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Article

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Cogent Economics & Finance

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Suggested Citation: Daru, Getasew; Melak, Degsew; Awoke, Wondim; Alemu, Sinkie (2023) : Farmers' participation in small-scale irrigation in Amhara region, Ethiopia, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 11, Iss. 1, pp. 1-19, <https://doi.org/10.1080/23322039.2023.2213951>

This Version is available at:

<https://hdl.handle.net/10419/304092>

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To cite this article: Getasew Daru, Degsew Melak, Wondim Awoke & Sinkie Alemu (2023) Farmers' participation in small-scale irrigation in Amhara region, Ethiopia, Cogent Economics & Finance, 11:1, 2213951, DOI: [10.1080/23322039.2023.2213951](https://doi.org/10.1080/23322039.2023.2213951)

To link to this article: <https://doi.org/10.1080/23322039.2023.2213951>



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Published online: 17 May 2023.



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Received: 01 March 2023
Accepted: 08 May 2023

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Farmers' participation in small-scale irrigation in Amhara region, Ethiopia

Getasew Daru^{1*}, Degsew Melak², Wondim Awoke³ and Sinkie Alemu⁴

Abstract: Irrigation has a critical role in improving food security and alleviating poverty. Long-term studies on small-scale irrigation have identified several factors that influence the participation of farmers in irrigation. However, farmers in the study area are still hesitant to participate in small-scale irrigation as a source of income. As a result, the focus of this study was examining farmers' engagement in small-scale irrigation. A stratified random sampling technique was used to select 184 respondents, and data was collected from those sample respondents. The double hurdle model was used to identify determinants and the extent of farmers' participation in small-scale irrigation. The model's first hurdle found that farmers' desire to participate in small-scale irrigation was highly influenced by their age (1.3%), educational level, extension contact (20.8%), training access (19.7%), dependency ratio, farm distance from water, and land topography. According to the result of the second hurdle, the level of farmers' participation in small-scale irrigation was highly affected by land size (11.6%), income, adult labor, educational level, age, and market distance. The study finds that strengthening income sources, land

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PUBLIC INTEREST STATEMENT

In Ethiopia, agriculture production is highly susceptible to natural, institutional, economic, and climatic related shocks. Hence, the application of climate-smart agricultural strategies like small-scale irrigation becomes an inevitable option to boost agricultural growth, achieve food security, and improve livelihood security. Irrigation agriculture is one method of agricultural intensification that plays a critical role in increasing agricultural productivity. Recently, in Ethiopia, small-scale irrigation has been an area of emphasis for policymakers and planners, so both governmental and non-governmental organizations have been encouraged to engage in irrigation development activities. However, the participation of farmers in irrigation farming is still limited compared to the irrigation potential of the country. Thus, investigating the factors affecting farmers' participation in irrigation farming is essential and serves as an input for enhancing farmers' participation and the extent of participation in small scale irrigation in the county.

utilization, training access, extension contact, market access, and education level would increase farmer participation in small-scale irrigation. Therefore, stakeholders should strive to deliver these essential services to encourage farmers to participate in small-scale irrigation.

Subjects: Rural Development; Economics and Development; Sustainable Development

Keywords: determinants; extent; participation; small-scale irrigation; double hurdle

1. Introduction

Climate change has a profound impact on agricultural production and the food security of people throughout the world (Sean et al., 2015). Thus, expanding irrigation is a promising climate adaptation solution as well as a critical option to meet future global food demand without further distracting natural ecosystems (Lorenzo, 2022).

Agriculture plays an indispensable role in the Ethiopian economy. The sector accounts for over 40% of gross domestic product (GDP), provides 83% of employment opportunity, supplies 70% of raw materials for the country's agro-industries, and about 70% of Ethiopia's foreign exchange is derived from exports of agricultural products (EEA, 2012; FAO, 2015). In addition, rain-fed agricultural production is struggling to keep up with the country's population growth. Despite all these facts, agriculture production is still very traditional and underdeveloped in Ethiopia. Enhancing irrigation production is a significant option to increase agricultural production (Mohamed, 2017; Tsegazeab & Surajit, 2016).

Small-scale irrigation is now a policy priority in Ethiopia as a means of ensuring household food security, adapting to climate change, alleviating rural poverty, and boosting economic growth by increasing agricultural production and productivity. Although Ethiopia has 3.7 million hectares of irrigable land potential, only less than 5% of it has been utilized (MoA, 2011; Tesfaw, 2018).

Similarly, as a strategy in the Amhara region, irrigated agriculture has become the critical option to mitigate recurrent drought and rainfall variability. Even with the availability of abundant water and land resources in the region, the potential for small-scale irrigation has not yet been completely exploited (Bitew, 2013). Particularly, the study area has 5600 hectares of irrigable land, yet smallholder farmers rely on rain-fed agriculture for their livelihood, which is highly vulnerable to climatic risk and biophysical factors. Even though small-scale irrigation contributes significantly to smallholder farmers' food security and overall livelihood improvement, so far many of them are hesitant to employ it as a livelihood activity (Yitna, 2013).

Previous studies conducted on small-scale irrigation were mainly focused on the overall contribution of irrigation to household food security, income, and entire household welfare (Ahmed, 2019; Feleke et al., 2020; Gebremichael, 2013; Seid, 2016; Tefera & Cho, 2017; Tesfaye & Beshir, 2018). Almost all of these studies have acknowledged the importance of small-scale irrigation in improving the livelihoods of rural smallholder farmers. Further, Lebete (2017) and Meja et al. (2020) pointed out that lack of know-how, poor market access and the low market price at harvest time, plant disease, and a shortage of experienced manpower on irrigation issues are all challenges that have hampered small-scale irrigation practices in Ethiopia. However, the extent to which these factors contribute to farmers' engagement in small-scale irrigation has been less investigated.

Even most of the existing studies simply consider one-way analysis (Abebe, 2017; Temesgen, 2019; Urgessa et al., 2020), that is, to identify the determinants of farmers' participation in small-scale irrigation, but less attention is given to distinguishing the factors affecting farmers' participation and the extent of farmers' participation in a separate analysis. This indicates there is

a methodological gap to analyze the participation and the extent (intensity) of participation in small-scale irrigation independently. This is the basic reason to conduct this study on location-specific socio-economic factors influencing farmers' participation in small-scale irrigation, particularly in the study area.

Similarly, in the study area (Hulet Eju Enesie district), some farmers are practicing small-scale irrigation to supplement rain-fed agricultural production as an alternative source of income to improve their living conditions. An empirical study is needed to understand why farmers are unable to use the full potential of their irrigable lands, but such a type of research is lacking in the study area. That is why the researchers were eager to carry out the study. Therefore, the objective of this study was to identify the determinant factors that influence farmers' participation and the extent of participation in small-scale irrigation.

2. Methodology

2.1. Description of the study area

This study was conducted in one of the districts with irrigation land water potential in the Amhara Region, Ethiopia (HuletEjuEnesie district). The district is geographically located at 10° 45 00"–11° 10 00"N Latitude and 37° 45 69–38° 10 00 E longitude. It has an altitude range of 1290–4030 meters above sea level (Lamesegn et al., 2018). The map of the study area is shown in Figure 1:

2.2. Research design

This study used a cross-sectional research design by considering the nature of the problem under investigation. This type of research design is suitable when the principle of the study is descriptive in the form of a survey and when the study is focused on a particular geographical place for a single period (Babbie et al., 2007). In addition, the researcher employed a mixed research design to include both quantitative and qualitative approaches. Therefore, the data, such as household head demographic characteristics, household income, land holding size, and oxen ownership information, were collected via a structured and semi-structured interview schedule.

2.3. Determination of sample size and sampling techniques

In order to achieve the objective of this study, data was collected from 184 households using a scheduled interview questionnaire. Sample respondents were identified using multi-stage sampling techniques. Hulet Eju Enesie district was purposefully chosen from the East Gojjam zone in the first stage because of its irrigation potential. In the second stage, two Kebeles in the district were chosen using the purposive sampling technique in consultation with the district agricultural office. The sample units (household heads) were chosen from each Kebele in the third stage by obtaining a list of households from the respective Kebele administrations. Finally, a simple random sampling procedure was used to select sample respondents from each kebele proportional to the population in each kebele (Table 1).

Table 1. Proportional sample distribution for each Kebeles

Name of Kebeles	Total Household	Total User	Total Nonuser	Sample from user	Sample non-user	Total Sample from each kebele
Qonter Silasie	721	285	436	31	40	71
Shegie keranio	1140	402	738	51	62	113
Total	1861	687	1174	82	102	184

Source; Own Summary (2021)

Table 2. Summary of independent variable and their hypothesized relationship

Independent Variables	Nature	Measurement	Expected sign
Demographic factors			
Age of HHH respondent	Continuous	in Year	±ve
Sex of HHH respondent	Dummy	'1' for male and '0' for female	±ve
Family size	Continuous	in number adult equivalent	+ve
Dependency ratio	Continuous	in number	-ve
Educational status	Categorical	'1' for unable to read and write, '2' for able to read and write, '3' primary & junior, '4' secondary school	+ve
Economic factors			
Land holding size	Continuous	In hectare (ha)	+ve
Gross annual income	Continuous	in number (ETB)	+ve
Number of oxen	Continuous	number	+ve
Institutional factors			
Training access	Dummy	'1' for accessed and 0 for non-accessed training	+ve
Contact with development agent	Dummy	'1' for contact and '0' for non-contact with DA	+ve
Credit access	Dummy	'1' for accessed and '0' for non-accessed	+ve
Market distance	Continuous	Walking hours	-ve
Market information access	Dummy	'1' for accessed and '0' for non-accessed	+ve
Environmental factors			
Farm distance from water source	Continuous	In kilometer	-ve
Terrain of the farm land	Dummy	'1' for suitable and '0' for unsuitable farmland	±ve

Source; Own summary (2020)

Considering household heads as a unit of analysis, it was attempted to select an acceptable sample size for this study, taking into account the nature of the problem under investigation, the desired degree of precision, and the availability of resources such as duration of time and research funds. Considering these factors, the sample size was determined using Yamane's (1967) formula.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where

n = total sample size of this study

N = total household head of the two kebele (Population size)

e = Confidence level (0.07)

Accordingly, the total sample size of this study was determined as 184. After determining the total sample size, sample households from two selected Kebeles were determined proportionally to the sample population in each Kebeles.

2.4. Data types, sources, and methods of data collection

For the achievement of this research objective, both quantitative and qualitative data types were collected from primary and secondary sources.

2.4.1. Primary data

Primary data was collected using structured and semi-structured interview schedules from both irrigation user and nonuser households in Shegie Keranio and Qonter Silasie Kebeles of Hulet Eju Enesie district. In this study, both closed and open-ended interview schedules were conducted to collect data on household demographic characteristics, cash income, number of oxen, size of farming land, irrigable land size, and other determinant variables of farmers participation in small-scale irrigation for both irrigation user and non-user households. The questionnaires for the interview schedule were prepared in English, and they were translated into the local language (Amharic) for more clarification by the data collectors.

2.4.2. Secondary data sources

Mainly, secondary data collection was to review a lot of important literature that was crucial to supporting the primary data and overall concept of small-scale irrigation in this study. Therefore, secondary information was obtained from various sources, such as published documents, including research journals, reputable articles, proceedings, websites, and other unpublished secondary sources like the reports of agricultural offices.

2.5. Method of data analysis

2.5.1. Double hurdle econometric model

After collecting relevant data from respondents' households, the data was analyzed using an econometric model. This study has dual dependent variables, which are farmers' participation decisions and the intensity of farmers' participation in small-scale irrigation. The nature of the first dependent variable (farmers' participation decision) is dichotomous; it takes a value of 1 if the household has participated and zero if it has not participated in small-scale irrigation practices. Thus, it can be estimated by binary probit regression. The second variable, the intensity of farmers' participation, was a continuous variable, and it has been measured by the proportion of the land irrigated by the farmers from the total farmland they owned.

Since this variable is a continuous limited dependent variable, it has been estimated by using a truncated regression model.

According to Cragg (1971) and Greene (2003), the Tobit model, Heckman two-step model, and double hurdle model are suited to estimate the factors determining farmer participation decisions and intensity of participation based on distinct basic assumptions. To identify the best-fit model for analysis, the researcher conducted a log-likelihood ratio test, and the double hurdle was found to be the best fit compared to the Tobit model for this study's analysis. Therefore, the double hurdle model is equivalent to the combination of the probit model (for the first hurdle) and the truncated regression model (for the second hurdle), where the error terms are assumed to be independent. Moreover, the double-hurdle model contains two equations with two different latent variables. The first equation is the participation decision equation, and the second equation is the intensity of participation equation. The equations are specified as follows for both the participation and extent of farmers' participation in small-scale irrigation:

Mathematical equation;

Farmers' participation equation;

$$Y_{i1}^* = X_1 \beta_1 + \varepsilon_{i1}, \varepsilon_{i1} \sim N(0, \delta_1^2), \quad Y_{i1} = \begin{cases} 1, & \text{if } Y_{i1}^* > 0 \\ 0, & \text{if } Y_{i1}^* \leq 0 \end{cases} \quad (2)$$

Extents (intensity) of farmers' participation equation;

$$Y_{i2}^* = X_2 \beta_2 + \varepsilon_{i2}, \varepsilon_{i2} \sim N(0, \delta_2^2), \quad Y_{i2} = \begin{cases} X_2 \beta_2 + \varepsilon_{i2}, & \text{if } Y_{i1} = 1 \text{ and } Y_{i2}^* > 0 \\ 0, & \text{if } Y_{i2}^* \leq 0 \end{cases} \quad (3)$$

Where, Y_{i1}^* = latent variable for the participation decision in small-scale irrigation,

Y_{i1} = observed decision of the farmer whether to participate or not participate in irrigation,

X_1 = the vector of explanatory variables that determine participation of farmers in irrigation farming,

β_1 = the vector of parameters related with explanatory variables determining participation decision of the farmer,

ε_{i1} = is the error term of the participation equation which is normally distributed

$(\varepsilon_{i1} \sim N(0, \delta_1^2))$, with zero mean and constant variance,

Y_{i2}^* = unobserved variable for extents of participation in irrigation.

Y_{i2} = the observed intensity of farmers participation in irrigation farming

X_2 = the vector of explanatory variables that determine intensity of participation in irrigation,

β_2 = the vector of parameters related with explanatory variables determining extents of participation in small-scale irrigation,

ε_{i2} = is the error term of the extents of participation equation which is normally distributed ($\varepsilon_{i2} \sim N(0, \delta_2^2)$) with zero mean and constant variance,

The subscript i refers to the i th household, and the subscripts 1 and 2 refers to the variables and parameters related to the participation equation and extents of participation equation respectively

2.6. Description of variables and their hypothesized relationships

Dependent variable; the nature of the first dependent variable (probability of farmers' participation) is dummy, so it takes one (1) if the farmer is participate and otherwise it takes zero (0) if farmers have not participated in irrigation practice. The second variable, extents of farmers' participation in small-scale irrigation is a continuous variable and measured in terms of actual irrigated land size in hectare.

Independent variables; based on the reference of different past literature the following factors were distinguished as explanatory variables for this study and its details are summarized below (Table 2)

2.7. Conceptual framework

Previous studies (Assefa et al., 2022; Gebregziabher et al., 2014; Temesgen, 2019; Yasab, 2020) analyzed farmers' participation in small-scale irrigation in different parts of the country. According to the literature review, factors determining farmers' participation and extent of participation in small-scale irrigation are grouped into four main categories. These are demographic factors (age, sex, family size, education, and dependency ratio), economic factors (landholding size, number of oxen and annual income), environmental factors (farm distance to the irrigation water source and topography of the farmland), and institutional factors (training access, market information, credit access, market distance and contact with development agent). The conceptual framework has been constructed to show the interaction between the variables. As shown in Figure 2 the arrows that point two ways indicate that there is an effect between the variables in both directions, whereas arrows' pointing only one direction show the effect is only from one to the other.

2.8. Societal benefits of the research

The result of this study has critical relevance for various levels of development practitioners (stakeholders) to make a concrete future plan on irrigation development. Information on determinants of farmers' participation and extent of participation in small-scale irrigation serves as input to make sound decisions for local extension agents who engage in the diffusion of technologies related to irrigation, input suppliers, and overall policy makers to achieve agricultural growth. In addition, this study provides information on the major factors that affect small-scale irrigation, and it is important to generate specific and immediate significant solutions to the farmers' problems and to expand small-scale irrigation practice in the study area.

Figure 1. Map of the study area (Hulet Eju Enesie district).

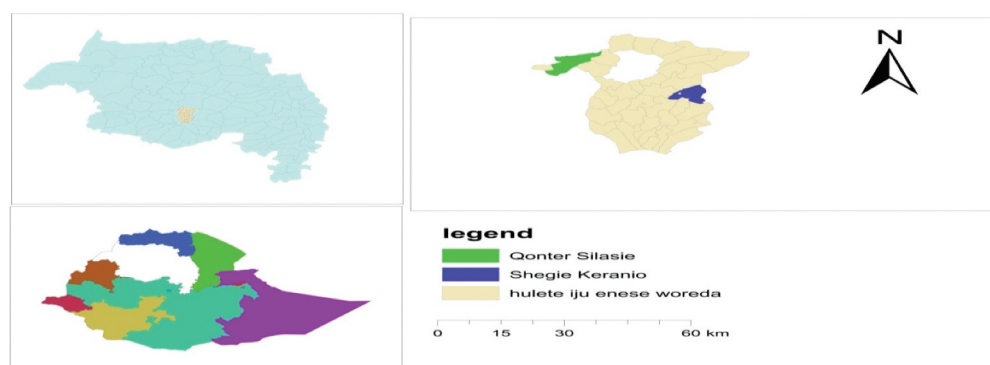
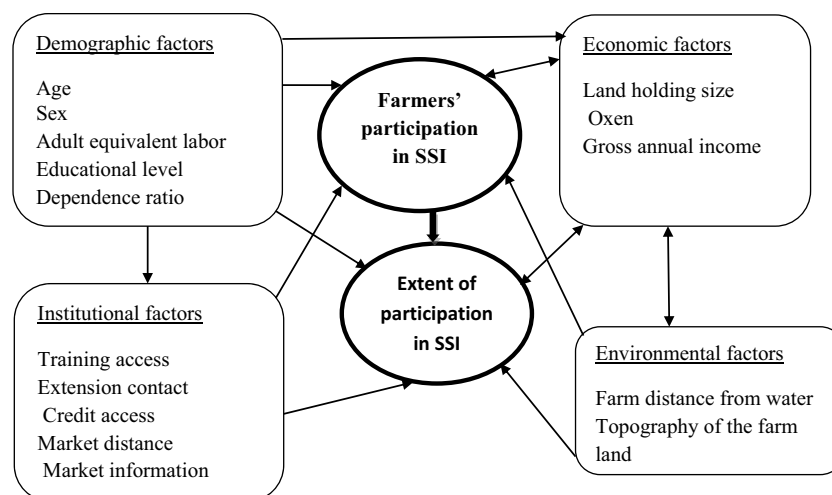


Figure 2. Conceptual framework, own design (2020).



3. Results and discussion

3.1. Descriptive statistics of household characteristics

The result of descriptive statistics (mean, standard deviation, minimum, and maximum) shows the demographic, socioeconomic, institutional, and environmental characteristics of sample households in the study area. The t-test and chi-square test were used to test the significance of continuous and categorical variables, respectively, as shown in Tables 3 and 4 below.

3.1.1. Age of household head

As shown in Table 3, the average age of irrigation user respondents was 40.2 years, with minimum and maximum ages of 22 and 72 years, respectively. While the average age of nonusers' respondents was 48.2 years, with 23 minimum and 74 maximum years of age. The t-test result showed that there was a significant difference in the mean age of irrigation user and nonuser household heads at a 1% significance level.

3.1.2. Adult equivalent labor

The average family size in the adult equivalent ratio of irrigation users' households was around 3.34, while the nonuser household respondents were 2.92, which implies irrigation users households had a relatively larger labor force compared to nonuser households. Even though, the t-test mean comparison showed that there was no significant difference in the mean of the adult labor force between irrigation users and nonuser household respondents (Table 3).

3.1.3. Dependency ratio of household heads

In the study area, the dependency ratio of irrigation user households was relatively lower than that of irrigation nonuser respondents. This might imply that irrigation-user farmers would have more active family members than nonuser farmers. The t-test mean comparison showed that there was no significant difference in the dependency ratio between irrigation users and nonuser household heads (Table 3).

3.1.4. Landholding size

The mean landholding size for irrigation user households was 1.69 hectares, with 0.5 and 3 minimum and maximum hectares, respectively. Whereas, the mean land holding size of nonuser households was 1.23 hectares, with a minimum of 0.25 and a maximum of 2.5 hectares. The t-test result showed that there was no significant difference in the mean cultivable land size between irrigation users and nonusers in the study area (Table 3).

Table 3. The Summary of t-test statistics for continuous variables

Variables	User Sample (N=82)				Non-user Samples (N=102)				t-test
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	
Age	40.25	8.22	22	72	48.25	10.75	23	74	5.552***
Adult labor	3.348	0.79	2	4.7	2.922	0.57	2	4.4	-4.20
Dependency ratio	27.49	12.68	0	60	40.23	17.04	0	75	5.625***
Land size	1.69	0.599	0.5	3	1.23	0.53	0.25	2.5	-5.847
Gross income	43890	15054	15000	82000	33376	15813	10000	75000	-4.579*
Oxen	3.20	0.797	1	4	2.29	0.752	1	5	-7.968
Farm distance to water	0.271	0.444	0.001	1.7	1.31	1.15	0.01	5	7.770***
Market distance	1.40	0.474	1	3	2.10	0.559	1	3.3	5.725***

***, * represent significant at 1% and 10% significant level respectively.

Source: Computed from own survey data, (2021)

Table 4. Statistical summary of chi-square test for categorical and dummy variables

Variables	Categories	Irrigation Users samples (N=82)		Irrigation Non-users samples (102)		x ² -test
		N	(%)	N	(%)	
Sex of household head	1= male	62	75.6	77	75.4	0.04
	0=female	20	24.3	25	24.5	
Extension contact	0=no	17	20.7	64	62.7	32.5601***
	1=yes	65	79.2	38	37.2	
Training access	0=no	14	17.0	73	71.5	54.1579***
	1=yes	68	82.9	29	28.4	
Credit access	0=no	25	30.4	54	52.9	9.353***
	1=yes	57	69.5	48	47.0	
Market info Access	0=no	20	24.4	73	71.4	40.475***
	1=yes	62	75.6	29	28.5	
Land topography	0=unsuitable	14	14.8	63	62.7	63.531***
	1=suitable	68	85.1	39	38.2	
Educational-level	1= unable read & write	9	10.9	58	56.9	41.7460***
	2= read and write	55	67.0	33	32.7	
	3= Pri & juni school	12	14.6	6	5.9	
	4= secondary school	6	7.3	5	4.9	

***, represent significant at 1% significant level

Source: Computed from own survey data, (2021)

3.1.5. The gross annual income of households

As shown in Table 3, the average gross annual income of irrigation users was 43,890 ETB, with 15,000 and 82,000 minimum and maximum ETB, respectively. While the average gross annual income of irrigation nonuser respondents was 33,376 ETB, with 10,000 and 75,000 minimum and maximum ETB, respectively. The t-test result indicated that there was a significant gross income difference between irrigation user and nonuser households at a 10% significance level.

3.1.6. Number of oxen owned

Oxen are the backbone of agricultural production as a major source of power for plowing and threshing purposes in the study area. As shown in Table 3, the mean of oxen owned by irrigation user household heads' was 3.2, whereas the mean of oxen owned by nonuser household respondents was 2.29. The t-test statistics indicated that there was no significant difference in the mean of oxen ownership between irrigation users and nonuser household respondents.

3.1.7. Market distance

As indicated in Table 3, market distance from respondents' residences was measured using man-walking distance in hours. The survey results showed that in the study area, the average market distance was approximately 1:50 hours. The average market distance for irrigation user households was 1:40 hours, with 1 and 3 minimum and maximum hours, respectively. On the other hand, the average market distance of nonuser households was 2:10 hours, with a minimum of 1 hour and a maximum of 3:20 hours of walking. The t-test statistics indicated that there was a significant mean difference in market distance between irrigation user and nonuser respondents at 1% of significant level.

3.1.8. Farmland distance from water sources

The descriptive result showed that the average farmland distance of irrigation user households was 0.27 km, with a 0.01 km minimum and a 1.7 km maximum distance of farmland from irrigation water sources. While the average farm distance for nonuser respondent households was 1.31 km, with a minimum of 0.1 km and a maximum of 5 km of farm land from a water source. The t-test statistics also indicated that there was a significant difference in the mean farm distance between irrigation users and nonuser respondents at the 1% significance level (Table 3).

3.1.9. Sex of the household head

The result in Table 4 indicated that of the total irrigation user respondents, 76.6% were male and 24.4% were female. While from total nonuser respondents, 75.4% were male and 24.6% were female household heads. The chi-square test result for this variable showed that there was no significant association between the sexes of household heads and farmers' irrigation participation.

3.1.10. Extension contact

From total irrigation user respondents, 79% had access to contact with a development agent; on the other hand, from total nonuser respondents, only 37.2% had access to contact with a development agent. The Chi-square test result confirmed that there was a significant association between the frequency of extension contact and farmers' participation in small-scale irrigation at the 1% significance level (Table 4).

3.1.11. Training access

The descriptive result indicated that 82.9% of irrigation user households had access to training services, whereas only 29% of nonuser respondents accessed training services on small-scale irrigation practice. The Chi-square test result revealed that there was a significant association between household access to training and their participation in small-scale irrigation at the 1% significance level (Table 4).

3.1.12. Credit access

As shown in Table 4, 69% and 47% of irrigation user and nonuser households, respectively, accessed credit services, whereas 30.4% and 52.9% of irrigation user and nonuser respondents, respectively, did not take credit access. The chi-square test result confirmed that there was a significant association between households' access to credit and farmers' participation in small-scale irrigation at 1% level of significance. This is due to the fact that farmers who get credit might use it for the purchase of improved seeds, fertilizer, herbicides, pesticides, farm materials, and farm oxen to increase their agricultural production.

3.1.13. Access to market information

Farmers' access to market information on agricultural input and output prices has a critical role in enhancing their profitability. In the study area, 75.5% of total irrigation users had formal and informal access to market information, and 24.5% did not access market information. While 28.5% of nonuser respondents had access to market information, 71.5% of them did not. The chi-square test showed that there was a significant association between farmers' access to market information and their participation in small-scale irrigation at the 1% level of significance (Table 4).

3.1.14. Land topography

The topographic situation of the farming land is an environmental characteristic expected as one determinant of household participation in small-scale irrigation. In the study area, 85.5% of irrigation users and 38.5% of nonusers had suitable land for irrigation, whereas around 14.5% of irrigation users and 61.5% of nonusers had unsuitable land for irrigation practice. The chi-square tests also indicated a systematic association between the topography of the farm land and farmers' participation in small-scale irrigation at 1% level of significance (Table 4).

Table 5. Estimation result of first hurdle (probit regression) on farmers' participation in SSI

Variables	Coefficient	Robust Std. Err.	Z	Marginal Effect
Sex	-0.3278	0.3406	-0.96	-0.1180
Age	-0.0477*	0.0221	-2.16	-0.0165
Land size	0.4636	0.3936	1.18	0.1609
Education	0.5201**	0.2541	2.05	0.1805
Income	1.838	0.0013	-0.12	0.9107
Dependency ratio	0.0444***	0.0095	-4.65	-0.0150
Oxen	0.1659	0.2427	-0.68	-0.0578
Extension contact	-0.5311*	0.2993	1.77	0.1797
Training access	-0.7706**	0.3209	0.01	0.2616
Credit access	0.0290	0.4362	-0.07	0.0100
Market information access	0.5027	0.3613	1.39	0.1734
Land topography	1.388***	0.4411	3.15	-0.4119
Adult labor	0.1362	0.2019	0.65	0.4727
Farm distance	-0.6778***	0.2019	-3.36	-0.2352
Constant	0.2225	1.4724	-0.15	
Number observation		=184		
Wald chi2(14)		=101.09		
Prob> chi2		=0.0000		
Log pseudo likelihood		= -36.9257		
Pseudo R2		=0.7080		

***p<0.01; **p<0.05; *p<0.1; represent significance level at less than 1%, 5% and 10% respectively

Source: Model output from survey data, (2021)

3.1.15. Education level

The descriptive result shown in Table 4 indicates that from total irrigation user respondents, 67% were able to read and write, whereas 57.8% of nonuser respondents were unable to read and write. This indicated that a large proportion of irrigation user respondents were capable of reading and writing; the opposite was true for nonuser respondent households. The Chi-square test result also ratified that there was a significant association between household educational level and their decision to participate in small-scale irrigation at 1% significance level

3.2. Determinants of farmers' participation in small-scale irrigation (SSI) practice

As shown in Table 5, the estimation result of the first hurdle of the double hurdle model (binary probit regression) showed that out of fourteen explanatory variables, seven were identified as significant determinants of households' probability to participate in small-scale irrigation practice in the study area. These variables were well distributed over three categories: *demographic factors* (age of household head, educational level of household head, dependency ratio), *institutional factors* (extension contact and training access), and *environmental factors* (topography of farmland and distance of farmland from a water source). The model results for significant variables are interpreted as follows:

3.2.1. Age

As indicated in Table 5, the age of the household head negatively influenced the probability of farmers' participation in small-scale irrigation at the 10% significance level. This result indicated that older farmers were less likely to practice small-scale irrigation than younger farmers. It is expected that irrigation may require an active labor force, as it may be very challenging for older farmers to participate. Holding other variables constant in the model, the probability of farmers' participation in small-scale irrigation would decrease by 1.6 % as the age of the household head increases by one year to a certain level. This result is consistent with the findings of Mango et al. (2018) and Deksis and Bayissa (2020), who found an increment in the age of the household head would not increase the likelihood of household participation in small-scale irrigation. However, Feleke et al. (2020) reported a positive effect of age on households' decisions to participate in small-scale irrigation.

3.2.2. Educational level of household head

The probability of farmers' participation in small-scale irrigation was positively and significantly determined by the educational level of household heads at 5% significant level (Table 5). More specifically, an increase in years of schooling to a certain level would increase the probability of farmers' participation in small-scale irrigation by 18%. This result seems to imply that well educated farmers are eager to use new agricultural technologies. This result is in agreement with another research finding (Tesfaye & Beshir, 2018; Yihdego et al., 2015), who reported the positive and significant influence of educational status on household irrigation practicability.

3.2.3. Extension contact

The estimation result showed that access to extension contact influences the probability of farmers' participation in small-scale irrigation positively and significantly at the 10% level of significance. This would imply that farmers with frequent extension contact were more likely to participate in small-scale irrigation practices, as expected. An increase in the frequency of extension contact would increase the probability of households' participation in small-scale irrigation by 17.9%. This result is consistent with the findings of Yihdego et al. (2015) and Abebe (2017). This variable was included in both the "first" and "second" hurdles of the model. However, it was only significant at the first hurdle. This might be an indication that the probability and extent of participation in small-scale irrigation can be affected by different sets of explanatory variables (Table 5).

Table 6. Estimation result of second hurdle (truncated regression) for extent of farmers' participation in SSI			
Variables	Coefficient	Robust Std. Err.	Z
Adult labor	0.0701**	0.0269	2.56
Extension cont	-0.03887	0.0529	-0.75
Age	-0.0066**	0.0030	-2.23
Oxen	-0.0102	0.0298	-0.34
Education	0.0452*	0.0243	1.86
Land topography	0.0525	0.0771	0.68
Income	0.5801***	0.9501	2.57
Land size	0.1136***	0.0421	2.69
Training access	0.0149	0.0740	0.20
Credit access	0.0117	0.0411	0.28
Market distance	-0.1048***	0.0374	-2.79
Market info access	0.1106	0.0695	1.59
Sex	0.0771	0.0654	1.18
Farm distance	0.341	0.0386	0.88
Constant	-0.1731	0.1519	-1.14
sigma	0.1544***	0.0141	10.88
Limit: lower = 0 upper = +inf Log pseudo likelihood =47.9676	Number of observation = 82 Wald chi2(14) = 168.67 Prob> chi2 = 0.0000		

*** p< 0.01; ** p< 0.05; *p<0.1; represent significance level at less than 1%, 5% and 10% respectively.
Source: Model output from survey data, (2021)

3.2.4. Training access

As expected, farmers' access to training positively influenced households' decision to participate in small-scale irrigation at 5% level of significance. Respondents who have access to training were more likely to participate in small-scale irrigation practices than those who have limited or lack access to training. Households that had frequent training access toward irrigation practice increased the probability of their participation by 26.2% (Table 5). Similarly, the research findings reported by Abiyu et al. (2015), Seid (2016), Legesse et al. (2018), and Yasab (2020) indicate that provisions for training on different agricultural practices would enhance farmers' adoption of the latest farm technologies. Like extension contact, this variable was also included in both hurdles of the model, but it was only significant in the first hurdle. This implied that once training motivates farmers to decide to participate in small-scale irrigation, the next decision (extents of participation) might be less likely to be influenced by training access. This result confirmed the assumption of the double hurdle model. That is, the first and second decisions were influenced by different sets of explanatory variables.

3.2.5. Dependency ratio

As shown in Table 5, this variable negatively and significantly influenced households' probability to participate in small-scale irrigation at 1% level of significance. With a one-unit increase in the dependency ratio of households, the likelihood of their participation in small-scale irrigation would decrease by 1.5%. This implied that households with a higher dependency ratio were less likely to participate in irrigation practices, and vice versa. Similar to this result, Gebremichael (2013) also reported that the availability of a working labor force enhances farmers' possibilities of using improved irrigation technologies.

3.2.6. Distance of farmland from water source

As revealed in Table 5, distances of farmland from water sources negatively and significantly determined farmers' decision to participate in small-scale irrigation at 1% significance level. In the study area, rivers are the major source of water for irrigation activity. Households whose farm land is located far from rivers were less likely to participate in irrigation practices, with a marginal effect of 23.5%. An increase in the distance of farm land from water sources (rivers) would decrease the likelihood of households' participation. Similarly, the previous finding reported that the distance of irrigation rivers from farmers crop land negatively affected farmers' participation in irrigation farming, Yasab (2020)

3.2.7. Land topography

The slope of the farmland that would be suitable or unsuitable for irrigation practice is a determining factor in small-scale irrigation participation. The result showed that, topography (sloppiness) of farming land was negatively affected households' decision to participate in small-scale irrigation at 1% significance level. As a household had sloppy (unsuitable for irrigation) farm land, the possibility of their participation in small-scale irrigation would decrease by 41.1% (Table 5). This result is consistent with the finding of Woldemariam and Gecho (2017) and Temesgen (2019).

3.3. Factors affecting extent of farmers participation in small-scale irrigation (SSI)

As shown in Table 6, the result of the second hurdle (truncated regression) indicates that adult labor in households, age of household head, land holding size, educational level of household head, annual income of households, and market distance were significantly affected extents (intensity) of farmers' participation in small-scale irrigation. The model results for significant variables are interpreted as follows.

3.3.1. Adult labor

the result of the second hurdle (truncated regression) indicated that extent of farmers' participation in small-scale irrigation was positively influenced by the availability of the adult labor force at 5% significance level. More specifically, a unit change in the adult labor force of household heads would increase the proportion of irrigated land by 7 %. Hence, irrigation users with a larger adult

labor force were more likely to expand their irrigated land size. This result is consistent with the finding of Kudaze et al. (2019), who found the availability of adult labor has a positive and significant effect on expanding land cultivated under irrigation. Adult labor was also included in both hurdles of the model, but this variable was significant only in the second hurdle. This indicates that the two decisions were determined by different explanatory variables. In other words, farmers might need a more adult labor force to expand their irrigated land size (Table 6).

3.3.2. *Age of household heads*

Like the result of the first hurdle, this variable has negatively influenced the extent of farmers' participation in small-scale irrigation. According to Table 6, the age of the household head negatively affected the extent of farmers' participation at 5% significance level. Furthermore, the coefficient of this variable showed that the proportion of irrigated land decreases by 0.6 % as the age of the household head increases by one year to a certain level. This indicated that, as farmers get older despite their farm experience, they tend to lose energy. Expanding irrigated land size may, therefore, be difficult for them. This result is in line with the report presented by Wakeyo and Gardebroek (2017) and Temesgen (2019). Like other variables, the age of household heads was incorporated in both first and second hurdles of the model, and the result implies the age of household head negatively affected both the participation and extent of farmers' participation in small-scale irrigation.

3.3.3. *Annual income*

As expected, household gross annual income has positively and significantly affected the extent of farmers' participation in small-scale irrigation at 1% significance level. Accordingly, a one unit (birr) increase in household annual income would increase the size of irrigated land by 58% (Table 6). This is due to the fact that households with a higher annual income could not be financially challenged to purchase different irrigation inputs and facilities at any time. This result is agreeable with the finding of Abebe (2017), who found households with better financial positions were expanding more land for irrigation. Like other variables, household income was included in both hurdles of the model, while the coefficient of this variable was significant in the second hurdle as a factor affecting the extent of farmers' participation in small-scale irrigation.

3.3.4. *Educational level*

The result of the second tier (truncated regression) also indicated the significant and positive effect of educational level on expanding irrigated land size. Based on the estimation result, the educational level of household heads had a significant and positive effect on farmers' decisions to expand their irrigated land size at a 10% level of significance. The coefficient of this variable implied that as household heads educational levels increase in the years of schooling to a certain level, that would increase the probability of farmers' expanding their irrigated land size by 4.5%. This implies educated farmers' are more willing to easily expand their irrigated land size than less educated farmers' in the study area (Table 6). This result is consistent with the findings of Wang et al. (2015) and Kudaze et al. (2019). Both farmers' ability to read and write and junior school education levels had a positive and significant effect on the first and second hurdle analyses. This indicates the crucial role of education in both the participation decision and the extent of participation of farmers.

3.3.5. *Land holding size*

Land is one of the most basic and mandatory natural resources as an input for agricultural production. The result in Table 6 also indicated that cultivable land size positively and significantly influenced farmers' decisions to increase cultivated irrigation land size at the 1% significance level. An increase in land holding size would increase the probability of households expanding their irrigated land size by 11.3%. This result implied that irrigation user farmers with larger land holdings were more likely to extend their irrigated land size than those with smaller land holdings. This result is consistent with the report presented by Pokhrelet al. (2018). Furthermore, land holding size was included in both hurdles, but it was significant only in the second hurdle.

3.3.6. Market distance

The result of the second hurdle also indicated that the distance of the market from household residence negatively and significantly affected the extent of farmers' participation in small-scale irrigation at 1% significant level. More specifically, as market distance increases by one walking hour, the likelihood of farmers expanding their irrigated land size decreases by 10.4% (Table 6). The long distance between the market and farmers' homes increases the difficulty of transporting agricultural inputs and outputs. This discourages them from selling their agricultural products to local retailers and reduces their profitability. Similar to this result, Wakeyo and Gardebroek (2017) reported a negative effect of market distance on the intensity of farmers' participation in small-scale irrigation.

4. Conclusion and recommendation

The purpose of this study was to identify determinants of farmers' participation and the extent (intensity) of participation in small-scale irrigation by using the double hurdle model. The study examined the effects of demographic, institutional, economic, and environmental factors on farmers' participation in small-scale irrigation. According to the findings of this study, farmers' participation was negatively affected by age, dependence ratio, farm distance from a water source, and topography. Farmers' participation in small-scale irrigation as part of their livelihood was positively affected by educational level, extension contact, and training access. The study also found that the availability of adult labor, agricultural land size, wealth, and educational level all influenced the intensity of irrigation to which farmers cultivated. In contrast, market distance and the age of household heads cause the proportion of irrigated land to decrease. These findings indicated that sets of explanatory variables were relatively influential on the dualistic decisions (participation and extent of participation) of farmers in small-scale irrigation.

Based on the findings of this study, the following recommendations are forwarded to all concerned stakeholders:

Access to frequent extension contact and training services positively and significantly influenced farmers' participation in small-scale irrigation. So, extension agents should provide the latest information on farm technologies related to irrigation via frequent extension service and by organizing training programs, demonstrations, and modern farm visits at the local level. Education had a positive and significant effect on farmers' participation and the extent of participation in small-scale irrigation. Therefore, the district agricultural office and educational sector should plan together to provide adult education by considering the living conditions of small-holder farmers in the study area. The distance between farm land and the water source hinders farmers participation in small-scale irrigation production; hence, governmental and non-governmental organizations should construct irrigation canals to deliver the water to the farmers' irrigation land. The result also indicated that farm land size had a positive and significant influence on the intensity of farmers' participation in small-scale irrigation. Therefore, the concerned stakeholders, including universities, research institutes, and agricultural offices, should initiate new technological practices to promote efficient land use techniques.

Acknowledgments

The authors wish to express their sincere gratitude to thank the farmers and local administrators of the study area for their assistance during the field work

Funding

The study was funded by University of Gondar.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Availability of data and material

The data sets are used and/or analyzed and included in the current study and can be available from the corresponding authors upon request

Authors' contributions

Getasew conceived the project idea and prepared the research proposal and instruments together with all co-authors. Data was collected by Getasew and coauthors have contributed to data analysis, manuscript write up, and review. All authors read and approved the final manuscript.

Citation information

Cite this article as: Farmers' participation in small-scale irrigation in Amhara region, Ethiopia, Getasew Daru, Degsew Melak, Wondim Awoke & Sinkie Alemu, *Cogent Economics & Finance* (2023), 11: 2213951.

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