



Overcoming climate change challenges: The role of irrigation in enhancing rice yield in Tanzania

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Abstract: Rural farmers face different challenges from climate change and weather variability, which have threatened crop production and productivity. Small-scale farmers try to cope with the prevailing situations by adjusting to different mechanisms, including adopting irrigation services. This study seeks to determine factors influencing rice farmers' decision to adopt irrigation technology and determine the significant contribution of irrigation to rice yields in the Mbeya Region of Tanzania. Data was collected through structured questionnaires, interviews, and focus discussions. Descriptive statistics, Logistic regression, and Ordinary Least Square regression by Stata software performed data analyses. The descriptive statistics characterized households' socio-demographic and economic characteristics. Logistic regression results affirmed that households' education, labor size, meteorological information, access to financial services, extension services, and previous farm outputs significantly influenced irrigation adoption by farmers. Ordinary Least Square regression results confirmed that irrigation significantly contributed to rice yield at $P > 0.05$ level. The study recommends adopting irrigation technology in Tanzania as a coping strategy for the negative impact of climate change and weather variations.

Keywords: irrigation, climate change, Mbeya, regression, Tanzania, weather, yield



1. Introduction

The global food demand crisis is exacerbated by water pressure from climate change and weather variability. Water scarcity has fueled crop production threats due to weather changes (Fan & Mccann, 2017). Rural African farmers feel significant impacts of less water, Tanzania inclusive since their entire agriculture relies on rain-fed, reducing crop outputs (Iglesias & Garrote, 2015). Population upsurge and socioeconomic activities are commonly reported causes of water shortage. Recent studies maintain that weather variability, including the change in rainfall patterns, high temperatures, and excessive sunshine is a more prominent cause of water shortage (Yu et al. 2018). Scholars uphold that adopting irrigation technology by the smallholder farmers could restrain the water shortage (Xing-guo et al. 2017; Jun et al. 2017). For example (Swanepoel & Hadrich 2015) argue that adopting irrigation technology is inevitable in most agricultural communities since water scarcity incidences are growing.

The critical negative impacts of drought necessitate rice farmers to adopt irrigation technology. Socioeconomic, demographic, and institutional factors influence the decision by households to adopt new introduced technology. Adopting new technology depends on attitude, awareness of the present technology, and information about the new technology. Therefore, adoption is a decision-making process that individuals must pass through. Farmers need to have information regarding the new technology to make proper decisions on whether to accept or reject the technology. If farmers accept the adoption, they have decided to reap the best out of the available options to maximize their utility. For rice farmers, their utility will target optimizing yields and productivity while minimizing the negative impact of water shortage resulting from weather variations to maximize their revenues and profits. Although farmers have to choose the best irrigation practices, they are limited to financial support, technology, and land (FAO, 2018). Smallholders choose the available basket of alternatives (Hunsaker et al., 2015). For instance, the crop type determines the irrigation system style as a means of water conservation (Ndhleve 2017). Also, farmers' expectations of reaping higher income influence households' decision to adopt new technology (Tang et al. 2016) observe that the farmers face risks in production the more they develop adoption capability.

Moreover, the availability of external supports such as subsidies, information, and extension services is reported to increase awareness of new technology adoption (Cremades et al., 2015). A farmer's history and record concerning the available technology and the challenges experienced by the current technology could influence a farmer's decision to adopt a similar or another counterpart's technology. Based on this background, the objectives of this research were twofold; first, it was to determine factors influencing farmers' decision to adopt irrigation technology as a solution to curb weather variability impact, and second, to evaluate the contributions of irrigation technology adopted by the smallholder rice farmers on their rice yields in the region.

2. Materials and methods

Description of the study area

Mbeya Region is located in the Southern Highlands of Tanzania. It is found between latitude 70 and 90 31' to the south of the equator and longitude 320 and 350 east of the Greenwich meridian. The region is among the best regions in terms of agricultural yields in Tanzania, and rice production is the primary agricultural crop in the region. Mbeya is experiencing a tropical climate which contributes to the performance of crop production. Rice is mainly cultivated in the Mbarali and Kyela Districts which were the center of this study. The total area under rice production by the two districts has been increasing from time to time, but currently, it is approximated to be above 20500 ha. The Mbarali District is bordered by Iringa Rural District in the north and Chunya and Mbeya rural Districts to the west and south, respectively. The main activities in the districts are crop production involving rice, maize, cassava, banana, cocoa, beans, and potatoes. However, rice is grown mainly in the area and is the symbol crop identifying the two districts and Mbeya Region. Mbarali receives an average rainfall ranging between 300mm to 900mm per annum from December to April, while Kyela District, located south of the Mbeya region, receives 350mm to 800mm. The Kyela District borders Makete to the east, Ileje District to the west, and the Republic of Malawi to the south.

Mbarali District has the largest area (The Usangu Basin), accounting for almost 28% of the total area under paddy. Rice production in the district is a rain-fed production mainly conducted during the wet season. However, due to weather variations, irrigation water is used to subsidize the rainwater. The available statistics show that total irrigated land is above 40,000 ha, mainly within the Usangu basin. The district's rice output contribution to the region account to above 60% of all total regional rice produce.

On the other hand, many households depend on paddy production, where other crops, including maize, beans, banana, and cassava, are farmed next to paddy. In the area, livestock keeping is also practiced, which is reported to cause land conflicts among farmers who compete for grazing land and cultivation area. Studies demonstrate that the mean households' rice farm size is 0.86 acres, whose yield is likely to earn the farmer an average amount of Tanzania Shillings (TZS) 670742.72, equivalent to US \$ 692. Also, (Ngailo et al., 2016) pointed out that average rice yields in the district account for 1.6 to 4 tons/ha, but areas with irrigated schemes recorded higher average rice yields from 4 to 6 tons/ha for uplands and 6-to-10-ton ha⁻¹ for lowlands. On a similar view, Kyela District covers about 2% of the Mbeya Region area. The production contributes to almost 20% of the total regional rice. Apart from crop production, livestock keeping is another crucial socioeconomic activity in the district. Although a total area of 450 square kilometers is covered with water, irrigation technology is not developed compared to Mbarali District; thus, rice production is solely rainfall dependant.

Irrigation and irrigation methods

Under the prevailing conditions of climate change and weather variability threats, small-scale farmers react in different ways such as adopting irrigation, fertilizer application, drought resistant seeds, and pesticides, to increase their resilience to the variations. Generally, irrigation is adopted by smallholder farmers in several areas of the Mbeya Region as means of subsidizing the rain-fed farming system when there is insufficient water to meet crops' moisture requirement. Similarly, it was identified that small-scale farmers in Southern Africa react to water shortage by irrigating their fields (Mango et al., 2018). However, going for irrigations depended on various factors such as geographical locations, water sources, financial status, and type of crops. There are several methods that rice farmers use to draw water from sources to the fields. The primary methods are flooding or gravity and a bucket or watering can. Other methods which are practiced by a few households are the sprinkler and water horses. Generally, most rice farmers use the gravity method, which previously accounted for 75% of the total households. However, sprinklers and water horses are usually located in the Mbeya District's urban areas.

Methods and data collection

This study was conducted in the two districts of Mbarali and Kyela in the Mbeya Region. Data collection was done during the 2017/18 farming season. The two districts were selected based on their performance in rice production status. Purposive sampling was used to select two wards from each district. After that, a random sampling technique was applied from each ward to obtain the required sample size of 240 households. To ensure successful interrogations, the authors trained enumerators who could understand and interpret the questionnaires to the respondents without distorting the required information. Since the survey was done during farming seasons, most households' heads were found in their fields doing different field management, including weeding, fertilizer applications, and others were transplanting. However, some household heads not found in their field were visited at home for the interview process. These steps were purposely done as the study targeted to interrogate household heads responsible for deciding whether to adopt irrigation or otherwise. Therefore, a questionnaire was used as a guide during the face-to-face interviews. The collected data were transferred into the Epidata and Stata software used for the analyses.

Analytical techniques

Descriptive Analyses. The descriptive data elicited from the respondents, including socio-demographic and economic characteristics, weather variables, extension and technological services, and institutional services, were analyzed by descriptive statistics. Variables' counts, percentages, and means were computed and presented (see Tables 1 and 4). On the other hand, to determine the impact of irrigation on the rice yield, the authors regressed the rice yield in Kg/ha with the set of explanatory variables, including the decision to adopt irrigation as the means of farmers' reaction to weather variability in the study region.

Empirical model estimation

Farmers are being challenged by the impact of weather variabilities such as insufficient water, prolonged dry spell, high sunshine, pests and diseases which affect their farming activities leading to poor rice growth and reduced yields. Smallholder farmers always desire to utilize the available means, whether temporary or permanent, to restrain the situation. The logistic Regression Model was used to determine the factors influencing rice farmers to adopt or not adopt irrigation technology in the event of less moisture availability in the study region. Many authors have widely used logistic regression to solve problems with dichotomous decisions (Kulyakwave et al., 2019). For instance, (Ntashangase et al., 2018) used the model successfully to determine the influencing factors

for farmers to adopt Conservation Agriculture (CA) in South Africa. Also, (Kontogeorgos et al. 2014) used a logistic regression model to determine the decision factors for implementing a Quality Assurance System (QAS) by cooperative. The model worked perfectly, and the results indicated that the size of the cooperative, the perception of QAS, and cooperative activities were the main determinants of the degree of cooperation with QAS.

Furthermore, the logistic model was used in the Zhejiang Province of China to assess factors encouraging farmers to outsource machinery. The findings revealed that land size and government subsidy factors encouraged the farmers to outsource machinery (Ji et al. 2017). Therefore, in this study, the logistic regression model was used to determine the choice factors that influence small-scale rice farmers to adopt irrigation services in the region.

Modelling the choice factors for irrigation adoption with the logistic regression model

The logistic regression model is selected because it has been used successfully in different studies, resulting in positive results when solving problems with binary variables. It should be noted that in the current research, the decision of rice farmers on whether to adopt or not to adopt irrigation technology is of a binary variable. The equations take the values of 1 if the household decides to adopt irrigation services and 0 if otherwise. This indicates the maximum utility a farmer could obtain by adopting irrigation technology. However, the adoption decision is influenced by the household head has socioeconomic, demographic, institutional, and ecological characteristics. The model parameter estimations are built based on equation 1 as described in (Gujarati, 2009).

$$Q_i = E\left(Y = \frac{1}{x_i}\right) = \beta_0 + \beta_1 X_i \quad (1)$$

When more than one independent variable is used to explain the model, it can be expressed as shown in equation (2).

$$Q_i = E\left(Y = \frac{1}{x_i}\right) = \beta_0 + \sum_{i=1}^n \beta_i X_{ki} \quad (2)$$

Where Q_i is the probability for a household i decided to adopt irrigation technology, β_0 is an intercept of the logistic regression, $\beta_1 \dots \beta_i$ are set of parameters to be estimated, $X_1 \dots X_{ki}$ is the vector variable that influences the household i decided to adopt or not adopt the technology.

$$Q_i = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \sum_{i=1}^n \beta_i X_{ki} + \mu_i \quad (3)$$

In equation 3, P_i is the probability of the household's head (farmer) i adopting the irrigation technology, and the $(1-P_i)$ is the probability that the same farmer i not decide to adopt the irrigation technology. Therefore, we could generate a logistic Model with an assumption that Z_i is an interpretable variable to be determined by the logistic equation Q_i

$$Q_i = f(Z_i) = f(\beta_0 + \sum_{i=1}^n \beta_i X_{ki} + \mu_i) = \frac{1}{(1+Z_i)} \quad (4)$$

By considering the above equations (1-4), we could come up with two important assumptions regarding our research objective as follow;

If the household's head decides to adopt irrigation technology equation (5)

$$Q_i = \ln\left(\frac{1}{0}\right) \quad (5)$$

If the household's head decides not to adopt the irrigation equation (6)

$$Q_i = \ln\left(\frac{1}{0}\right) \quad (6)$$

Table 1: Description of variables for the logistic regression model

Variables	Variable description	Group	Observation	Mean
Households characteristics				
Age	If the household head age < 45, the is 1,	1	126	0.35
	Otherwise 0	0	114	0.25
Gender	If household is male = 1, Otherwise 0	1	205	0.29
		0	35	0.34
Educ	education of household is literacy =1,	1	135	0.34
		0	105	0.25
Labs	If labor size is > 2.7 = 1, Otherwise is 0	1	118	0.25
		0	122	0.35
Environmental				
Drought	experience drought yes=1, Otherwise 0	1	145	0.23
		0	95	0.40
ExTemp	extreme temperature yes=1, Otherwise 0	1	54	0.31
		0	186	0.30
Achange	Awareness of weather variation yes=1, or Otherwise, 0	1	126	0.30
		0	114	0.29
Extension and technological information services				
Metinf	Access to weather information Yes=1, Otherwise 0	1	32	0.41
		0	302	0.17
Govinf	Government as information source =1, Otherwise 0	1	23	0.17
		0	217	0.31
Finsv	Access to financial services Yes=1, Otherwise 0	1	110	0.39
		0	130	0.19
Seedq	Seed quantity >3Kg/ha, or Seed quantity =< 3Kg	>3	165	0.26
		<=3	175	0.39
InforExt	Accessibility to extension and technological updates =1, Otherwise 0	1	159	0.35
		0	81	0.20
ylag1	previous rice output Kg/ha	>3431	82	0.39
		<=3431	158	0.25

Operationalization of the logistic model for the irrigation technology adoption

The model developed was then fed with the selected variables presented in the descriptive (Table 1). The variables are selected from the data collected during the survey based on the farmers' characteristics, including; socioeconomic characteristics, institutional factors, and weather variability.

An empirical model for estimating irrigation decision impact on the rice yield

The authors intended to realize the significance of using irrigation technology as a means of rice farmers' reaction to weather variability. Thus, the relationship between the rice yield and farmers' decision to adopt irrigation service was established using the simple Ordinary Least Square regression. Additionally, the authors desired to find out the utility achieved by rice farmers following their decision to use the available irrigation services in the local areas and how they could be transmitted to their rice yields in return. The use of the OLS model to express a linear relation between the dependent and independent variables has been widely explained in (Gujarati, 2009). The author suggests the use of independent dummy variables. Based on his conclusion, we used the farmer's rice yield (Kg ha⁻¹) as a continuous dependent variable and the irrigation adoption decision as a dummy variable. Other variables, such as socioeconomic, weather, and institutional variables, was used as explanatory variable in Equation 7.

$$Y_i = \beta_0 + \beta_1 d_{1i} + \beta_2 d_{2i} + \beta_3 d_{3i} + \dots + \beta_k d_{ki} + \beta_{k+1} D_i + \mu_i \quad (7)$$

Where Y_i is the farmers' rice yield in Kg ha⁻¹, β_0 is the intercept of the regression equation $\beta_1 \dots \beta_{k+1}$ are the respective coefficients of the explanatory variables used in the model, d_{ki} denotes a set of independent variables, including the socioeconomic and demographic characteristics, weather variables, and institutional variables, D_i indicates the dummy variable, the households head's decision to opt irrigation technology. The dummy variable takes the 1 or 0, indicating the presence (for example, decided) and absence (for not decided) for the referred attribute. The μ_i is an error term of the model, which is assumed to be normally distributed with a mean of 0 and constant variance (σ^2). Therefore, by substituting the respective variables in equation 7, we could obtain equation 8, which used the variables defined in (Table 2).

Table 2: Descriptive statistics and definition of variables

Variables	Variable description	Group	Observation	Mean
Households characteristics				
Age	If the household head age < 45, the is 1, Otherwise 0	1	126	0.35
		0	114	0.25
Gender	If household is male = 1, Otherwise 0	1	205	0.29
		0	35	0.34
Edu	education of household literacy =1, Otherwise 0	1	135	0.34
		0	105	0.25
Laborsize	If laborsize is > 2.7 = 1, Otherwise is 0	1	118	0.25
		0	122	0.35
Marit	If household is married = 1, Otherwise 0	1	230	1501.26
		0	10	560
Offinc	household ern off-farm income = 1, Otherwise 0	1	102	1596.08
		0	132	1374.64
Environmental				
Drough	experience drought yes=1, Otherwise 0	1	145	0.23
		0	95	0.40
Atchan	Awareness of weather variation yes=1, or Otherwise 0	1	126	0.30
		0	114	0.29
Extension and technological information services				
AccFin	Access to financial services Yes=1, Otherwise 0	1	110	0.39
		0	130	0.19
Ext	Accessibility to extension and technological updates =1, Otherwise 0	1	159	0.35
		0	81	0.20
Metinf	Accessibility to weather information yes=1, Otherwise=0	1	32	1365.63
		0	208	1484.62
Irrtech	If the farmer decided for irrigation yes=1, Otherwise=0	1	72	1827.78
		0	168	1314.88

3. Results and discussion

Results

Socioeconomic characteristics of the rice farmers

As presented in (Table 3), the distribution of the rice farmers' socio-characteristics indicates that most (56 %) rice farmers were between below or equal 45 years with a mean age of 36.5. In terms of farming activities Furthermore, Table 3 illustrates that almost all (95.8 %) respondents were married. The figure is very worthwhile in increasing family labor to participate in rice production. This agrees with (Otekhile & Verter, 2017), who noted that most (61.3%) of the Lagos state farmers were married; thus, duos assist in many agricultural activities.

Studies have shown that education is essential to farmers as it can help them access credits to support agricultural activities. This study noted that only 3% of the farmers had not acquired any formal education. This confirms that in the study region, most farmers have some literacy which would help them overcome any related problem that could impede rice performance. Table 3 further illustrates that most (83%) households have 2 to 4 members. Provided that most families in the rural area utilize family labor in farming activities, this number appears inadequate. Therefore, a reasonable number of family sizes is required, as other studies proposed that rural families with up to 7 individuals could be sufficient for major farm operations. On the aspect of farm size, it is shown that the majority of farmers have 1-3 acres. This is very true for most African rural farmers characterized by subsistence farming with poor implements. However, studies report small farm size as a constraint when farmers want to diversify farm activities (Kuivanen et al., 2016).

Table 3. Descriptive statistics of the respondents (n=240)

Variable name	Characteristics	Frequency	%	Mean
Age	Below or equal to 45years	134	56	36.5
	Above 45	106	44	56.5
Sex	Male	186	77.5	119.0
	Female	54	22.5	121.0
Marital Status	single	10	4.2	106
	Married	230	95.8	121
Education	Illiterate	6	2.5	143
	literate	41	17.1	111
	Primary	169	70.4	120
	Secondary	22	9.2	134
Family size	University	2	0.8	132
	less than 2	22	9.2	1
	2-4	200	83.3	2.7
	5-7	18	7.5	5.4
Farm size	Above 7	0	0.0	0
	1-3	194	80.8	1.75
	4-6	40	16.7	4.65
	Above 6	6	2.5	8.12
Off-farm income	Income < .425	138	58	1374
	Income >=.425	102	42	1596
	Total	240	100	

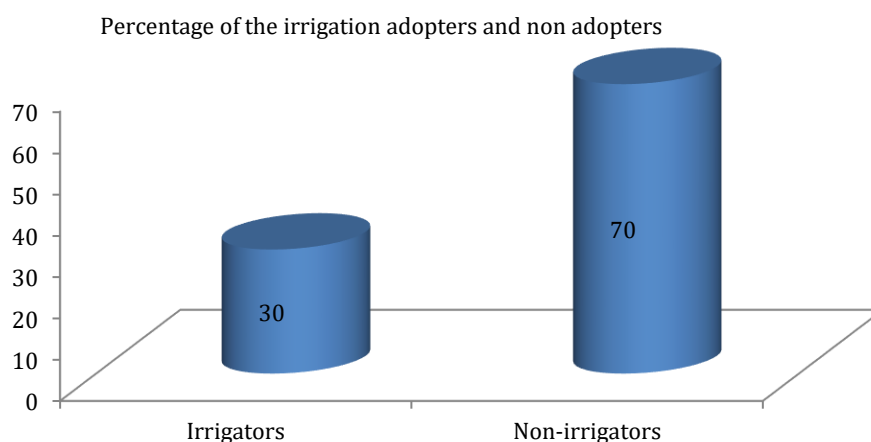
Source: Authors Survey, 2018

The study also revealed that most (73%) household heads have off-farm activities besides rice farming. This off-farm income could be used to support families and rice farming, especially in buying labor, improved seed varieties, pesticides, and machinery. Scholars uphold that off-farm income could help reduce production-associated risks (Akhtar *et al.* 2019). Contrary to our findings, the study of (Baoling *et al.*, 2019) reported that off-farm income could lead farmers to reduce their yields due to time competition and leasing out their lands.

Characteristics of adopters and non-adopter of irrigation

Among rice farmers, a few farmers, 30%, adopted the irrigation technology, compared to the majority of farmers, 70%, who have not adopted the irrigation technology in the study area (Figure 1). This implies that most farmers are reluctant to decide to use irrigation to practice sustainable agriculture. Regarding the reaped mean rice yield, our finding revealed that adopter group acquired higher average yield of 1827.8 kg ha⁻¹ compared to the less amount of 1314.9 kg ha⁻¹ acquired by non-irrigation adopters. Through focus discussion, we found that the main reasons were lack of education and extension service (Ndhleve, 2016).

Figure 1: Percentages of adopters and non-adopters of irrigation practices



Factors for irrigation technology adoption

Table 4 presents results on essential factors influencing farmers' decision to adopt irrigation technology. In this section, the results for estimating the logistic regression model on rice farmers' decisions for adopting irrigation are presented.

The education level of the household's head. As presented in (Table 5), household heads' education was significant at $P > 0.001$ probability level.

Table 4: Logistic regression results for farmers' decisions for irrigation adoption

Decision to Irrigate	Variables definition	Odds Ratio	Std. Err.	z	P>z
Age	Age of household head	0.9785	0.0161	-1.3200	0.1870
Gender	Gender of household head	0.7903	0.4078	-0.4600	0.6480
Educ	Education of the household head	3.4779	1.5022	2.8900	0.004***
labs	labor size in the household	0.3903	0.1610	-2.2800	0.023**
Metinf	Meteorological information	2.6280	1.3339	1.9000	0.057*
Drough	Experience drought	0.7655	0.0692	-2.9600	0.003***
Govinf	Government Source of Information	0.5193	0.3746	-0.9100	0.3640
Finsv	Accessibility to credits	2.6251	1.0407	2.4300	0.015**
ExpeTem	Experience high Temperature	0.8316	0.3600	-0.4300	0.6700
Ylag1	previous farm outputs	1.0001	0.0001	2.5900	0.0100**
Achange	Awareness to weather changes	0.7788	0.3102	-0.6300	0.5300
Seedq	Amount of seeds used	0.7505	0.2480	-0.8700	0.3850
InforExt	Extension and Technological information	2.6863	1.1494	2.3100	0.021**
_cons	Constant of the model	0.8992	1.3900	-0.0700	0.9450
N of Obsn= 192		LR ch ² (14)=55.79	Prob>chi ² =0.0000	Pseudo R ² =0.2338	

Note: the asterisk value represents significant results at 1%, 5%, and 10% level of significance

This implies that the education level of the household heads increases by one level of schooling significantly influences the farmer's decision to adopt irrigation technology positively. Thus, as education level increases one time, farmers decide to opt for irrigation technology by 3.5 times when other factors are fixed. This is similar to what (Ndhlve, 2016) reported that as years of schooling increase, farmers acquire different knowledge which could help in their agricultural activities, such as accessing credits and adopting new technologies in South Africa. The results in (Table 4) indicate that labor size was significant at a 0.05 level of probability. This means that the labor size positively influences rice farmers' decision to adopt irrigation technology. That is, the increase of family labor size one time increases farmers' decision to adopt irrigation by 0.39 times. The possible reason could be what was observed by (Lopez-Ridaura et al., 2018) that an increase in labor size is essential to enable different farm operations which require more labor to perform activities such as weeding, fertilizer, and pesticide application. Similarly, irrigation operations require additional laborers to take over activities such as supervising water delivering into the field and constructing furrows, which is labor intensive. On the other hand, meteorological information was found to influence the farmers' decisions positively.

The results indicate it was very significant at a 10% probability level. Thus, as farmers' access to meteorological information increases by one time, it increases their decision to adapt to weather variability by 2.7 times, provided other logistic model factors remain fixed. The probable explanation is as access to weather information help in providing early warning regarding changes in weather conditions. A similar argument was presented in the work of (Kumar and Khan 2018) that if agro-meteorological information could be available, more than 75% of farmers would be worthwhile for crop production in India.

The results in Table 4 indicate that drought was very significant at a $P > 0.001$ level of probability. This means that when other factors are fixed, farmers' decision to adopt droughts cases increases by 0.77 times when the frequency of drought occurrence increases one time. This implies that as farmers experience frequent dry spells, conditions will increase their decisions to go for irrigation services. Our finding is supported by the study of (Webber et al., 2018), who noted that understanding the effect of Climate change significantly drought cases could help farmers to plan for adaptation measures, including irrigation technology. The accessibility to financial services positively influenced rice farmers' decision to adopt irrigation (Table 4). The empirical results indicate that with an increase in one-time accessibility to financial aid, farmers' decision to venture into irrigation will increase by 2.6 times, and this was significant at $P > 0.05$ probability level. Loboguerrero et al. (2019) point out that financial supports to farmers increase production, efficiency,

and food availability. This is true because access to finance by farmers could accelerate the adoption of technology, pay water bills, and purchase other farm inputs, including labor, which increases production. Previous rice output was another essential variable influencing farmers' decision to adopt irrigation technology. As shown in (Table 4), previous farm outputs were significant at a 5% probability level. Thus, as 1 kilogram of output increases one time, a farmer's decision to participate in irrigation technology increases by one time when other independent factors are constant. Farm productivity increases individual confidence to invest more resources in agriculture. Thus, as farmers' outputs increase, they facilitate their decision to adopt modern technology inclusive to earn more income. A similar comment was disclosed in the study of (Loboguerrero et al., 2019), who argued that continuing farm investment could depend on the outputs received by farmers; however, they claimed that due to a decline in farm outputs, the off-farm income could also be used for such investment.

The result proposes that extension and technological information was significant at $P > 0.05$ level of probability (Table 4). This insists on the essentiality of information dissemination to the farmers. This means increases in access to extension and technology services one time could increase farmers' decisions to participate in irrigation technology by 2.7 times when other factors are fixed. Studies indicate that the availability of extension services is the key point towards the climate change adaptation network (Mohamad et al., 2017). Therefore, if farmers are informed of the event of less rainfall and extended dry spells and are given the correct information regarding extension services and the availability of adequate technology, their decision to adopt the best adaptation mechanisms would increase.

On the other hand, other selected variables, which were thought to be among the factors influencing farmers' decisions to adopt irrigation were insignificant (Table 4). However, the age factor goes in line with experience. It was argued that farming experience could easily influence the adoption of new technology, and similarly, farmers between ages 41-50 could adopt technology compared to those above 70 years (FAO, 2015). Also, factors such as awareness of weather changes and an increase in sunshine duration could influence farmers to adopt new technology such as irrigation; however, in this study, they were insignificant.

Modelling the contribution of irrigation technology to rice yields

Table 5 shows estimated parameters for adopting irrigation technology to improve the study region's rice yields. In addition to irrigation, the Ordinary Least Square regression illustrates that others independents variable such as availability and accessibility of extension and technological information, access to financial services, the marital status of the household heads, and the income from off-farm jobs were also significant to rice yields as they are shown in the regression model equation 9.

$$Y_i = -0.79 + 316.231 * IrrAdop + 243.91 * ExTech + 297.607 * Accfin + 842.96 * Marts + .002 * offinco \quad (9)$$

Therefore, the results in (Table 5) show that rice farmers' adoption of irrigation technology significantly influenced rice yield. Irrigation adoption by farmers was significant at a 5 % level. It is identified that since the coefficient of irrigation adoption was positive, the rice yield was increased by 316.231 kg ha⁻¹. Although the region suffers from less moisture due to the prolonged dry spells, which have negatively affected plant growth and yield, adopting irrigation increases rice yield, which will strongly impact the farming community.

Table 5: Parameter estimates of Ordinary Least Square regression

Yd (Kg/ha)	Definition of variable	Coef.	Std. Err.	t	P>t
IrrAdop	Irrigation Adoption	316.231	121.6631	2.6	0.010**
ExtTech	Extension and technology information	243.91	116.7812	2.09	0.040**
Accfin	Access to Financial Services	297.607	110.6212	2.69	0.010**
Marts	Marital status of the Household head	842.957	272.9272	3.09	0.000***
Offinco	Off-farm income	0.002	0.0003	6.49	0.000***
_cons		-0.788	289.3059	0.00	1.000

*** at a 1% level of significance

** at a 5% level of significant

Various studies have also reported the positive impacts of irrigation (Fateme, 2013), which explored the impact of irrigation on agriculture for Iran farmers. The results show that adopting irrigation helped to improve people's livelihood in rural areas through increased farm production. The improvement was measured by higher income, improved rural houses, and farmers could

expand their farms and improve rural infrastructure. Similar results were also observed in Brazil, whereby irrigation contributed to sustaining rural livelihood (Antônio *et al.*, 2014).

According to (Moyo, 2016), adopting irrigation was paramount to escaping rural poverty in South Africa. He argues that irrigation technology could increase farmers' livelihood through increased production, income, and diversification of income opportunities. Further, irrigation adoption provides pathway opportunities for adopting modern seed technology, fertilizers, and pesticides, boosting production and income. The comparison between Irrigators and non-irrigators in South Africa revealed that the irrigator earned the mean annual income of R 125 007 and non-irrigators earned R 57 608 ('R'-South African Currency). Another study by (Peter, 2015) in Swaziland commented that adopting irrigation has shifted farmers from subsistence to commercial production. Apart from the irrigation adoption, as shown in (Table 5), accessibility to extension and technological services significantly influenced rice farmers' income at 5% level. A study by (Emmanuel *et al.*, 2016) indicates that access to extension and technology services through individuals or different media, fora, and or training groups increase farm income by 243.91 Kg ha⁻¹ on average.

Similarly (Linh *et al.* 2019) commented that access to financial services significantly influenced farm income positively. The results also show that the household heads' marital status and off-farm income significantly influenced farmers' income. This finding concurs with (Chen *et al.* 2019), who advocate diversification as it is very risky to focus only on one income source from agriculture because of many uncertainties the sector has, including climate change and weather variability.

Discussion

The affordable strategies which enable farmers to cope easily and increase their resilience to the threats brought by weather variability impact need to be adopted for sustainable crop production. Farmers' adoption and application of irrigation technology provide rational, efficient water use as a natural resource, increase sustainable agricultural crop yields, and boost farmers' income (Moyo 2016). Our findings revealed that the majority are reluctant to adopt irrigation technology. This situation results in a significant population with unsustainable income due to the prevailing poor rainfall distribution, which cannot support rice production. Irrigation technology has improved living standards and people's well-being through an increased crop yield, income, and opportunity to grow various crops, including vegetables, to subsidize income from the major crops.

Our results from the Logistic regression model for adopting irrigation technology show that among the predictor variables, seven variables significantly influenced farmers' decision to adopt irrigation in the Mbeya region of Tanzania. These factors include the education of the household's head, labor size, access to meteorological information, farmers' experiences with droughts events, accessibility to financial credits, previous farm outputs, and access to technological information. Therefore, based on our findings, these factors are the fundamental driving force for farmers as they are impacted significantly and positively on their decision-making towards irrigation technology adoption. Regarding our survey, the factors could be a good starting point for policymakers to intervene to increase the number of farmers participating in irrigation technology. For example, from the findings, if the education level of the household head is increased could also increase the ability to venture into irrigation technology by 3.5 times when other factors remain fixed. Thus, it implies that improving accessibility and education opportunities increases the number of irrigation adopters.

Similarly, increased access to financial credits, extensions, and technological services, on the other hand, requires good policies from responsible authorities (Linh *et al.*, 2019). Our results showed that the opportunity to access meteorological information increases farmers' decisions by 2.7 times. This is obvious since early warning information regarding weather changes makes farmers plan for the best coping strategies.

According to the Ordinary Least Square regression model results, the findings show that rice farmers' use of irrigation technology brings benefits through increased rice yields and income. It is shown that irrigation as a predictor variable in the model significantly increased rice yield by approximately 316.23 kg ha⁻¹. It implies that using irrigation technology in rice production significantly positively influences the rice yield and farmers' income. From a policy view, it further shows that adopting irrigation could make farmers adopt other essential technologies, including agro-machinery, improved seed variety, pesticides, etc., which could be used efficiently to increase rice production (Peter, 2015). The positive contributions could be so meaningful if the number of irrigators in the study region increased as we believe that increase in yields and income would have multiplier effects to the community through the enhancement of livelihoods. The government could assist this trend by subsidizing irrigation equipment, seeds, fertilizers, and pesticides (Ji *et al.*, 2017). The available evidence revealed that most farmers have yet to accept irrigation technology.

Therefore, the current findings have proved irrigation profitable to the adopters. The policymakers in Tanzania should promote irrigation through demonstrations, trainings, providing extension services, and using the available radios, televisions, and newspapers to reach farmers easily.

4. Conclusions and recommendations

Most rice farmers in the Mbeya region are yet to adopt irrigation technology, which is an essential coping strategy to increase their resilience from the impact of weather variability to attain sustainable farm outputs. This study aimed to determine factors influencing rice farmers' decision to adopt irrigation technology and the significance of the irrigation application to rice yields in the Mbeya region of Tanzania. Data collected in the study region from February to April 2017 are used in this research. The authors used the logistic regression model to determine the main deterministic factors influencing farmers' decision to adopt irrigation technology and the Ordinary Least Square regression model to estimate the significance of irrigation technology application to rice yield. The findings revealed that 30% of farmers have already adopted irrigation technology, whereas 70% of farmers have yet to adopt irrigation technology in the study area. The main factors that influenced the decision to adopt irrigation were the household head's education level, labor size, accessibility to meteorological information, experiences of drought events, accessibility to financial services in terms of credits, previous farm outputs, and availability of extension and technological information. The findings also indicated that the average rice outputs acquired by irrigation adopters were higher than for the non-adopters. Further findings revealed that the majority of farmers, 73%, have off-farm income, which could be used to support the adoption process provided good policies are available.

Apart from the findings, we have observed some limitations that must be considered. The data used for this study only represent one region of Tanzania, which we think is inadequate to draw a conclusion for the whole of Tanzania. On the other hand, the survey covers only rice farmers in the Mbeya region. Thus, the findings could not be considered general conclusions for all farmers doing other crop varieties. Therefore, to have a robust conclusion, more studies should be carried out for similar crops in other regions of Tanzania, making our findings noticeable, applicable, and acknowledgeable.

Additionally, we saw financial factors influenced farmers' decision to adopt irrigation, and most financial institutions are business oriented with high interest. However, adopting irrigation technology aligns with purchasing implements, new seed variety, fertilizers, etc., which require farmers to demand external funds. Therefore, we urge the policymakers and financial institutions to give special consideration to rice farmers so that they can benefit by adopting irrigation through added production, income, sustainable food security, improved house standards, and employment.

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Conflicts of interest

The author declares no conflict of interest.

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