Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa

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Abstract

This article concerns the adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle. Chinyanja Triangle is a region that experiences mid-season dry spells and an increase in occurrences of drought due to low and erratic rainfall patterns which is attributed largely to climate variability and change. This poses high agricultural production risks, which aggravate poverty and food insecurity. For this region, adoption of small-scale irrigation farming as a climate-smart agriculture practice is very important. Through a binary logistic and ordinary least squares regression, the article determines factors that influence the adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on income among smallholder farmers. The results show that off-farm employment, access to irrigation equipment, access to reliable water sources and awareness of water conservation practices, such as rainwater harvesting have a significant influence on the adoption of small-scale irrigation farming. On the other hand, the farmer's age, distance travelled to the nearest market and nature of employment negatively influenced the adoption of small-scale irrigation farming decisions. Ordinary least squares regression results showed that the adoption of small-scale irrigation farming as a climate-smart agriculture practice has a significant positive influence on agricultural income. We therefore conclude that to empower smallholder farmers to quickly respond to climate variability and change, practices that will enhance adoption of small-scale irrigation farming in the Chinyanja Triangle are critical as this will significantly impact on agricultural income.

Key words: Climate-smart agriculture; adoption; small-scale irrigation farming; household income; Chinyanja Triangle; Southern Africa

1.   Introduction

The rural poor in Sub Sahara Africa (SSA) earn their livelihoods mostly from climate-sensitive rain-fed agriculture. Their production is typically limited to a 3-6 months rainy season and crops grown are mainly staple cereal crops meant to sustain their livelihoods [1]. However, yields for these crops are subject to weather driven fluctuations and are generally low. Dependence of smallholder farmers in SSA on such climate sensitive, seasonal staple production systems often lead them into facing multiple-scale poverty traps [2]. More so, this often makes economies in the region (SSA) the most vulnerable to climatic variability and changes [3, 4, 5].

It therefore requires that African governments assist the smallholder farming sector to transform and adapt to the various challenges including climate variability and change. Gaining access to relevant climate-smart technologies and other sustainable productivity improving practices that will enable them to increase farm productivity, achieve climate resilience, improve nutrition incomes and food security, and achieve other developmental goals is therefore key [6, 7]. Adopting improved land and water management practices amongst other sustainable technologies can assist smallholder farmers in SSA to achieve the aforementioned goals [6]. Some of these technologies may include, improved water management in agriculture, adopting small-scale irrigation, use of improved crop varieties, fertilizers and other innovative practices more suited to their local conditions. Of interest is the adoption of small-scale irrigation which currently does not play a significant role in African agriculture especially when compared to other regions like Asia and Latin America [8]. Statistics show that, irrigated land in Africa as compared to cultivated land is only about 6% for Africa, compared with 14% Latin America and 37% for Asia [9, 10].

It is critically important to consider small-scale irrigation as a conventional practice in smallholder agriculture that improves: farm productivity, adaptation to climate variability and change and achievement of household and national developmental goals. In sub-Saharan Africa, the adoption of small-scale irrigation farming is hugely important for smallholder farmers, especially when one considers that rainfall is highly unreliable and insufficient in many places [6, 11]. Drought – especially mid-season – due to low and erratic rainfall, poses high uncertainty and agricultural production risks in sub-Saharan Africa [12]. This leads to threats of widespread poverty and food insecurity. Small-scale irrigation is possibly a viable climate-smart technology to consider in SSA given that the continent have ample fresh water resources [8] even though their distribution is not even across agro-ecological zones. More so, small-sale irrigation is an important step towards intensification of farming systems [13], and in helping farmers insure against drought risk and transform their farming activities [14, 15]. More so, small-scale irrigation also necessitates off-farm production which improves food supplies [16].

With regard to the views above, this article aims to analyse the adoption of small-scale irrigation as a climate-smart agriculture practice in the Chinyanja Triangle, southern Africa, and assess its contribution to people's livelihoods.. More specifically, the article aims to identify factors that influence smallholder farmers' decisions to adopt small-scale irrigation and assess the influence of adoption on household incomes. Data from smallholder farming systems in the Chinyanja triangle found in southern Africa is used.

2.   Related literature on small-scale irrigation farming and livelihood outcomes

There is scanty literature on studies that assess dynamics of small-scale irrigation adoption and their livelihood impacts in SSA. However, closely related literature which discusses adoption of small-scale irrigation in SSA is available. For instance, Bacha et al. [17] conducted a

study in the Ambo district of western Ethiopia to assess the impact of small-scale irrigation development on poverty reduction using a case study of Indris irrigation system. Their study found out that the incidence, depth and severity of poverty were significantly lower among households with access to small-scale irrigation. A related study by Tesfaye et al. [18] evaluated the impact of small-scale irrigation on household food security in Ada Liben district of Ethiopia. In their study, they found out that 70% of irrigation users were food secure while only 20% of non-users were found to be food insecure. Their findings pointed to the fact that small-scale irrigation enabled adopters to grow a variety of crops more than once in a year and ensured increased and stable production, income and consumption which resultantly improved their food security status. In the Tigray region of Ethiopia, small-scale irrigated agriculture was found to benefit households by providing opportunities to increase agricultural production through double cropping and by utilizing modern technologies and high yielding crops in an intensive farming system [19]. In the same Tigray region Gebrehaweria et al.[20] examined a representative sample of 613 farm households composed of 284 non-irrigators and 331 irrigators and found that average incomes on non-irrigating households were less than those of irrigators by about 50% and that overall average income gain due to access to irrigation ranged from 4000 Birr to 4500 Birr per household per annum. In another study in Ethiopia, IFAD [21] concluded that small-scale irrigation schemes have increased production, incomes and diet in the Southern Nations, Nationalities and People (SNNP) and Oromia regions. More so, the same study found out that, cash generated from selling horticultural produce (vegetables and other produce) was used to cover the households in food deficit months (July and August). Increased diversity of crops across the scheme and transforming from cereal-livestock to cereal-vegetable-livestock system was seen to have significantly improved household nutrition.

In India, Chamber [22] found out that reliable and adequate irrigation increases employment opportunities, disposable incomes which ultimately contributes to food security. More so, Singh et al.[23] also carried out his study in India and found small-scale irrigation to be effective in reducing poverty. Also in India, Hussain et al.[24] reiterated that access to affordable and reliable irrigation leads to improved productivity and greater returns from farming. More so, this creates employment opportunities both on and off-farm which can transform into improved livelihoods and improved quality of life in the countryside [18, 24, 25]. Related, Kumar [26] also confirmed the positive effects of small-scale irrigation in boosting India's food production and generating surpluses which can be used as drought buffer.

In a slightly different region of Southern Africa, Mudima [27] carried out an investigation on five irrigation schemes on their livelihood impacts. The study show that irrigation schemes acted as sources of food security for the participants and their surrounding communities. The main livelihood contributions of the irrigation schemes came through increased productivity, stable production and incomes. Also, the study found out that members of the irrigation schemes never ran out of food supplies as compared to their counterparts relying on rain-fed agriculture.

It is important to note that literature on the effectiveness of small-scale irrigation in SSA is still scarce particularly in Africa. The scantiness is even worse if we are to consider studies that have analysed the livelihood impacts of small-scale irrigation as a potential climate-smart agricultural technology. With improved threats from climate variability and change in various parts of the world including SSA studies to assess the effectiveness of small-scale irrigation adoption in sustainably increasing productivity and incomes should be a priority. This study therefore aims to analyse dynamics of small-scale irrigation adoption and its influence on income in smallholder farming within the Chinyanja Triangle, Southern Africa. Policy recommendations

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targeting improved out and up-scaling of small-scale irrigation adoption for effective adaptation to climate variability and change in the region are derived.

3.   Research methods

3.1.   Description of study sites

The study was conducted in the Chinyanja Triangle and covered Furancungo in Tete Province of Mozambique, Budula Siliya in Zambia's Eastern Province, as well as Linthipe and Nsipe in the central and southern regions of Malawi (Figure 1). The common denominator in this region is the inhabitants' mother tongue, Chichewa. This region forms a triangular shape. Culturally, the majority of people in the region share the same beliefs. It is hypothesised that they could share similar approaches to resource management, especially in terms of the land on which they depend for their livelihoods and the adoption of certain agricultural practices [28]. According to the characterisation by scholars from the Consultative Group for International Agricultural Research (CGIAR) [29], 37.9% of the area in the Chinyanja Triangle is under shrub cover, which is classified as closed-open deciduous trees. Tree cover occupies 31% of the study area. Cultivated and managed areas make up 24% of the area and water bodies occupy 4%. Herbaceous species cover 2.04% of the site and bare, artificial and associated areas take up less than 1%. The study sites are dominated by maize as the staple food crop, mixed with legumes and groundnuts.
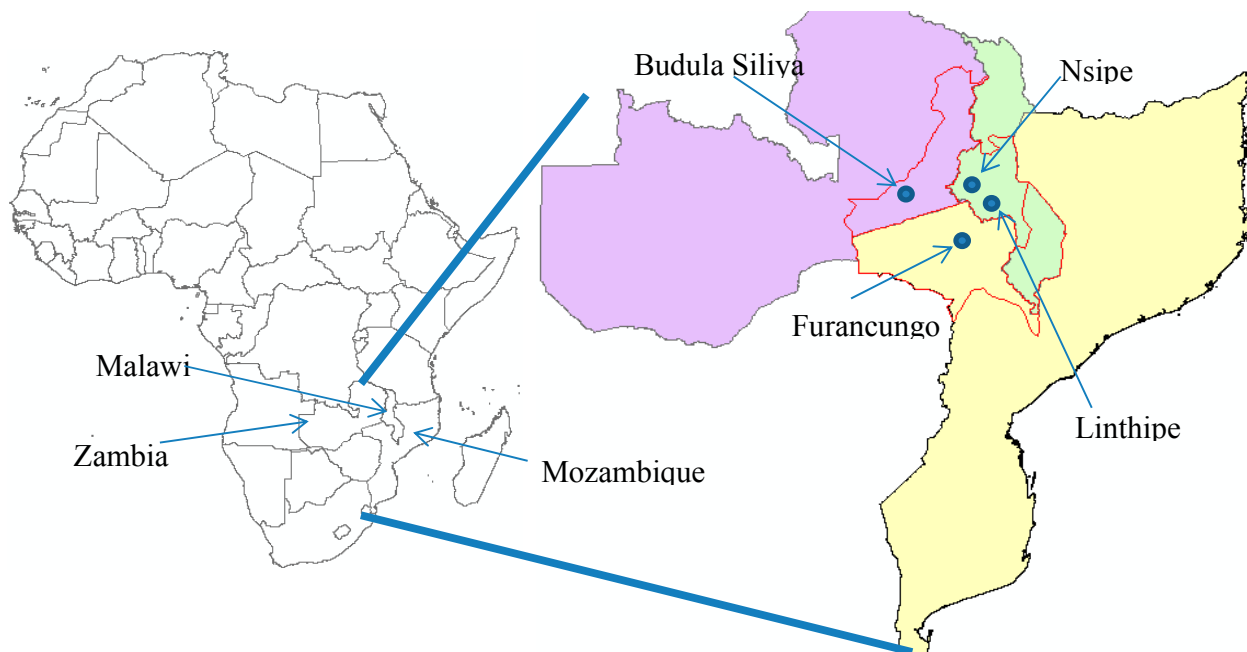
Figure 1: Map showing the location of the Chinyanja Triangle and research sites

3.2.   Sampling methods, data collection and data source

3.2.1. Sampling

Sampling units for this study were drawn using the multistage spatially stratified random sampling design of the Land Degradation Surveillance Framework [30]. Four sites, as described in Section 2.1, were used to make up the sample data. There are 16 clusters within each site. For the Africa Rising sites, the two mother trials (established during the 2012/13 growing season) were used as centre clusters with the other 14 clusters randomly spread around them. Each cluster covers an area of 2 km^2 with 10 randomly located sampling plots from where a Land Condition Survey (LCS) was conducted. For each cluster, five farmers who owned odd numbered plots (1, 3, 5, 7 and 9) were considered for a socioeconomic questionnaire. The socioeconomic data was collected from owners of the plots sampled during the LCS, thereby

geo-referencing farmers to their sampled plots and not their place of residence. Plot owners were identified during the LCS by locals from the nearest village.

3.2.2. Data collection and source

The household survey was conducted to collect primary household socioeconomic data using structured questionnaires. Collected data includes the socio demographic and economic characteristics of the households, land characteristics and Integrated Soil Fertility Management (ISFM) technology usage, livestock ownership and species, as well as irrigation and water harvesting technology practices. Extension service personnel, agriculture research officers and trained enumerators collected data between December 2012 and June 2013. Data on different livestock species was further converted into standard livestock units (LUs) using nutritional and feed requirement factors for sub-Saharan Africa [31, 32].

Data was collected from 312 households. In this context, a household was defined as a group of people who normally live together and eat their meals in the same dwelling [33]. The data obtained was used to estimate the binary logistic and OLS regression models. For the purpose of this study, the heads of the selected households, whether male or female, were implicitly assumed to be the sole decision-makers in the adoption of irrigation farming decisions. Household heads were therefore selected to respond to the structured questionnaire. Predictor variables of adoption were selected from the broad range of the household's socioeconomic aspects, including demographics, farming activities, institutions, processes of adoption and asset endowment.

3.3. Data analysis

In this article, both descriptive and econometric data analysis methods are used. The crop production system in the studied areas on the four different sites represents multi-crop agricultural production. Where land holdings are fixed, the allocation of land into crop type and the adoption of small-scale irrigation farming are possibly endogenous. The adoption decision of small-scale irrigation farming and associated technologies is distinct, as a farmer can decide to adopt or not adopt, in which case the smallholder farmer faces a dichotomous decision problem to adopt or not adopt irrigation farming. In this context, smallholder irrigation farming adopters practised irrigation farming at the time of the survey, while the rest are taken as non-adopters. Similar definitions of adopters and non-adopters have been used by other writers [34]. In the OLS-based impact analysis, only farmers who had practised irrigation farming for at least one season were considered. The econometric models for adoption and the model on the effect of the adoption of small-scale irrigation farming on income are specified in Section 2.3.1 below.

3.3.1 Modelling the adoption of small-scale irrigation farming

The general assumption is that there is a desire to maximise the expected utility of adopting new technologies like small-scale irrigation farming [13,35]. Although the utility-maximising objective of individual smallholder farmers everywhere might be the same, the specific characteristics that influence their technology adoption decisions are far from uniform. The farmers' responses to the adoption of small-scale irrigation farming are assumed to be consistent with utility maximisation. Binary logistic regression is a common statistical procedure in which

the probability of a dichotomous outcome (adoption or non-adoption) is related to a set of explanatory variables and has been widely applied in adoption studies [32, 34, 36-40] . In this research, smallholder farmers' adoption of small-scale irrigation farming is based on an assumed underlying utility function. According to this model, the farmer will adopt small-scale irrigation farming if the utility obtained from small-scale irrigation faming exceeds that of non-adoption. Considering the probability of an event = Prob (Y = 1 if the smallholder farmer adopted and 0 otherwise), the smallholder farmer's behaviour towards irrigation farming is described as an indirect utility that is derived from the adoption of small-scale irrigation farming, which is a linear function of k explanatory variables (X) expressed as:

$$Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_{ki},$$

(1)

where β_0 is the intercept term and $\beta_1, \beta_2, \beta_3, \ldots\ldots, \beta_i$ are the coefficients associated with each of the *k* explanatory variables (X_1, X_2, X_3,…,X_{ki}). The X vector of variables (including socioeconomic, farming, institutional factors and other household-specific characteristics that influence the individual farmer's decision whether to adopt or not) explains the adoption of irrigation farming by the smallholder farmer, i.e. it explains the likelihood of the adoption of irrigation farming by the individual (i_{th}) farmer (see Table 1).

Considering $P_i = \frac{e^{zi}}{1+e^{zi}}$, where P*i* denotes the probability of the i_{th} farmer's adoption decision and (1-P_i) is the probability of non-adoption, the odds of adoption (Y = 1) versus the odds of non-adoption (Y = 0) can be defined as the ratio of the probability that a farmer adopts (P_i) to the

probability of non-adoption (1-P_i), namely odds = $P_i/(1-P_i)$ [41]. By taking the natural

logarithms, one gets the prediction equation for the individual farmer:

$$\text{Ln}\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{i=1}^{n} \beta_i X_{ki} = Z_i, \tag{2}$$

where Z_i is referred to as the odds ratio in favour of the adoption of irrigation farming.

3.3.2 Variable selection and hypothesis on adoption decisions model

Table 1 gives a full description of the dependent variable, explanatory variables and initial

hypotheses of selected predictor variables on adoption decisions. Previous studies on the

adoption of agricultural technologies, such as the determinants of micro-irrigation adoption [42

43, 44], economic theory on adoption and the researchers' own perceptions of the socioeconomic

setting of the study locations guided the selection of variables and their expected signs [33, 35-

40].

Table 1: Description of the variables specified in the binary logistic model of adoption

Variable acronym	Description	Measurement	Posited sign
Dependent variable			
Irrig_fmng	Whether farmer adopted irrigation farming or not	Dummy (1 if yes, 0 if no)	+
Explanatory variables			
Gender	Sex of household head	Dummy (1 if male, 0 if female)	+
Age	Age of household head	Years	-
Hsize	Household size	Numbers	+
Edu	Educational background of the household head	Number of years of formal education	+
Ext	Access to agricultural extension services	Dummy (1 if yes, 0 if no)	+
Occup	Nature of main occupation of the household head	1 if farming, 2 if formal employment, 3 if small-scale business, 4 if casual labour, and 5 if skilled labour	+/-
offfarm_emp	Members of the household with off-farm employment	Numbers	-
CreditAcc	Access to credit	Dummy (1 if yes, 0 if no)	+
IrrigEquip	Household's access to irrigation equipment	Dummy (1 if yes, 0 if no)	+
ReliableWaterSos	Access to a reliable water source that can be used for irrigation purposes	Dummy (1 if yes, 0 if no)	+
Aware_Conserv	Awareness of some of the water conservation practices, such as rainwater harvesting	Dummy (1 if yes, 0 if no)	+
DistMktsqrt	Distance to the nearest market (square root)	Kilometres	-
landszecult	Size of land available for cultivation	Hectares	+/-

3.3.3 Modelling effect of the adoption of irrigation farming on income

The continuous dependent variable is agricultural income. As such, the OLS regression model can be used without a doubt. Getacher et al. [34] have also used the approach to estimate the effect of irrigation technology adoption on total agricultural income. To estimate the effect of the adoption of irrigation farming on household agricultural income, a multiple OLS regression model is used that is specified as follows:

$$Y_i = \beta_0 + X_{1i}\beta_1 + X_{2i}\beta_2 + \cdots\ldots\ldots + X_{ki}\beta_k + p_i\beta_{k+1} + \varepsilon_i \;,$$

(3)

where Y_i = agricultural income;

X_{ki} is a vector of the household's socioeconomic characteristics and other farm-specific characteristics. These characteristics include LUs, contact with agricultural extension and labour;

p_i denotes the adoption of small-scale irrigation farming status for a farmer; a dummy variable is specified as 1 for adopters and 0 for non-adopters; and

ε_i is the error term, which is assumed to be normally distributed with a mean of 0 and unit variance.

Table 2 below shows the explanatory variables used in the OLS regression model with their specifications.

Table 2: Description of the variables specified in the OLS regression model

Acronym	Description	Type of measure	Posited sign
Dependent variable			
Agricultural income	Income from agricultural production	US$	+
Explanatory variables			
Irrig_fmng	Whether farmer adopted irrigation farming or not	Dummy (1 if yes, 0 if no)	+
Ext	Access to agricultural extension services	Dummy (1 if yes, 0 if no)	+
landszecult	Size of land available for cultivation	Hectares	+/-
Labour	Labour force size	Active labour force members	+
econactiv	Economically active population	Numbers	-/+
offfarm_emp	Members of the household with off-farm employment	Numbers	-
Group	Household member belongs to a farmer group	Dummy (1 if yes, 0 if no)	+
LUhh	Livestock units	Numbers	+
mainCrop_1	Main crop grown by household	1 if cereal, 2 if horticultural, 3 if mixed	+/-
DistMktsqrt	Distance to the nearest market (square root)	Kilometres	-
Literacy	Level of literacy in the household	Numbers	+
Adopt_LSW	Household adopted any available water, land or soil conservation practices	Dummy (1 if yes, 0 if no)	+/-

3.3.4 Descriptive statistics of variables used in the two econometric models

The statistics of the variables specified in the two empirical models (the adoption of irrigation farming model and the income model), as shown in Table 1 and Table 2, are given in Table 3 below. The table shows summary statistics on the profile of enumerated smallholder farmers.

Table 3: Statistics of variables used in the econometrical models

Variable	Mean n=312	Standard deviation n=312	Minimum n=312	Maximum n=312
Age	46.589	15.308	20	90
Hsize	5.837	2.379	1	15
Edu	5.045	3.637	0	17
Ext	0.692	0.462	0	1
Occup	1.311	0.909	1	5
offfarm_emp	0.776	1.354	0	8
CreditAcc	0.237	0.426	0	1
IrrigEquip	0.333	0.472	0	1
ReliableWa~s	0.487	0.501	0	1
Aware_Cons~v	0.792	0.407	0	1
DistMkt	30.142	21.135	0.3	95
DistMktsqrt	5.133	1.951	0.55	9.75
landszecult	6.126	7.041	0.3	41
Labour	3.288	1.807	0	12
econactiv	2.824	1.754	0	10
offfarm_emp	0.776	1.354	0	8
Group	0.340	0.474	0	1
LUhh	1.457	4.093	0	60
mainCrop_1	1.154	1.109	1	14
Literacy	2.458	1.970	0	11
Adopt_LSW	0.712	0.454	0	1
Irrig_fmng	0.471	0.50	0	1

4. Results and discussion

4.1. Validity of the binary logistic model

Coefficients of the binary logistic model were estimated by the maximum likelihood method using STATA 12 software. The results of the binary logistic model are given in Table 4. The number of observations used in the model is 312. Prob > Chi2 = 0.000 and a pseudo R2 of 42.2% shows that the model is valid and the model estimates fit very well with the data at an acceptable level.

4.2. Results of the model and discussion

Table 4 reports the coefficients (B), standard errors of the coefficients (S.E), odds ratios and the p-values. Odds ratios show the predicted change in odds for a unit increase in the corresponding explanatory variable. Expressed in terms of variables used in the model, the logistic regression equation is:

$\text{Ln} \left(\frac{P_i}{1-P_i} \right)$ = Ln (Odds) (reporting coefficients of only significant variables)

$\quad$ = -(0.040*Age) -(2.813 formal employment)- (1.462 Small-scale business) + (0.604*offfarm_emp) + (0.706*IrrigEquip) +(2.921*ReliableWaterSos) + (0.964*Aware_Conserv) -(0.199* DistMktsqrt) $\quad$ (4)

These estimates provide information on the relationship between the significant explanatory variables and their influence on the adoption of irrigation farming within the study area, where the dependent variable is on the logit scale.

The results of the logit model (Table 4) show that, among the hypothesised explanatory variables, only eight significantly influenced the adoption of irrigation farming. Age, formal employment, Small-scale business, offfarm_emp, IrrigEquip, ReliableWaterSos, Aware_Conserv and DistMktsqrt were the significant variables in the binary logistic model. Contrary to the hypothesis, Gender, Hsize, Edu, Ext, Casual labour, Skilled labour, CreditAcc and landszecult did not significantly influence the adoption of small-scale irrigation farming.

Table 4: Parameter estimates of the binary logistic regression model for factors influencing the adoption of irrigation in the Chinyanja Triangle

Variable	B	(S.E)	Odds ratio	(P-value)
Gender	0.543	0.452	1.721	0.229
Age***	-0.040	0.012	0.961	0.001***
Hsize	0.046	0.074	1.047	0.537
Edu	0.011	0.05	1.011	0.830
Ext	-0.482	0.383	0.618	0.208
Occupation				
formal employment***	-2.813	0.983	0.060	0.004***
Small-scale business*	-1.462	0.794	0.232	0.066*
Casual labour	-1.554	1.653	0.211	0.347
Skilled labour	-1.099	0.924	0.333	0.234
offfarm_emp***	0.604	0.179	1.829	0.001***
CreditAcc	-0.171	0.414	0.843	0.680
IrrigEquip**	0.706	0.358	2.027	0.049**
ReliableWaterSos***	2.921	0.367	18.564	0.000***
Aware_Conserv**	0.964	0.471	2.623	0.041**
DistMktsqrt*	-0.199	0.104	0.819	0.055*
landszecult	0.006	0.023	1.006	0.811
_cons	-0.381	0.925	0.683	0.680

***=1% level of significance, **=5% level of significance, *=10% level of significance

Age has a negative impact on the adoption of small-scale irrigation farming, which suggests that the odds of adoption are higher among younger farmers than older farmers. Specifically, results show that a one-year increase in the farmer's age reduces the odds of adoption by about 4% (1 to 0.96). The average age of 46 for a population with a life expectancy of 40 shows that most farmers are ageing. As farmers get older, despite their accumulated experience in farming, they tend to lose energy, have short planning horizons and become more risk averse, so adopting new irrigation practices may be difficult for them. This result is expected and is consistent with other scientists' findings [45, 46-48]. Moreover, small-scale irrigation farming is time and labour intensive. The proper management of irrigable crops (especially fruit and vegetables) also requires storage and transportation facilities, as well as market availability and access to the market, which acts as an adoption barrier to the older farmers.

The household head's occupation was another variable that was thought to influence the adoption of small-scale irrigation farming. In terms of the sub-categories of nature of employment, formal employment and small-scale business were found to have a significant negative impact on the adoption of small-scale irrigation farming. The odds of adoption were found to decrease if the household head's main occupation was either formal employment or involvement in a small-scale business. A probable explanation is that for households with formal employment and those involved in small-scale businesses, time will be the major limiting factor when it comes to focusing on agricultural activities. Household heads will tend to focus more on their work and small businesses and, as a result, the adoption of small-scale irrigation farming becomes more difficult. This finding agrees with that of Abera [49], who argues that irrigation is

generally a labour- and time-intensive endeavour, and households usually find it difficult to synchronise small-scale irrigation farming with other off-farm activities.

In addition, the number of household members with off-farm employment was found to significantly influence the adoption of small-scale irrigation farming. The predicted change in the adoption of small-scale irrigation farming was found to be 1.83 for every increase in membership of the household with off-farm employment by 1. This could probably be because off-farm activities play a supportive role in agricultural practices, especially as an alternative source of agricultural financing. Therefore, an increase in household members with off-farm employment increases the chances of adoption because of its supportive role. This result is consistent with that of Namara et al., [50], who concluded that off-farm employment activities improve income for the farmer and that income can be used to complement agricultural activities. However, the result was not as expected, but was still acceptable, as empirical studies by Herath and Takeya [51] noted the role of off-farm income in the adoption of agricultural practices as unclear and a contested terrain.

As expected, access to irrigation equipment influenced the adoption of small-scale irrigation farming positively and significantly at a 5% level. The odds of adoption were found to be 2.03 times greater for farmers with access to irrigation equipment, compared to those without access. Access to irrigation equipment necessitates the adoption of small-scale irrigation farming. Moreover, access to a reliable water source that can be used for irrigation also influenced the adoption of small-scale irrigation farming as expected. The odds of adoption are 18.6 times greater for farmers with access to reliable water sources, compared to farmers without reliable

water access. In this case farmers whose fields neighbour rivers and small water channels like streams. The results thus highlight the importance of the necessary irrigation equipment and reliable water sources in setting up successful small-scale irrigation farming systems. Based on the binary logistic model, access to irrigation equipment and a reliable water source are vital for any farmer to try small-scale irrigation farming.

Awareness of water conservation practices such as rainwater harvesting was also selected as an explanatory variable to explain variability in the adoption of small-scale irrigation farming. Results show that awareness of water conservation practices within the study sites had a positive and significant influence on the adoption of small-scale irrigation farming. The odds of the adoption of small-scale irrigation farming were found to be 2.62 times greater for farmers who were aware of water conservation methods practised within the study sites in comparison to those who were not aware of such methods. This could be because the farmers who are aware of water conservation practices are more likely to adopt such practices. This necessitates the adoption of small-scale irrigation farming, since earlier results indicate that access to reliable water sources positively influences the adoption of irrigation farming. Besides farmers who have installed rain water harvesting technologies such as water tanks would divert more of their time to adopt small-scale irrigation practices in riparian areas instead of going to fetch water for domestic use.

The distance travelled to access the nearest market was another variable that was thought to influence the adoption of small-scale irrigation farming. The results show that the distance travelled to access input and/or output markets has a significant negative influence on the

adoption of irrigation farming. Odds of adoption decrease by about 18% with a one-kilometre increase in distance to the nearest input or output market for the farmer. This might be explained by the fact that most smallholder farmers now appreciate the role of markets in their farming activities. As a result, access to markets influences their farming intensification decisions. Farmers closer to input markets are motivated to adopt small-scale irrigation farming, since they realise that their production will be improved and they can easily sell the surplus to nearby markets. For farmers who travel long distances to access output markets, the situation might be very different. As much as they realise the importance of the adoption of small-scale irrigation farming in raising agricultural output, they may be discouraged to adopt the practice when they plan on selling their surpluses because long distances come with additional marketing costs, which they cannot afford.

4.3. Impact of the adoption of small-scale irrigation farming on income

The adoption of small-scale irrigation farming was hypothesised to positively influence smallholder farmers' agricultural income. In the OLS-based impact analysis, the dependent variable is agricultural income. The adoption of small-scale irrigation farming is selected as an independent variable to explain variation in agricultural income. The results of the analysis are shown in Table 5.

Table 5: Impact of the adoption of irrigation farming on agricultural income: OLS results

SqrtAgricIncome	Coefficient	Standard error	P-value
Irrig_fmng**	2.052	0.940	0.030**
Ext	1.70	0.972	0.081*
landszecult	0.097	0.067	0.147
Labour**	0.645	0.318	0.043**
econactiv	-0.371	0.315	0.240
offfarm_emp	-0.173	0.373	0.643
Group	0.620	0.989	0.531
LUhh	-0.087	0.116	0.452
mainCrop_1*	0.747	0.399	0.062*
DistMktsqrt*	0.423	0.256	0.099*
Literacy	0.036	0.264	0.893
Adopt_LSW**	-2.247	1.004	0.026**
_cons**	5.979	1.780	0.001***

=1% level of significance, ***=5% level of significance, *****=10% level of significance

As expected, the results confirm that the adoption of small-scale irrigation farming within the Chinyanja Triangle explains variation in agricultural income. The adoption of small-scale irrigation farming is found to have a significant positive impact (at a 5% level) on agricultural income. This could be because farmers who use small-scale irrigation farming can intensify and diversify their agricultural activities, which increases their production. Increased production will lead to increased income from agriculture (through the sale of surpluses) *ceteris paribus*. With small-scale irrigation, farmers can produce off-season, as they can supplement their crops with water in the case of mid-season dry spells or shortages. In other words, small-scale irrigation farming reduces climate risks, improves crop production and reduces agricultural production's overdependence on rainfall [34,52].

Factors like access to extension, labour, crops grown, distance to the nearest market, and the adoption of land, soil and water conservation practices also had a significant influence on agricultural income.

5.   Conclusions and implications

This study was undertaken to improve our understanding of how efforts to promote the adoption of small-scale irrigation farming as a climate-smart agriculture practice can influence the income of smallholder farmers in the Chinyanja Triangle. Several useful conclusions that provide insight into pathways to increase smallholder farmers' adoption of small-scale irrigation farming in the study area and improve agricultural income have emerged from this research.

Firstly, results indicate that promoting small-scale irrigation farming as a climate-smart agriculture practice for adoption by smallholder farmers should consider the farmer's age, main occupation, off-farm employment status, access to and availability of micro-irrigation equipment, water source reliability, awareness of certain water conservation measures and distance to the nearest markets. The lesson from this article is that failure to consider these socioeconomic aspects may lead to inappropriate results when aiming for higher rates of adoption of small-scale irrigation farming as a climate-smart agriculture practice in the study area.

For example, the rehabilitation of reliable water sources will be an important move that can positively impact on the adoption of small-scale irrigation farming. More so, assisting farmers to access intermediary irrigation farming technologies and equipment will also enhance adoption. Raising farmers' awareness of water conservation practices, such as rainwater harvesting

methods and techniques, through extension or any other means will be critical towards improving the uptake of small-scale irrigation farming.

Secondly, results suggest that succeeding in enhancing the adoption of small-scale irrigation farming as a climate-smart agriculture practice through careful consideration of the socioeconomic aspects and other farm-specific attributes will enhance farmers' income. This is an important finding, since the main motivation for urging farmers to adopt technology is their welfare. Enhancing the adoption of small-scale irrigation farming within the Chinyanja Triangle will be a great step towards improving farmers' agricultural income and combating climate variability and change.

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6.   References

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