken by this program as presented in the following Table.

**Table1.** *Modern small-scale irrigation schemes in Walmara district*

| Peasant Associations | Irrigation potential (ha) | Construction year (E.C) | Programs constructing | Number of Beneficiaries | | |
|---|---|---|---|---|---|---|
| | | | | Male | Female | Total |
| Barfata Tokkoffaa | 65 | 2008 | AGP II | 125 | 27 | 152 |
| Talacoo | 94 | 2005 | AGP I | 75 | 23 | 98 |
| Duufaa | 30 | 2007 | AGP II | 339 | 68 | 407 |
| Bakakkaa & Q/oddoo | 65 | 2004 | AGP I | 107 | 14 | 121 |
| Markos | 106 | 2005&2011 | AGP I & II | 352 | 106 | 458 |
| Walmara Cooqee | 30 | 2007 | AGP II | 103 | 29 | 132 |
| Barfata Lammaffaa | 130 | 2011 | AGP II | 297 | 95 | 392 |
| Dhohaa & Laaftoo | 158 | 2011 | AGP II | 120 | 33 | 153 |
| Tulluu W/Daalachaa | 150 | 2011 | AGP II | 199 | 51 | 250 |
| Total | 828 | - | - | 1717 | 446 | 2163 |

*Source: Walmara district office of agriculture*

### 2.3. Sampling procedure

Sample households were selected employing a multi-stage sampling procedure. First, Walmara district was purposively selected. Second, peasant associations within the district were classified into highland and mid-highland by their ecology. Third, peasant associations within each ecology were stratified into irrigators and non-irrigators. Fourth, two peasant associations from each ecology, a total of four kebeles were randomly selected from those kebeles having irrigation access. In the fifth stage, the representative sample households were selected using systematic random sampling.

The rule of thumb employed to decide the required sample size. Accordingly, 220 sample households were selected. Out of this, 121 households were non-irrigators and 99 households were irrigators. The sample selected from each peasant association was determined using the proportional sampling method expressed as follows:

$$ni = \frac{(Ni)(n)}{\Sigma Ni} \quad (1)$$

Where ni = sample from $i^{th}$ peasant association

Ni = population living in $i^{th}$ peasant association.

ΣNi = the total population living in the selected peasant associations

n = the required total sample size

**Table2**. *Total sample distribution over the selected kebeles*

| Name of *Kebeles* | Total household | Sample selected | Participant | Non participant | Proportion |
|---|---|---|---|---|---|
| Talacoo | 544 | 60 | 27 | 33 | 27.3% |
| Barfata | 777 | 86 | 39 | 47 | 38.9% |

| | | | | | |
|---|---|---|---|---|---|
| Tokkoffaa | | | | | |
| Bakakkaa & Q/Oddoo | 325 | 36 | 16 | 20 | 16.3% |
| Waajituu Harbuu | 349 | 38 | 17 | 21 | 17.5% |
| Total | 1995 | 220 | 99 | 121 | 100% |

*Source: District office of agriculture and own computation result*

### 2.4. Data type and method of collection

Primary and secondary data sources were used. Stractured and semi-structured questionnaires used to collect the primary data from sample households. Secondary data were collected from different sources like the district bureau of agriculture, published journals, records of kebele administration, etc.

### 2.5. Method of data analysis

*2.5.1. Descriptive Data Analysis*

Mean, percentage, standard deviation, etc. were used to summarize the socio-economic variables. chi-square and t-test were performed to check the statistical significance of the dummy and continuous variables respectively. STATA V15.3 was the package used to analyze the collected data.

*2.5.2. Econometric Data Analysis*

Participation in irrigation was used as a dummy dependent variable to assess factors affecting household participation decision in irrigation. Logistic regression was the model used. The functional form of the Logit model is expressed as:

$$Pi = E(D=1|Xi) = \frac{1}{1+e^{-(\beta o+\beta iXi)}} \quad (2)$$

Equation 2 can be simplified as:

$$Pi = \frac{1}{1+e^{-Zi}} \quad (3)$$

Equation 3 is expressing the probability that the household participate in irrigation, and the probability that the household not participate in irrigation can be expressed as:

$$1-Pi = \frac{1}{1+e^{Zi}} \quad (4)$$

The odds ratio in favor of participation in irrigation is the ratio of the probability of participation in irrigation to the probability of non-participation. Functionally, this can be expressed as:

$$\frac{Pi}{1-Pi} = \frac{1+e^{Zi}}{1+e^{-Zi}} = e^{Zi} \quad (5)$$

Taking the natural Logarithm of equation 5, we get:

$$Li = \ln\left[\frac{Pi}{1-Pi}\right] = \beta_o+\beta_1X_1+\beta_2X_2+\beta_3X_3+ \ldots + \beta_nX_n +U_i \quad (6)$$

Where: Pi - is probability of participation in irrigation

Li - is the logarithm of the odds ratio

$\beta_1$ $\beta_2$ $\beta_3$ ……. $\beta_n$ are the coefficients to be estimated

$X_i$ - are the vectors of explanatory variables

Ui - is disturbance term

## 3. Result and Discussions

### 3.1. Descriptive results

**Sex of the household head:** From the total sample households, 35 (16 percent) were female-headed households, and 185 (84 percent) were male-headed households. As presented in Table 3, out of 99 irrigation user households, 11 percent were female-headed and 89 percent were male-headed households. From this result, the sex of the household head has its own implication on household participation in small-scale irrigation as the chi-square test is showing a significant difference.

**Access to credit services**: 95 irrigation user households (96 percent) and 104 irrigation non-user households (86 percent) had access to credit services. From this result, there was a positive and significant relation between household participation in irrigation and access to credit services. From this households having access to credit services are more likely to participate in irrigation. The chi-square test also showed that there is a significant relationship between access to credit services and participation in irrigation.

**Table3.** *Descriptive results of dummy variables by participation in irrigation*

| Variables | | Participation in irrigation | | | | | | Chi-square |
|---|---|---|---|---|---|---|---|---|
| | | No | % | Yes | % | Total | % | |
| Sex of the household head | Female | 24 | 20 | 11 | 11 | 35 | 16 | 3.1* |
| | Male | 97 | 80 | 88 | 89 | 185 | 84 | |
| Access to credit services | No | 17 | 14 | 4 | 4 | 21 | 10 | 6.3** |
| | Yes | 104 | 86 | 95 | 96 | 199 | 90 | |
| Occurrence of crop pests | No | 68 | 56 | 42 | 42 | 110 | 50 | 4.13* |
| | Yes | 53 | 44 | 57 | 58 | 110 | 50 | |
| Access to extension contact | No | 17 | 14 | 13 | 13 | 30 | 14 | 0.04 |
| | Yes | 104 | 86 | 86 | 87 | 190 | 86 | |

**Source:** Own household survey conducted during 2020

Note: * and ** shows the significance levels at 10% and 5%

**Occurrences of crop pests**: 58 percent of irrigator households and 44 percent of non-irrigator households responded that their crop fields were affected by pests during the main season 2019. From this result, households whose crop production affected by pests during the main season are more likely to participate in irrigation during the off-season. The chi-square test result is also proving that there is a significant relation between occurrence of crop pets and household participation in irrigation.

**Access to extension contact:** The result revealed that 86 percent of non-irrigator household heads and 87 percent of irrigator household heads have access to extension contact. This indicates that access to extension was almost equally available to both irrigator and non-irrigator households. The chi-square test also showed that there was no significant relationship between access to extension contact and household participation in irrigation.

**Table4.** *Descriptive results of continuous variables by participation in irrigation*

| Variables | Irrigators | | Non-irrigator | | Combined | | t-test |
|---|---|---|---|---|---|---|---|
| | mean | St.dev | mean | St.dev | mean | St.dev | |
| Age of head (years) | 42.3 | 10.4 | 45.4 | 9.2 | 43.9 | 9.9 | -2.5** |
| Education of head (years) | 4.5 | 4.0 | 3.7 | 3.7 | 4.1 | 3.8 | 1.38 |
| Dependency | 0.9 | .62 | 0.9 | 0.8 | 0.91 | .71 | -0.31 |
| Livestock (TLU) | 6.3 | 3.7 | 7.5 | 4.1 | 7.0 | 3.9 | -2.2** |
| Family size (AE) | 4.9 | 2.0 | 4.4 | 1.8 | 4.6 | 1.9 | 2.7** |
| Off-farm income in 1000 Bir | 7.2 | 9.7 | 8.1 | 10.2 | 7.7 | 10.1 | 0.67 |
| Market distance (KM) | 5.2 | 2.3 | 5.5 | 2.1 | 5.4 | 2.2 | -1.30 |
| Irrigation distance (KM) | 1.9 | 0.8 | 2.3 | 0.7 | 2.2 | .8 | -3.3*** |
| Land owned (hectares) | 1.7 | 1.2 | 1.4 | 1.2 | 1.5 | 1.2 | 2.3** |

**Source:** Own household survey conducted during 2020

Note: ** and *** shows the significance levels at 5% and 1%

**Age of the household head:** The combined mean age for the total households was about 43.9 years with a standard deviation of 9.9. Similarly, the mean age for irrigator and non-irrigator households were 42 and 45 years with standard deviations of 10.4 and 9.2 respectively. From this result, aged household heads are less irrigation participants compared to the younger household heads. The t-test result also showed that the mean age for irrigator households is significantly different from that of non-irrigator households.

**Livestock holding:** Livestock holding was among the important factors that determined household decision to participate in small-scale irrigation. The mean livestock holding for irrigators and non-irrigators were 6.3 and 7.5 with the standard deviations of 3.7 and 4.1 while the combined mean was 7 with a standard deviation of 3.9. From the t-test result, the mean livestock holding for irrigators and non-irrigators was significantly different.

**Distance from irrigation site:** According to the result in Table 3, distance from irrigation site was a very important variable that significantly related with participation in irrigation. The mean irrigation distance to irrigators and non-irrigators were 1.9 and 2.3 KM with standard deviations of 0.8 and 0.7 respectively. The t-test result also revealed that there was a significant mean difference between irrigators and non-irrigators regarding distance from the irrigation site.

**Family size**: The mean family size for irrigators and non-irrigator households 4.9 and 4.4 with standard deviations of 2 and 1.8, while the combined mean for the sample households was 4.6 with a standard deviation of 1.9. The significance test result also showed that there is a significant mean difference between irrigation participants and non-participants.

**Land ownership:** Land owned was among the important factors that determined household participation decision in small scale irrigation. The average land ownership was 1.7 and 1.4 hectares for irrigators and non-irrigators with standard deviation of 1.2 for both. The t-test result also confirmed that there was significant mean difference between irrigators and non-irrigators regarding land owned.

### 3.2. Econometric results

To estimate factors affecting household participation in small-scale irrigation, a logistic regression model was used. Before running the model, multi-collinearity was tested using variance inflation

factors (VIF), and the result revealed that there was no problem of multi-collinearity since the mean VIF was 1.20. So, all 13 independent variables were included in the model to estimate factors affecting participation in small-scale irrigation and the result is presented in Table 5

**Table5.** *Logistic regression results of factors affecting participation in irrigation.*

| Participation in irrigation | Coef. | St. Err. | t-value |
|---|---|---|---|
| Sex of the head | 1.286 | 0.473 | 2.72*** |
| Age of the head | -0.069 | 0.022 | -3.18*** |
| Education of the head | 0.052 | 0.044 | 1.19 |
| Family size (AE) | 0.425 | 0.111 | 3.84*** |
| Dependence ratio | -0.041 | 0.238 | -0.17 |
| Livestock holding (TLU) | -0.150 | 0.047 | -3.18*** |
| Land owned (hec.) | 0.466 | 0.145 | 3.22*** |
| Distance of irrigation site (KM) | -0.493 | 0.239 | -2.06** |
| Off-farm income (Birr) | 0.000 | 0.000 | -0.13 |
| Crop pests | 0.979 | 0.384 | 2.55** |
| Extension contacts | 0.666 | 0.539 | 1.24 |
| Market distance (KM) | -0.056 | 0.070 | -0.80 |
| Credit access | 1.315 | 0.699 | 1.88* |
| Constant | -1.025 | 1.733 | -0.59 |
| Mean dependent var. | 0.450 | St.dev. | 0.499 |
| Pseudo r-squared | 0.219 | No. obs. | 220.0 |
| Chi-square | 40.939 | Prob. > chi2 | 0.000 |
| Akaike crit. (AIC) | 264.427 | Bay. cr. (BIC) | 311.9 |

*Note: *** p<0.01, ** p<0.05 and p<0.05* (significance levels at 1%, 5% & 10%)*

**Source:** Own household survey conducted during 2020

**Sex of the household head:** As expected, the sex of the household head positively and significantly affected household participation in small-scale irrigation at a 1 percent probability level. The possible reasons might be the physical, socio-cultural, and time constraints that females are facing hindered females from participating in small-scale irrigation in the study area. This result is consistent with the findings of Wakene (2018), Kinfe et al. (2012) and is contrary to the result reported by Jirane (2015).

**Age of the household head**: The age of the household head was hypothesized to negatively affect households' participation in irrigation. Accordingly, it affected household participation decisions negatively and significantly at a 1 percent probability level. The possible reason is that the older farmers are less likely to adopt modern technologies compared to the younger and educated farmers. This result is consistent with the findings reported by Molla (2017) and Jirane (2015).

**Family size AE:** Adult equivalent family size positively and significantly affected household participation in small-scale irrigation at a 1 percent probability level. The result of the focus group discussion showed that family labor is one of the most frequently used inputs for production in irrigation in the area; most commonly for protecting the field, hoeing, and other agronomic practices. Therefore, irrigation participation demands more labor force and the households with a large labor force are more likely to participate in small-scale irrigation than the households with a smaller number of labor forces. This result is consistent with the findings of Wakene (2018) and Kalkidan et al. (2016).

**Livestock holding:** Against the hypothesis, livestock holding negatively and significantly affected irrigation participation decision of the households at 1 percent probability level. The possible reason might be the additional income that the households drive from selling animal by-products like selling milk, butter, cheese, and others as their additional income sources to support their lives, and hence may not look for irrigation use. This result is consistent with the findings reported by Hamda (2016).

**Land owned:** As expected, the size of land owned positively and significantly affected participation in small-scale irrigation at a 1 percent probability level. The result of the focus group discussion highlighted that land is the most important determinant of crop and livestock production. Households having larger land sizes easily perform crop production and livestock rearing compared to households owning smaller land sizes or not owning land at all. This is because of the high land rental price for crop production and for grazing. This result is consistent with the findings reported by Agena (2017), Molla (2017), Wakene (2018), and Temesgen (2019).

**Distance from irrigation site:** As expected, distance from irrigation water source negatively and significantly affected household participation in small-scale irrigation at a 5 percent probability level. Households living closer to the irrigation sites are more likely to use irrigation. The reason may the advantage of performing agronomic practice, suitability to guard the plots during day and night, the lesser walking time required and etc. This result is consistent with the findings reported by Molla (2017), Wakene (2018), and Temesgen (2019).

**Occurrence of crop pests:** Contrary to the hypothesis, the occurrence of crop pests and diseases positively and significantly affected household participation in small-scale irrigation at a 5 percent probability level. According to the survey result, crop pests and diseases are commonly occurring on crop fields of the farmers mainly in the main season than off-season (irrigation), and impose severe yield loss that may reach almost total yield loss. To withstand these problems, affected farmers try all the best to participate in small-scale irrigation during the off-season, even by paying expensive prices for land rent according to responses of the focus group discussion participants. This result is consistent with the results reported by Birilie (2017).

**Access to credit services:** As expected, credit services affected participation in small-scale irrigation positively and significantly at a 10 percent, which means, households having access to credit were more likely to participate in irrigation. This is because of those farmers having access to credit services are more capable to purchase irrigation inputs like seeds, fertilizers, labor, motor pumps, irrigable land, and etc. This result is consistent with Birilie (2017) and Temesgen (2019).

## 4. Conclusion and Recommendation

The study was conducted with the main objective of assessing factors affecting household participation in small-scale irrigation in Walmara, central Oromia, Ethiopia. A multi-stage sampling method used to select 220 sample households from four randomly selected peasant associations. Descriptive and econometric data analyses were done.

The descriptive result showed that the sex of the head, access to credit services, occurrence of crop pests, age of the head, livestock owned, family size, distance from irrigation site, and land ownership were the variables that showed significant relation with irrigation participation.

Similarly, the logistic regression results also revealed that sex of the head, age of the head, family size, livestock holding, land owned, distance from irrigation site, the occurrence of crop pests, and access to credit services were the variables that significantly affected participation in small-scale irrigation.

Therefore, agricultural policy interventions that promoting the establishment of institutions that providing financial, material and technical supports to farmers are recommended.

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