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Determining Factors Influencing the Adoption of Spate Irrigation in Guguf, Northern Ethiopia

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Abstract
Spate irrigation is the diversion of floods running off from mountainous catchments, diverted by hydraulic structures and applied to low-lying irrigable fields in arid and semi-arid areas to improve farmers' livelihood. Despite its higher potential to support the livelihood of farmers, spate irrigation has received less emphasis. Given this, the study attempted to determine factors affecting farmers' adoption of spate irrigation. The study was carried out in 2018 on 150 households selected using systematic sampling from three irrigation schemes located along the Guguf stream, northern Ethiopia. A questionnaire with 0.82 reliability was employed for the collection of the required data and analyzed using binary logistic regression model. Results revealed that out of the sixteen explanatory variables entered into the binary logit model nine of them were found statistically significant at ($p \leq 0.10$) to estimate the likelihood of farmers' participation in spate irrigation. These are a distance of plot from diversion head and residence, sex of household head, livestock in the tropical unit, farm size, farm experience, farm ownership, spate water availability and age of the household head. Thus, training, market support and supporting females are required.

Keywords: Guguf, spate irrigation, adoption, Weynalem, Waekel, Kusra, Northern Ethiopia
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1. Introduction

Water is associated with life (Abrha, 2006). Most notably, access to safe and sufficient water is a basic human right. However, in arid and semi-arid areas, water is scarce. Moreover, the allocation of this scarce resource is a major challenge for people living in these areas (Abraham Mehari, 2007). According to David & Ploeger (2014), approximately 2.8 billion people live in river basins affected by physical water scarcity.

Studies show that about 270 million ha in the world is irrigated (Dejen, 2011) but its contribution to global food production is 40%. Similarly, 6% of the 209 million ha arable land in Africa is under irrigation. In Ethiopia, the situation is even worse with irrigated land of only accounting for 170 thousand ha of the 3.5 million ha irrigation potential (Haile, 2015). Hence, the country has not yet been capable to meet the basic food demand of its rapidly growing population.

Using spate irrigation is a direct way for farmers to cope with water stress (Ajani, 2013; FDRE, 2002). Spate irrigation systems solve local problems and run natively through which local resources are used to decrease the cost of irrigation infrastructures and cause local societies capable (Habtu & Yoshinobu, 2006). In many environmentally marginal areas ranging from arid to semi-arid areas of mainly Africa and Asia where spate irrigation flourish (Briggs, 2005; Mehari Haile et al., 2005), there are often insufficient scientific answers available to overcome local problems with the resources available (Morgan et al., 2012). Feasibility studies also suggest that spate irrigation can support many farmers in many irrigable areas (Ham, 2008; Negash et al., 2019).

Spate irrigation is practiced in many semi-arid lowlands of Ethiopia. The low-lying areas settlers of Guguf stream highly rely on the utilization of floods generated from the surrounding mountains for their livelihood. These practices have been playing a vital role in improving the livelihood of farmers in the country. However, the adoption of floods for irrigation is affected by different factors (Nazari et al., 2018). The factors influencing farmers' participation in perennial streams irrigation have been examined by different researchers (Aseyehegn, et al., 2012; Kangalawe et al., 2014; Yehzbalem, 2005) and they have concluded social, economic, and institutional factors affect adoption of irrigation, but little research has focused on factors influencing farmers' participation in spate irrigation. Given this, the main objective of the study was to analyze factors that determine the adoption of flood irrigation in Guguf, Raya Valley, Ethiopia.

2. Materials and Methods

2.1 Study area

The Guguf catchment is geographically located between 12° 42' – 12° 49' N latitudes and 39° 31' – 39° 45'E longitudes. Guguf stream originates from the high lands of Enda Mokoni district including mountain Tsibet, the highest mountain in the northern region, Tigray. The altitude of the Guguf catchment ranges between 1523 and 3055 m.a.s.l. Figure 1 shows the geographical location of the study area.

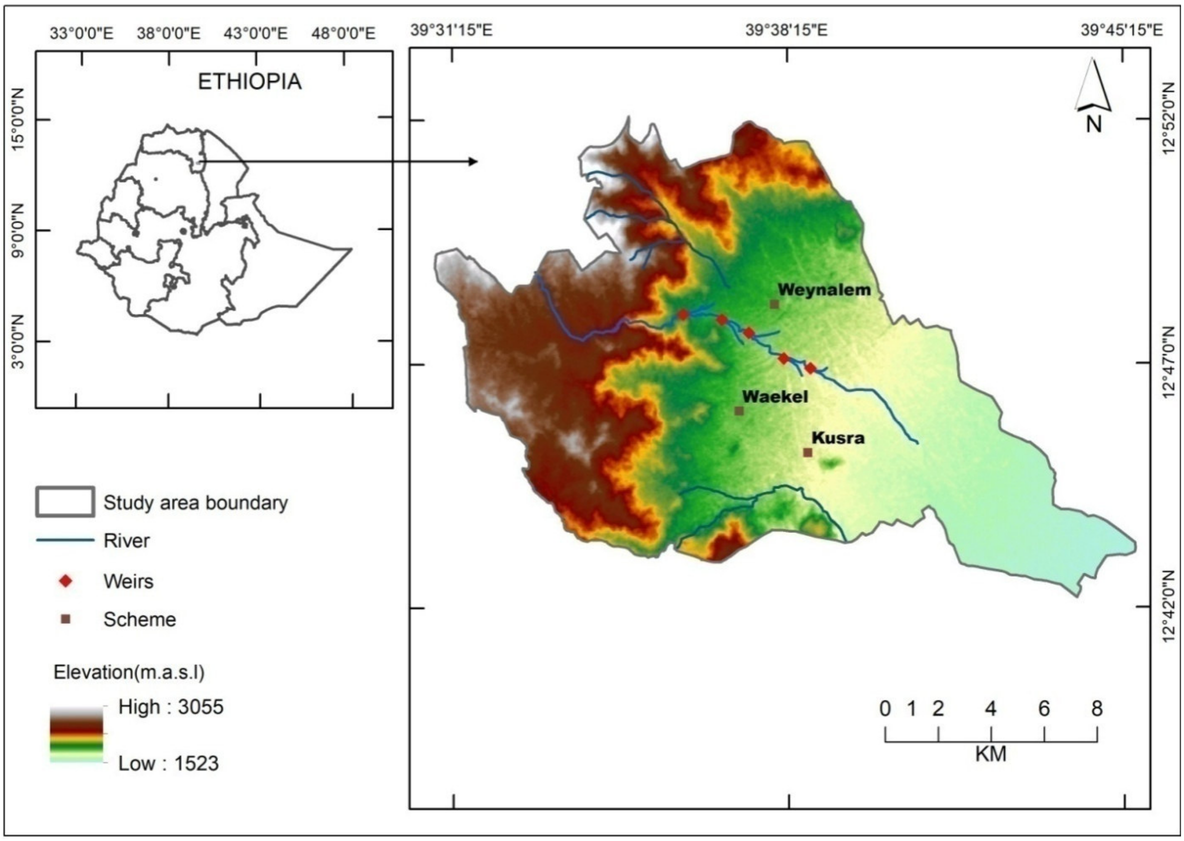

Figure 1: Location of the study area Produced Using Arc GIS 10.3

The upper watershed, which is characterized by steep mountains of high elevation and gently sloping hills is the dominant supplier of water, sediment and nutrients for the low-lying Guguf River irrigated fields. Weynalem, Waekel and Kusra are the three schemes in the upper, middle and lower reach of Guguf River respectively. The catchment has an average annual rainfall of 683.2 mm and an average annual temperature of 21.5 ^{0}c (NMA, 2017).

In general, two rainfall seasons can be observed in the study area: little rains (Belg), which generally occurs from March to May, and the summer (Kiremt) that take place from June to September. Irregularity of the rainfall distribution within a growing season and variability of onset and offset of the rainy seasons are main constraints for the dryland crop production. Thus, the farmers in the study area adopt flood to compliment rainfed agriculture. The spate irrigation system under Guguf stream is one of the ancient irrigation areas in the region which covers 650 ha. (Haile et al, 2013). This ephemeral stream water is used for irrigation, drinking and other domestic purposes. The spate flow from the stream supplies many command areas in Raya Valley. However, the flood decreased by 0.23×10^{6} m^{3} yr^{-1} from 1980-2015 (Negash et al., 2019) making its adoption difficult. The spate flow from Guguf supplied Weynalem, Waekel, and Kusra schemes. Each scheme has different diversion weir (Figure 1), main diversions (Maegels) and canals (Melwen) to convey water to the field. The three schemes under Guguf catchment have share management arrangements in common and govern their respective diversions to adopt flood for irrigation. The schemes are named by their near villages where most irrigators are located.

2.2 Materials and Methods

A survey design was employed to investigate the adoption of the spate system. The population for this study consisted of participating and non-participating farmers in Guguf spate irrigation system. The number of the beneficiary and non-beneficiary households of the schemes of Guguf was 800 (Haile, 2013) and 738 respectively of which about one third were female-headed households (ARDORAD, 2016).

Table 1: Total households and their participation in spate irrigation

Sample	Users				Non-Users				Total HH	
Site	Male	Female	Total	%	Male	Female	Total	%	No	%
Weynalem	247	40	287	19	140	100	240	15.6	527	35
Waekel	278	50	328	21	143	109	252	16.4	580	37
Kusra	153	32	185	12	147	99	246	16	431	28
Total	678	122	800	52	430	308	738	48	1538	100

Source: (ARDORAD, 2016; Haile, 2015)

From Table1 it can be observed that the number of irrigator households was higher in Waekel (21%) scheme and lower in Kusra scheme (12%) which may indicate at the downstream (Kusra scheme) the flood is not reliable while at the top stream (Weynalem scheme) it may be erosive to divert. Different strategies can be used to determine the sample size. This study applied the following equation (Kangalawe et al., 2014).

$$n = \frac{\left[\frac{z\alpha}{2}\right]^2 P(1-P)}{M^2} = 150$$

Where n stands for sample size, p (0.5) is the assumed proportion of irrigators of the population in the schemes considered, the two-tailed critical value at 95 % confidence interval given by $\frac{z\alpha}{2}$ is 1.96 and M (0.08) is the estimated marginal error between the population mean and sample mean. Therefore, based on the equation the required sample size for the entire irrigation system was estimated to be 150 households. 10% of the users and non-users from all the three schemes were selected proportionally. 78 farmers who participate and 72 farmers from the non-users in the irrigation system were sampled.

Table 2: Sample of Household Heads and their Participation

Sample	Users				Non-Users				Total HH	
Site	Male	Female	Total	%	Male	Female	Total	%	No	%
Weynalem	24	4	28	19	14	10	24	16	52	35
Waekel	27	5	32	21	14	11	25	17	57	38
Kusra	15	3	18	12	13	10	23	15	41	27
Total	66	12	78	52	41	31	72	48	150	100

Source: Computed from the Target Population, 2017

First Weynalem, Waekel and Kusra schemes were purposefully selected because the spate irrigation that the researcher sought to assess is not practised in all villages of the 'Tabias' crossed by Guguf stream. Next households were selected using systematic sampling as it is an easier and less costly way of sampling as the list of households' heads was available in their respective administrative units of the villages. The K^{th} household head was selected using the formula K = $N//n$. Where K is the K^{th} household from the list, N is the total number of households across the system and n is the proportionate size (sample size) from each scheme surveyed.

A questionnaire was used to gather data about the factors that influence the adoption of spate irrigation by farmers. The questionnaire was administered to 150 respondents. Questions were pretested on 30 respondents (10 female and 20 male) before the commencement of the main. The pretesting was done in Burqa spate irrigation scheme which has similar irrigation practice with the study area. The reliability of the questionnaire was found to be 0.82 indicating high correlation of responses among farmers. Besides, observation and focus group discussion was used to collect data.

Data were analysed using binary logistic regression model. It was used to determine the factors that predict farmers' participation in spate irrigation. By reviewing related literature the researcher identified institutional, social and economic factors that affect farmers to adopt irrigation practices (Hosseini et al, 2011). Besides, the Chi-square test, descriptive statistics like frequencies, mean and standard deviation were also used for comparing differences in the distribution of categorical data. T-test was also employed to compare the mean of continuous variables of users and non-users of spate irrigation. Statistical package for social science (SPSS) version 20 software was employed to analyze the data.

2.3 Binary Logistic Regression Model

This model was used to analyze which, how and how much the assumed predictors affect farmers to use spate water for irrigation. The dependent variable, in this case, is a dichotomous variable which takes the value of 1 if the respondent uses spate irrigation and 0, if otherwise. The explanatory variables included in the study were of both types i.e. binary and continuous depending on the nature of the variable to be considered (Creswell, 2014).
In adoption studies, responses to a question such as whether farmers adopt a given practice could be 'yes' or 'no', a typical case of a dichotomous variable. A variety of statistical models can be used to establish a relationship between factors and adoption of technologies or practices. The models for analyzing dummy dependent variables are linear and non-linear probability models. The non-linear models have weaknesses such as generating predicted values outside the 0-1 intervals, which violate the basic tenets of probability; the variance of the disturbance term is heteroskedastic and the assumption of normality in the disturbance term is no longer tenable (Maddala, 1983).
The inadequacy of the linear probability model suggests that a non-linear specification may be more appropriate and the appropriate model for this is S-shaped curve bounded in the interval of 0 and 1. The S-shaped curves satisfying the probability model as those represented by the cumulative logistic function (logit) and cumulative normal distribution function (probit). In most applications, the models are similar the main difference is, logistic distribution has slightly flatter tails which indicate the conditional probability Pi approaches to 0 as the value of explanatory variables gets smaller and smaller or 1 at a slower rate as the value of explanatory variables gets larger and larger than probit (Gujarati, 2003). The choice between these two models revolves around practical

concerns such as the availability and flexibility of computer program and experience.

The primary reasons for choosing the logistic distribution are 1) from a mechanical point of view, it is an extremely flexible and easily used function, and 2) it lends itself to a meaningful interpretation. The logit model is simpler in estimation than the probit model. Therefore, in this study, a binary logistic regression model was used to analyze the factors influencing the adoption of spate irrigation in Guguf spate irrigation system

Model Specification

According to Maddala (1983), the binary logit model can be used without any change even with unequal sampling rates. Logit is the natural logarithm of the odds ratio. In this study, the model was used to estimate the probability of farmers' participation in spate irrigation practice. The logit model is specified as follows:

$P_i = \frac{1}{1+e^{-Zi}}$ .... (1)

Where P_i is the probability to use spate irrigation for the i^{th} farmer, e is the base of natural logarithms and Zi is a function of m explanatory variables (Xi) and expressed as:

$Zi = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m$ ....(2)

Where β_o is the intercept and β_i are the slope parameters in the model. The slope indicates how the log-odds in favour of the decision to manage spate water for irrigation change as explanatory variables change. Since the conditional distribution of the outcome variable follows a binomial distribution with a probability given by the conditional mean Pi, interpretation of the coefficient will be understandable if the logistic model can be rewritten in terms of the odds and log of the odds. The odds to be used can be defined as the ratio of the probability that a farmer uses (Pi) to the probability a farmer does not use (1-Pi). But

$(1-P_i) = \frac{1}{1+e^{-Z(i)}}$ .... (3)

Therefore, $(\frac{Pi}{1-Pi}) = \frac{1+e^{Z(i)}}{1+e^{-Z(i)}} = e^{Z(i)}$ .... (4)

and $(\frac{P(i)}{1-P(i)}) = \frac{1+e^{Z(i)}}{1+e^{-Z(i)}} = e^{\beta o} + \sum_{i=1}^{m} \beta i\, Xi$ .... (5)

Taking the natural logarithms of the odds ratio of equation (5) will result in what is called the logit model as indicated below.

$\ln (\frac{P(i)}{1-P(i)}) = \ln\ [e^{\beta o} + \sum_{i=1}^{m} \beta i\, Xi] = Z_{(i)}$ ....(6) If the disturbance term Ui is considered, the logit model becomes:

$Z_{(i)} = \beta o + \sum_{i=1}^{m} \beta i\, Xi$ .... (7)

Where Zi represents a farmer's adoption of spate irrigation (dependent variable). Therefore, the above binary logit econometric model was utilized for the study to analyze factors that influence farmers to use spate water for irrigation.

Famers' decision to use or not to use spate irrigation at any time may be influenced by the combined effect of socio-economic and institutional factors which are related to their objectives and constraints. In the course of determining factors influencing the adoption of spate irrigation, the main task was exploring the factors potentially influence and how (the direction of the relationship) these factors are related with the dependent variable. The factors affecting the utilization of spate water irrigation were analyzed using a binary logit model and the analysis was done at the household level. The model specifies a functional relationship between the probability of utilization of spate water for irrigation and various explanatory variables. The variables to be used in the logit model are defined below.

The dependent variable of the model is dichotomous representing the preferred status of the farmers to adopt spate water for harvest. It was represented in the model by (1) for those farmers who use spate water for irrigation and (0) otherwise for those farmers who are not using spate water.

Table 3: Definitions of variables used in the regression analysis

Expected direction of the relation between HHs characteristics and decision to participate in SI		
Explanatory Variables	Variable definition and level of measurement	direction of relationship
SEX	Sex of household head; binary 1 if male, 0 else	(+)
AGE	Age of the household head in years; continuous	(+)
HHLAB	Household labor is man equivalence; continuous	(+)
HHLIT	Literacy status of household head, binary 1if literate, 0 otherwise	(+)
EXTCON	Number of extension contact farmer contacted, 1if yes, 0 else	(+)
TRAINING	SI Training received by farmers; binary, 1 if yes, 0 otherwise	(+)
CREDIT	Credit access of household head; Binary 1if yes, 0 otherwise	(+)
DISTMKT	The average distance of a market from the homestead in minutes	(-)
OFF-FARM	Engagement of farmer in off-farm employment 1 if engaged, 0 else	(+)
FARMSIZE	The size of the plot in hectare; Continuous	(+)
LIVESTOCK	Livestock holding in TLU	(+)
PLOHODST	The average distance of plot from home in a minute; Continuous	(-)
TENURE	Weather farmer perceives a risk of loss of land 1 if perceive 0 else	(+)
FARMEXP	Farming experience of a farmer in years	(+)
PLODIVDIS	The average distance of plot from diversion head in minutes	(-)
FLOODAV	Flood availability as perceived by farmers' 1 if available, 0 else	(+)

Note:
Dependant variable- decision to adopt SI
Signs (+/-) in braces indicate the expected sign of coefficients of the specified variable to spate irrigation participation

Source: Own Design, 2017

3. Results and Discussions

3.1 Socio-economic characteristics of farmers

In this section, the household characteristics of participants and non-participants were presented and selected variables were used for logistic regression analysis in section 3.1.2. In addition to tabular presentation and description of variables, all variables under consideration were tested to see their statistical significance. The household characteristics that determine farmers' participation in spate irrigation activities comprise social, economic, and institutional characteristics.

As shown in Table 4, the variable household sex was related positively and significantly with the utilization of spate irrigation. The result was in line with that of the expectation. The chi-square test of sex distribution between the two groups was run and the difference was found to be significant ($\chi 2=27.31$ df. 1 Sig. at $P \leq 0.01$). The findings reveal that out of the total sampled household heads of users and non-users 84.62 % and 56.94 % respectively were male and only about 15.38% and 43.06% were females respectively. The study found a positive relationship between sex (maleness) and use of spate water for irrigation. The positive sign implies that the male-headed households were better in using spate water irrigation than female household heads.

Due to cultural influences, most of the time male household heads tend to work in spate irrigation activities. This situation limited female-headed households from participation in spate irrigation and reduces their ability and willingness to involve in spate irrigation. Moreover, most spate irrigation activities are more labor-intensive and associated with risks (for instance diverting flood during the night for irrigation) which are physically difficult to be performed by female-headed households. Male headed households have a better likelihood to use spate irrigation than female-headed households. The findings of Zainab (1998) also agree with the sex of the household heads determines their participation in irrigation.

It is expected that those farmers with increased formal education be disposed to decide to participate in spate water harvesting practices. Thus, educational level is hypothesized to influence the adoption decision of farming households positively. Generally, it is believed that exposure to education increases the farmers' management capacity and reflect a better understanding of the benefits of better irrigation management practices. From this perspective, there seems to be lack of high level of education among the sample households in the Guguf spate system. This variable, therefore, has a significant positive influence ($\chi 2=11.76$ df.=1 Sig. at $P \leq 0.05$) on the adoption of spate irrigation. This could be an implication that users of spate water harvest practice had better educational status than non-users. Empirical evidence indicates that the higher the level of education, the greater is the possibility for farmers to become aware of the uses of better agricultural practices for securing food self-sufficiency (Shiferaw et al, 2002).

Studies did so far indicate that age affects the farmers' participation in irrigation use (Hadush, 2014). It may have a positive or negative effect on the adoption of irrigation practice. With age, a farmer may get experience and can react in favor of the use of better technologies. Age of household head can determine the decision of farm household to participate and use spate water. The average age of the total sample household heads was 44.3 years, indicating that most of them are still capable of farming. Table 4 showed that the average age of the sampled households was found to be 48.13 and 40.5 for users and non-users respectively. The analysis of t-test (t=5.22, p=0.000) confirmed that there is a statistically significant mean difference in age of users and non-users.

The average number of available labor for users and non-users was found to be 2.21 and 1.82 respectively (Table 4). Results of t-test (t=3.1, p=0.002) showed that labor availability is an important factor in spate irrigation participation. The researchers' observation also revealed that spate irrigation structure activities are more labor-intensive for construction of water harvesting structures, and watering crops which are performed by active age male-headed households. Thus, farmers who have more labor are expected to adopt spate irrigation than those who had a shortage of labor. The study result shows that users have more active household member than non-users. Labor requirement reaches its peak during the main agricultural period when spate irrigation activities, land preparation, sowing, weeding, harvest and movement to and from the market were undertaken. The focus group discussion held with the farmers indicates that the farmers with a shortage of labor employ daily labor for agricultural practices when the over mentioned practices overlap (locally called Wagle). This result matches with the prior expectation that the variable influences the adoption of spate irrigation positively.

Age may have a positive effect on the adoption of spate irrigation. With age, a farmer may get experience about his/her and can react in favor of the use of better irrigation practices. Table 4 indicates that farmers of Guguf spate system have relatively rich experiences of agriculture. The distribution of experience among the sample households indicates that the mean experience of users and non-users were found to be 26.56 and 24.43 years respectively. The implication is that users have higher years experience than that of non-users of spate. Furthermore, the age by experience in agriculture cross-tabulation data indicates that the relatively older farmers have better experience in agriculture. The result of t-test (t=7.94, p=0.000) indicates that experienced farmers tend to use spate than non-experienced farmers (Table 4). The result confirmed with a prior expectation in that with longer experience in farming, wide knowledge and experience is gained, enabling farmers to perceive risks and constraints related to the effective transfer of new experiences and coping mechanisms. This implies that long experience increases the probability of adopting spate irrigation practices.

Table 4: Description and summary statistics (mean and percentage) of the variables used in the binary logistic model (n=150)

Variable	Description	Users	Non-users	Significance
Adoption	Dependent variable: decision to adopt (%)	52	48	
Sex [b]	Sex of the respondent (%)			0.000[c]
	Female (%)	15.38	43.06	
	Male (%)	84.62	56.94	
Literacy [b]	Literacy status of the household head (%)			0.001[c]
	Literate (%)	65.38	62.5	
	Illiterate (%)	34.62	37.5	
Extension advice [b]	Extension advise a farmer receive (%)			0.72
	Get advice (%)	69.2	44.1	
	Not get advice (%)	30.8	55.9	
Training [b]	Training about spate irrigation farmer received (%)			0.000[c]
	Take training (%)	33.3	27.8	
	Not take training (%)	66.7	72.2	
Credit [b]	Credit access to the household (%)			0.001[c]
	Get access (%)	76.9	48.6	
	Not get access (%)	23.1	51.4	
Off-farm [b]	A farmer engaged in off-farm employment (%)			0.000[c]
	Engage (%)	37.18	15.28	
	Not engage (%)	62.82	84.82	
Tenure [b]	Farmers' perception towards tenure (%)			0.000[c]
	Yes %	96.2	69.5	
	No (%)	3.8	30.5	
Diversion-plot dist. [a]	Mean distance of plot from diversion head in minutes	16.47	38.26	0.000[c]
Age [a]	Mean age of household head in years	48.13	40.5	0.000[c]
Household labor [a]	Mean household labor in man equivalence	2.21	1.82	0.002[c]
Market-home dist. [a]	Mean distance of market from a homestead in minutes	38.7	44.8	0.01[c]

Table 4: Description and summary statistics (mean and percentage) of the variables used in the binary logistic model (n=150)

Variable	Description	Users	Non-users	Significance
Farm Size [a]	Size of a farm in hectares	1.01	0.81	0.000[c]
Livestock [a]	Livestock holding in TLU	6.45	4.91	0.000[c]
Plot-home dist. [a]	Mean distance of plot from a homestead in minutes	34.42	39.44	0.011[d]
Flood availability [b]	Availability of flood as perceived by farmers (%)			0.000[c]
	Available (%)	75.98	42.1	
	Not available (%)	24.02	57.9	
Experience [a]	mean farm experience of household head in years	26.56	24.43	0.000[c]

Source: Survey Result, 2017
n= Number of respondents =150
Continuous variables and use t-test
b Dummy variables and use $\chi 2$ test
c and d represent significant at 1% and 5% respectively

Farm size is an indicator of wealth and social status. Larger farm size may encourage farmers to invest and can bear the risk in case of crop failure. The results (Table 4) show that the farm size of users is higher than non-users. The p-value also confirmed that there is a significant mean difference of farmland size for users and non-users indicating the farmers with larger farm size in the Guguf spate irrigation had more likelihood to adopt spate irrigation. Teklehaimanot (2003) also reported a positive association between farm size and adoption of water harvesting technology.

Livestock plays a significant role in the farming system of Guguf spate system. Livestock holding size is one of the indicators of a wealth of the household in the study area. To indicate the livestock holding of each household, total tropical livestock unit (TLU) per household was calculated. Their main contribution is oxen kept for providing draft power, income generation, cows to provide farm households with milk and butter for consumption and sale, donkey and camel for transporting goods, whilst sheep, goats and poultry are mainly kept for sale as well as for their meat. The livestock holding size varied between the considered categories of farmers. The average livestock size owned by users and non-users of spate irrigation was 6.45 and 4.91 respectively (Table 4). Spate irrigation users have relatively large livestock size than non-users. Tropical livestock unit owned (TLU) is found significant at ($p \leq 0.001$) and affect adoption positively. This means that those farmers who own large livestock units tend to adopt spate irrigation. The more livestock ownership is considered as more asset possession, which in turn leads to an investment decision. (Yehzbalem, 2005) have reported a positive and significant relationship between tropical livestock units owned and adoption of water harvest technology.

Non- farm activities refer to non-agricultural activities in which households working as casual in activities outside agriculture, pretty trade or self-employed in similar activities. Of the total sampled household, only 26.7 % involved in non-farm activities. The analysis between the categories shows that 37.18% of the users were involved in non- farm activities while 15.28% (less than half of the users) of non-users were involved in non-farm activities (Table 4). Farmer's involvement in nonfarm income is positively correlated ($p \leq 0.000$) with participation in spate irrigation. The focused group discussion undertaken with farmers revealed that the main constraints for using spate irrigation were finance, technological, know-how and labor. The success of an irrigation system in a given community may depend on whether it is technically effective and financially beneficial to the community. Therefore, the farmers who earn money from non-farm activities have a better likelihood to adopt spate irrigation. A positive and significant association between non-farm income and adoption of water harvest technology has also reported by (Boyd et al., 2000).

As indicated in Table 4, 44.1 per cent and 55.9 per cent of the non-users and users get agricultural extension advice respectively. More contact may help a household to be convinced by the development agent to participate in spate irrigation. However, the Chi-Square result (χ^2= 3.23, df. 1 at $p \leq 0.05$) is not consistent with the prior expectation as the value of p is 0.72) that the frequent access of extension service is a potent force which accelerates the effective dissemination of agricultural information to farmers.

Agricultural credit is an important institutional service to finance poor farmers in a rural area. In this study access to credit was expected to increase the probability of using spate water harvest. Farmers reported several problems like lack of capital, technology, lack of skill, labor and market problem associated with spate water irrigation activities. Shortage of credit hampered improvement in crop and livestock productivity. The survey result indicates about 76.9% and 48.6% of the user and non-user respondents got credit. This implies that spate water users had better access to credit compared to non-users. The Chi-Square result (χ^2= 10.67, df. 1 at $p \leq 0.05$) also confirmed that there is a significant difference in getting credit between spate irrigation users and non-users. In this study, most sampled households faced with a shortage of working capital for crop and livestock production.

Land tenure issues can have a variety of influences on spate irrigation. Land tenure is an important institutional issue that is of relevance to water harvest practices. Farmers need to get a minimum level of land security that assures those benefits from their investments in spate irrigation. Lack of tenure may cause people to be reluctant to invest in spate water on land, which they do not formally own. Farmers like to construct bunds because it implies a more definite right of ownership (Bossio et al., 2013). In the study area, the major means of land acquisition was through land distribution and inheritance. The survey result revealed that about 96.2 per cent of users and 69.4 per cent of non-users own land. Table 4.12 indicated that the vast majority of the users cultivate their land themselves. According to the discussion held with the farmers even most of those farmers who share outcrop give to their relatives. The land tenure was found statistically significant at (P ≤ 0.01) probability level.

For proper implementation and effective utilization of spate irrigation, farmers need training on operation up to maintenance level. In this study, components of training such as field visit, and demonstration trials which focus on upgrading farmers' knowledge and skills on operation and maintenance of water harvest structures were assumed to improve adopting of spate irrigation. Training and visiting in different water harvesting activities are expected to be correlated significantly with the spate water harvest utilization. Of the total respondents, about 33.3 % of user households have participated in training on irrigation while 66.7% do not have. 27.8 % and 72.2% of the non-users were trained and not trained respectively. Training given by rural development workers gives due emphasis to crop production, spate irrigation activities, water use and management. The Chi-square result for training revealed that there is a significant difference between the groups at 1% probability level (Table 4). (Teklehaimanot, 2003) reported a significant and positive association between training and adopting water harvest practices.

Farmers whose plots are found nearer to the diversion head and their residence are more likely to use spate irrigation because the time and energy required are lesser than those farmers whose plots are found at a distant location. The mean residence-plot distance of users was found 34.4 minutes which is relatively shorter than non-users 39.4 minutes. As indicated in Table 4, the distance between farmers' home and the plot had a negative relation and was found statistically significant at 5% probability level. This implies that farm households with a low distance between homestead and plot have closer supervision of the plot on which spate water harvesting is practiced. Bekele (2003) found a negative correlation between the distance of a plot from dwelling and conservation decision. The result of this study, however, agrees with the finding of (Yehzbalem, 2005). The study shows a negative association between the use of spate irrigation and distance between diversion head and plot (P ≤ 0.00). As farmers are nearer to head weir, there would be a chance of frequent contact than who lives at a further distance.

Promotion and adoption of spate irrigation need ease market access for delivery of heavy and perishable commodities for products. Many respondents have stated that market place is the main place to exchange any information. Farmers are also motivated to use improved agricultural technologies if they have access to an attractive market for their output to sell at a good price. The mean distance between residence and market of non-users and users were 4.48 and 3.9 km respectively. Thus, implying the mean market distance of users from their residence is lower than the non-users. If farmers are closer and having access to market services, they can easily purchase improved agricultural inputs and sell their agricultural outputs without moving long distances. The longer the distance from the market, the more time it takes and the cost of transportation may lessen the loose market value. It was hypothesized that those farmers who live in remote areas are in most cases reluctant to use spate irrigation. This is possibly because they have limited access to modern agricultural inputs and market access for some easily perishable products. Table 4 indicates that distance of the market place from the dwelling can affect the adoption of spate water harvest practice at 1% probability level.

3.2 Determinants of households' participation in spate irrigation using binary logit model

In this section, the analysis of selected explanatory variables that were expected to have an impact on the decision of a given Famer on using spate irrigation was presented. The binary logistic regression model was fitted to estimate the effect of hypothesized explanatory variables on the probability of being users or non-users of spate irrigation. As discussed earlier (section 2.3), the logit model was used to analyze the determinants of the farmers' spate irrigation. Before running the binary logistic regression analysis, both the continuous and discrete explanatory variables were checked for the existence of multi-collinearity problem using Variance Inflation Factor (VIF) and contingency coefficients, respectively. The results reveal that there was no problem of association among the explanatory variables.

Sixteen independent variables were selected based on theoretical explanation and the results of various empirical studies. Out of the sixteen explanatory variables hypothesized to influence spate irrigation in the study area, nine were found to be significant at less than or equal to ten per cent probability level. Table 5 shows the sign, magnitude and statistical significance of the estimated parameters and how much the observed values were correctly predicted by the logistic regression model. The model result shows that the logistic regression model correctly predicted that 86.7 per cent of the sample households. The sensitivity (correctly predicted spate water users) and the specificity (correctly predicted non-users) of the logit model were 82.1 and 91.7 per cent, respectively. Thus, the model predicts both groups accurately (Table 5).

The results of the model, Table 5, confirm a prior expectation in that participation of farmers in spate irrigation was influenced by several factors. The effect of the model estimates was interpreted about the significant explanatory variables as follows. Hence, based on the model result, distance from plot to weir (diversion head) and from residence to plot were found to have a negative sign, while the remaining significant variables sex, livestock in total tropical unit (TLU), farm size, farm experience, farm ownership, spate water availability and age of the household head were positively associated with participation of farmers' in spate irrigation. Based on the model $Z_{(i)} = \beta o + \sum_{i=1}^{m} \beta i Xi($ section 2.3), the variables that explained farmer's adoption of spate irrigation were presented below.

Table 5: Binary logistic regression model estimation of farmers participation in SI

Predictor Variable	Estimated Coefficient (B)	Standard Error	Wald Statistics	Level of Significant	Expedition
Sex of HH	1.753	0.944	3.449	0.063*	0.173
The education level of HH	0.055	0.764	0.005	0.942	1.057
Extension Contact	0.924	0.718	1.654	0.198	0.397
Training SI	0.497	1.383	0.320	0.984	1.614
Access to Credit	1.889	0.732	6.666	0.101	0.151
Non-farm Income	1.019	0.753	1.835	0.176	0.361
Land Security	2.236	0.932	5.752	0.016**	0.107
Plot-Weir Distance	-1.197	0.708	2.860	0.091*	0.302
Age of HH	0.117	0.046	6.337	0.012**	1.124
Man-Equivalence	0.270	0.593	0.208	0.648	0.763
Home-Market Distance	-0.105	0.351	0.090	0.746	0.900
Farmland Size	2.047	0.971	4.445	0.035**	7.746
Livestock in TLU	0.965	0.292	10.933	0.001***	2.624
Home-Plot Distance	-0.578	0.312	3.444	0.064*	0.561
Availability of Spate W	1.398	0.601	5.407	0.020**	0.247
Farm experience of HH	0.249	0.070	12.667	0.000***	1.283
Constant	-13.03	5.6	0.000	0.997	0.000
Sensitivity	82.1%				
Specificity	91.7%				
Correctly predicted	86.7%				
Log likely hood	67.96				
R-square	0.809				
Number of Observation	150				

Source: Survey Result, 2017

***Sig. at 1%, **5% and *10% probability level

Adoption= -13+ (1.753*Sex) + (2.236*Tenure) + (–1.197*Plot weir distance) + (0.117*Age) + (2.047*Farm size) + (0.965*TLU) + (- 0.578*home plot distance) + (1.398 *Spate availability.) + (0.249*Farm experience)

Sex of household head has significant positive influence with the adoption of spate irrigation ($p \leq 0.10$). The result was in line with that of the expectation. Therefore, based on the equation the farmer's likelihood to adopt spate irrigation could be determined as:

$\text{Adoption}_{\text{Sex-Male}}$ = -13+ (1.753*1) + (2.236*1) + (–1.197*30) + (0.117*35) + (2.047*0.78) + (0.965*2) + (-0.578*20) + (1.398 *1) + (0.249*15)
= -41.407

An odds ratio of 41.407 gives a probability of 41/ (1+41) = 0.97 or 97%. Therefore, a male farmer with this particular pattern on the predictor variables was found extremely likely to adopt. This could be because of a cultural belief that prohibits female from some labour demanding works, such as operation and maintenance of irrigation structures.

As hypothesized earlier, the variable farming experience influenced the adoption of spate irrigation positively and significantly at ($p \leq 0.01$) probability level. The farmers who have long years of experience in farming have used spate irrigation than those who have lower years of experience in farming. This showed that the experienced farmers may use their experience and practice developed from a long period of close contact with nature of using and taking the advantages obtained from utilization and also they may develop the confidence in handling the risk and the better income from spate irrigation practices. Similar findings were also reported by (Yehzbalem, 2005).

Availability of relatively appropriate farm size is highly important to motivate farmers to invest in their farm. Farm size was positively related to the utilization of spate water and significant at ($p \leq 0.05$) probability level. This constitutes with what was expected earlier large farm size constitute to utilize spate water for irrigation. The positive relationship shows that the larger the size of the farm in favor of the probability of utilization of the spate irrigation increases.

Ownership of livestock (in TLU) influences the utilization of spate for irrigation. As livestock labor, product and income increase the utilization of spate irrigation increase, it was found significant at ($p \leq 0.01$) probability level and affects the decision to participate positively. This means that as farmers own large livestock units, the probability to involve in spate irrigation increases. This is due to more livestock ownership is considered as more asset possession, which in turn lead to invest or spend time, energy and effort in irrigation. The other is that as farmer own large livestock population; they need to have available fodder to provide their livestock population.

Distance between home and plot is significant at ($p \leq 0.1$) and related negatively with the farmers participating in the spate irrigation activities. The result is consistent with the idea in the assumption, which means those farmers who are near to their plot may have more likelihood to use spate irrigation. The reason may be households who live at a remote place from their plot get difficult to supervise plots and control spate water including floods occurring in the night.

The age of the household head positively affects the probability of participation in spate irrigation. As the age of the household head increases by 1 year up to a certain level, the probability of participation in spate irrigation would increase by 11.7% marginal effect, other variables in the model remaining constant.

The irrigation water found in the study area is flood water of river diversion which uses gravitationally with canals. Availability of irrigation water is statically significant ($p \leq 0.05$) and positively motivates the household head in spate irrigation participation and adoption. This coincides with the fact that the more the availability of spate water in the command area he/she will be encouraged to participate in the irrigation system. Therefore, those household heads that are with more floodwater availability near their farmland are 13.89% more likely to participate in the spate irrigation system than those households who have less availability of water for irrigation.

Distance between plot and weir correlates negatively with the utilization of the spate water harvesting and was significant at ($P \leq 0.1$) probability level. The interpretation of this implies that those households who own farmland that is close to the head diversion (weir) tend to use spate irrigation than those who own farmland located far from the weir. The reason for this could be, as the plot distance from the weir is smaller the reliability of spate water to utilize for harvest increases.

The findings show that land security was found significant ($p \leq 0.05$) and has a significant impact on the probability of adoption of spate irrigation. Thus, households who have their farm are more probably encouraged to invest more in including diverting spate water irrigation systems than that share or rent others farm. As the marginal effect of the above econometric result shows that household heads that own farmland are more likely to participate and adopt a spate irrigation system than those household heads that have no farm within the entitled command area for irrigation.

4. Conclusion

Spate irrigation is the diversion of floods running off from mountainous catchments, diverted by hydraulic structures and applied to low-lying irrigable fields in arid and semi-arid areas to improve farmers' livelihood. The Guguf spate irrigation system is one of the community managed irrigation practices for a long time in Raya Valley, Northern Ethiopia. Despite its higher potential to support the livelihood of farmers and achieve food security, adoption of flood irrigation has received a little attention. Given this, the study attempted to analyze factors that determine farmers' participation in Guguf spate irrigation system using a binary logit model. The estimates of the binary logit model revealed that, distance from plot to diversion head and from residence to plot were found to have a negative relation, while the remaining significant variables sex, livestock in tropical livestock unit (TLU), farm size, farm experience, farm ownership, spate water availability and age of the household head were positively associated with participation of farmers' in spate irrigation. The male-headed households were better in using spate irrigation than female household head more likely because of the cultural belief that prohibits female from some labour demanding works, such as operation and maintenance of irrigation structures. The farmers who have long years of experience in farming have used spate irrigation than those who have the lower years of experience probably due to their knowledge and skill developed from a long period of close contact with nature. Land security also affects the participation of farmers in spate irrigation positively as farm owners are encouraged to improve their farm. The livestock also determines participation in irrigation. The ownership of at least one pair of oxen is a good indicator of wealth as they serve as the main source of draught power. With some technical and financial support from agencies, the farmers have the potential to produce a surplus. Farmers experience was associated with the adoption of spate irrigation. Thus, development agents in the irrigation system should arrange experience sharing among farmers to enhance farmers' participation in spate irrigation.

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