DETERMINANTS OF MICRO IRRIGATION ADOPTION FOR MAIZE PRODUCTION IN SMALLHOLDER IRRIGATION SCHEMES: CASE OF HAMA MAVHAIRE IRRIGATION SCHEME, ZIMBABWE

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ABSTRACT

This study is an assessment of the determinants of micro irrigation adoption for maize production in smallholder irrigation schemes. The focus of the study was on Hama Mavhaire irrigation scheme in Midlands Province, Zimbabwe. An assessment of the major production constraints in the scheme was carried out, factors that influence the decision to adopt micro irrigation for maize production identified, the extent of adoption of micro irrigation for maize production and the contribution of micro irrigation to maize yields were determined. Questionnaires, semi structured interviews and focus group discussions were used as data collection tools. Friedman test for ranking was used to rank the production constraints and the logit regression analysis to determine the factors that influence the adoption decision. One sample t-test was employed to ascertain the level of micro irrigation adoption for maize production and multiple regression to determine the impact of micro irrigation on maize yields in smallholder irrigation schemes. Ranking results showed that input unavailability followed by inefficient irrigation systems are the major production constraints. The gender, age and agricultural training of household head had a significant ($P<0.05$) influence on the adoption decision. Results from the study show that 66.7% of trained farmers and 33.3% of untrained farmers adopted micro irrigation. This shows the importance of training in decision making. One sample t-test results showed no statistically significant ($P>0.05$) difference between the hypothesised (0.35) and generated (0.31) mean adoption values. The hypothesis of low adoption of micro irrigation for maize production was accepted. Micro irrigation was found to have a significant ($P<0.05$) impact on maize yields in the smallholder irrigation scheme. Intervention by the government, Non Governmental Organisations (NGOs) and other stakeholders in the provision of low cost micro irrigation systems for smallholder farmers may enhance the uptake and result in increased maize yields in these schemes.

Key words: Adoption, Micro irrigation, Maize, Smallholder

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INTRODUCTION

Agriculture is the cornerstone of Zimbabwe's economy contributing 27% of Gross Domestic Product (GDP), 17% of foreign currency earnings and 37% of employment [1]. Zimbabwe is subtropical, varying in height above sea level. Lowlands (where most communal areas are located) are warm and dry with an average annual rainfall of between 400 and 600 mm. Mountainous regions are wetter with 1500 to 2000 mm average, annual rainfall. Rainfall in the lowlands is concentrated over a short period of time during summer and the winters are dry. In times of drought, the low yield area is usually hard hit as its meager water resources are severely depleted leaving misery for man and animals. Overtime, the government of Zimbabwe has invested heavily in the development of smallholder irrigation schemes. These efforts have been made in an attempt to modernise communal peasant farming which is risky due to its dependence on the erratic natural rainfall. This will in turn culminate in rural growth and development through improved household food security in these low rainfall areas [2]. Estimates are that about 132,700 hectares are being irrigated in Zimbabwe with only 9% in the smallholder farming sector [3]. Of the 9%, about 640 hectares, representing 0.04% of the irrigated land in smallholder irrigation schemes are under micro irrigation [4]. Maize is one of the major cereal crops produced by smallholder irrigation farmers in Zimbabwe. The staple accounts for over 63% of the irrigated land in the smallholder schemes.

The irrigated agricultural sector is facing increasing challenges in the face of a rapidly growing population, decreasing availability of land and immense competition for scarce water resources [5]. Due to decreasing investments and declining performance of many large-scale irrigation schemes, interest has been developing in recent years for crafting ways to improve the productivity and livelihoods of the world's small-scale farmers [6]. Low cost micro irrigation technologies developed by International Development Enterprises (IDE) and other stakeholders offer a breakthrough technology approach to increasing smallholder irrigation potential [7]. However, stakeholders have questioned the contribution of these schemes to the national economy. As such, world lending towards the schemes has dropped by about 50% in recent years in real terms. Compounding this, low water use efficiencies of about 30%-60% are a cause of concern since water is a scarce resource that needs to be efficiently utilised to increase the land that is irrigated.

Conceptual framework
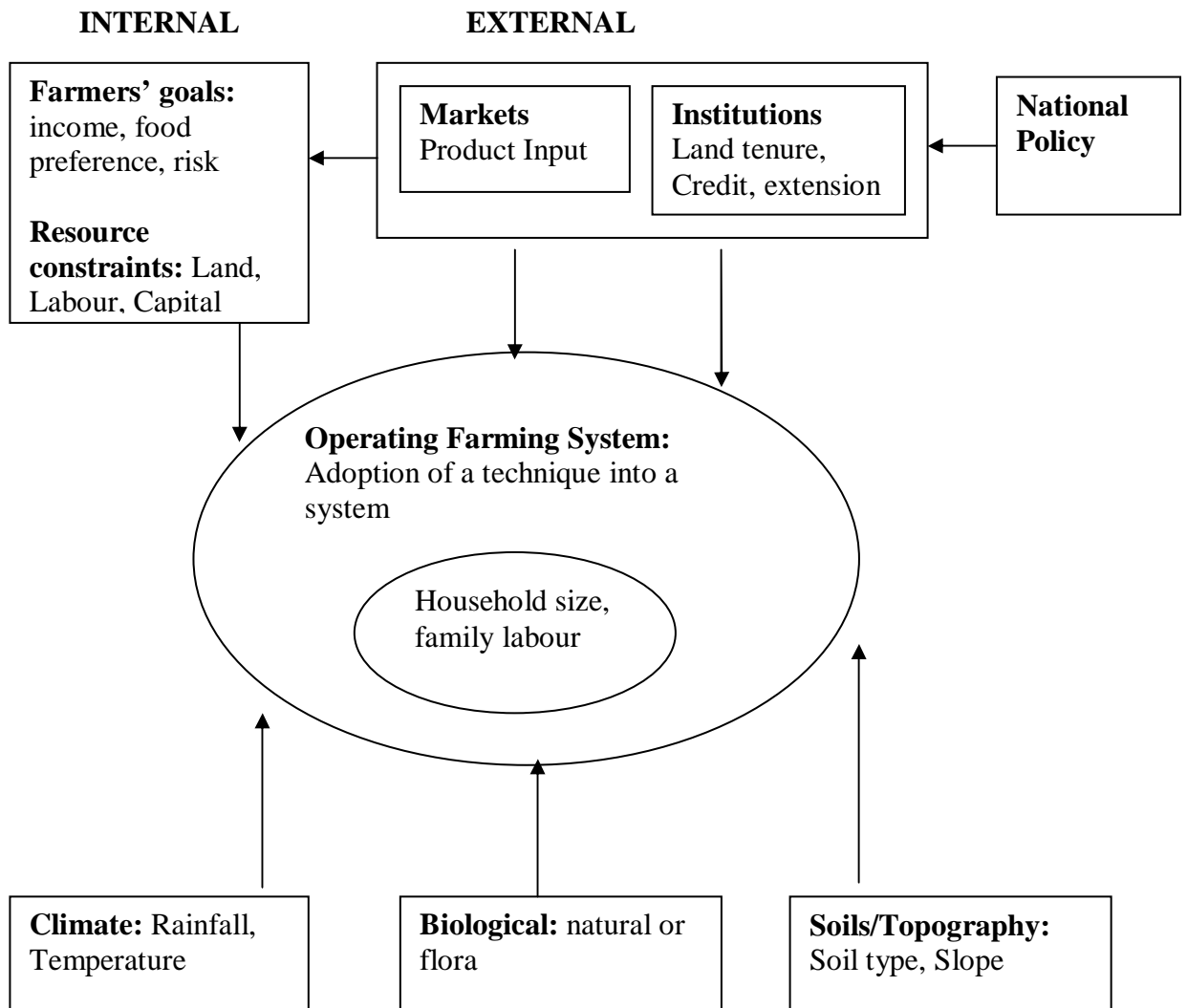
Source: [8]
Figure 1: Factors influencing adoption decision

There are various farmer circumstances that influence decision for technology adoption as shown in Fig.1[8]. These may include natural (climate, soils or topography), institutional (government policies) as well as farmer specific (education level, age, household size and attitudes) factors.

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Literature on smallholder irrigation focuses mainly on the "formal" irrigation [9]. The government has had too much control on smallholder irrigation schemes and in the process puts pressure on the irrigators to:

- Use conventional irrigation methods which the government can afford to finance such as flood irrigation;
- Pay water rates;
- Practice prescribed crop rotations and plant on specific dates; and
- Produce surplus food crops for the market and later cash crops.

The strong government grip has culminated in the emergency of "supervision by management" from government staff especially Agricultural Research and Extension (AREX) officers in an attempt to raise yields in the sector [10]. However, with the old irrigation technologies dominant in the smallholder sector which require a lot of water, studies have shown that farmers are unlikely to improve their yields in the absence of a reliable supply of water [11]. Furthermore, with a large number of people in management, it is almost impossible to make quick decisions in times of water scarcity.

Main objectives of smallholder irrigation
The government has mainly propelled these objectives which include:

- To counteract the effects of drought, which is prevalent in the small-scale farming areas;
- To increase and sustain food production per unit area of land (a scarce resource);
- To ensure food security and hence reduce malnutrition in the communal areas;
- To create employment opportunities in the rural areas;
- To improve the standards of living of small scale farming societies (communities); and
- To produce for the export market hence a source of foreign currency [11].

The main aim of smallholder irrigation development was to help break the cycle of persistent rural poverty and food insecurity and increase smallholder incomes. However, studies have shown that the reluctance to address irrigation directly and more innovatively in a more commercially oriented environment has deprived smallholder farmers of improved livelihoods [11].

Viability of smallholder irrigation
Though productivity in most smallholder irrigation schemes falls below the potential levels, studies have shown that smallholder irrigation schemes are financially viable if there is sound management [11]. Viability of smallholder irrigation schemes employing micro irrigation technology can also be assessed from the perspective of issues such as biodiversity creation and preservation as well as the reduction of rural-urban migration. Studies in India have revealed that:

▪ Smallholder irrigation farmers in India are now able to grow high value crops such as paprika and guar beans for both the local and export markets thereby effectively participating in the mainstream economy;

▪ Irrigation development in most of the communal areas has resulted in infrastructural development in the form of road and telephone networks;

▪ Smallholder irrigators have shifted from peasant agriculture and are now producing commercially [12].

▪

The concept of micro irrigation

Micro irrigation is a method of delivering slow, frequent applications of water to the soil using a low pressure distribution system and special flow control outlets. It can also be called drip, bubbler, and dribble or trickle irrigation [13]. The outlets used may be lying just above (dribblers) or just below the soil surface (emitters). The typical rate of emission from the emitters is 2 to 20 L/hr [13]. Perforated or porous tubes may also be used as outlets and range from 12 to 16mm in diameter installed 0.1 to 0.3m below the soil surface or laid along the crop rows. These tubes apply 1 to 5L/min per 100m of tube. To maintain an adequate flow in the tubes, pumps supply pressure of between 0.1 to 0.3atm. With this system, only the immediate area close to the emitter is wetted. The moisture then advances through the soil until some level where there is a match between infiltration rate or evaporation and the emission rates. About 1m diameter patch of the ground receives moisture [13].

Water use efficiency and productivity in smallholder irrigation schemes

Studies conducted show that after decades of expanding irrigation and improving productivity in the smallholder sector, farmers face the emerging crisis of slow modernization and constrained water availability [14].Taken together, these crises profoundly compromise rural livelihoods due to the low water use efficiency, productivity and low crop yields.

Of late, experience in Tunisia, Zambia and India demonstrates that the mix of farmer investments and government subsidies has the greatest impact on both water saving and incomes through switches to more rewarding technologies even on food crops such as maize and rice [14]. Central to this was the identification of affordable, appropriate and efficient systems that tend to add value so that the smallholders were to work themselves out of poverty through more incomes from less water and spending less time watering while expanding production. The initiative to modernise smallholder irrigation came after studies revealed that the overall irrigation efficiency (excluding micro irrigation) in the smallholder irrigation sector of 93 developing countries (Zimbabwe included) was 45% in the late 1990s. This meant a loss of more than half the water mobilized for irrigation [14].

Micro irrigation has been identified to have 95% irrigation efficiency and the amount of water saved by achieving this level of efficiency in the world's smallholder irrigated area could meet about half the demand for additional water supplies in the sector [14]. Such savings are the main option for addressing water shortage challenges in smallholder irrigation sectors of developing countries.

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METHODS

Study area description

Figure 2: Map of Zimbabwe showing Chirumhanzu (Study Area)

Hama Mavhaire irrigation scheme is in Chirumhanzu District in the Midlands Province of Zimbabwe. It is 200km from Harare. This is an area of erratic rainfall between 400mm and 510mm per annum with temperatures ranging from 24^0C to 31^0C and is in natural farming Region IV. Soils are mainly from the granite parent material. Due to the climatic conditions in the area, crop production may not be productive and most farmers concentrate on livestock production, mainly the small ruminants. The introduction of irrigation schemes in the area has seen some crops mainly maize, groundnuts and some high value crops such as paprika and sugar beans being produced by the farmers. The main irrigation systems in the area are sprinkler and flood.

Data collection

A case study was conducted at Hama Mavhaire irrigation scheme and the unit of analysis was the individual household. The sample included adopters and non adopters of micro irrigation kits. Purposive sampling enabled identification of Hama Mavhaire scheme where maize was being produced under the micro irrigation system. From the 179 farmers at the scheme, 67 were randomly selected using the lottery technique. The sample size was considered large enough to increase the power of the study. Budgetary and time restrictions were also considered in limiting the sample size.

This method allowed for equal chances of inclusion in the sample for every farmer in the scheme. Structured questionnaire interviews were conducted using semi structured questions. In addition, focus group discussions took place with farmers and village heads together with AREX officers. During all these processes, participation was voluntary and ethical considerations were taken into account with the farmers being assured of the confidentiality of the information they divulged to the researcher. Ethical considerations were also made and the researcher conformed to the norms and values of the community by accepting to be a part of the people dealt with. The researcher treated the respondents as humans and with dignity.

Techniques

For constraint ranking, Friedman test which yielded mean ranks for the constraints depending on responses based on a pre-determined scale was used. Since the researcher had been in the area previously, there was knowledge on the universe of production constraints faced by the farmers. Scaling was from 1 "extremely severe" to 5 "not a serious problem".

The one sample t-test allowed for the comparison of hypothesised mean adopters to the mean generated from the study. The number of adopters was obtained from the sample where farmers were noted to have been free to adopt without coercion.

A multiple regression model allowed for the establishment of the relationship between a dependent variable (maize output) and several independent variables affecting the maize yields. A set of independent variables was established and included credit level, income level, and education level. This model enabled the assertion of the combined effect of different variables on maize yields in the study area.

The model used can be expressed as:

$$Y = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_n X_n + U \tag{15}$$

Where:

Y = Dependent variable

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B_0 = Constant

$B_1, \ldots, B_n$ = Partial regression coefficients

$X_1, \ldots, X_n$ = Independent variables

n = nth variable

U = disturbance term

The disturbance term contains all factors other than those captured in the model but that affect the maize yield.

The dependent variable (adoption) was a dichotomy, that is, it had only two distinct possible values for adoption or no adoption. Without loss in generality, the outcomes were coded as (Y = 1 for adopters) and (Y =0 for non-adopters) yielding a binary dependent variable. Since the response was qualitative, a qualitative response model (the logit model) was used. This is a non linear model since binary dependent variables ("dummy Y's) are not effective in linear regression models [15]. This model assumes that the probability of observing the dependent variable (adoption of micro irrigation), P_i, relies on a vector of independent variables, (X_{ij}) and a vector of unknown parameters, (B) [15]. The likelihood of observing the dependent variable (P_i) was tested as the function of variables including sex, age and training of household head therefore:

$$P_i = F(Z_i) = F(a + BX_i) = 1 / \{1 + \exp(-Z_i)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Where:

$F(Z_i)$ = the value of the standard normal density function associated with each

possible value of the underlying indexes Z_i.

P_i = the probability of observing a specific outcome of the dependant variable (such as

adoption of micro irrigation for maize production).

B = regression parameters to be estimated.

X_i = set of explanatory variables.

a = regression intercept.

BX_i = linear combination of independent variables so that:

$$Z_i = Log \{P_i / (1-P_i)\} = B_O + B_1X_1 + B_2X_2 + \ldots + B_nX_n + U \ldots\ldots\ldots\ldots\ldots\ldots\ldots[2]$$

The dependant variable (Z_i) is the natural logarithm of the probability that a particular choice (adoption of micro irrigation for maize production) would be made [15]. This model implies diminishing magnitude of the partial effects for the independent variables and the coefficients give the signs of the partial effects of each of the independent variables on the adoption probability [15]. The dummy variables included were defined to distinguish between two groups and the coefficient estimates the ceteris paribus difference between the two groups such as males and females.

RESULTS

Results (Table 1) show that farmers view late input delivery as the major constraint. This was followed by the inefficient irrigation systems being used by the farmers. A mean rank value of 2.85 placed water shortage at Hama Mavhaire irrigation scheme as the third obstacle to sound production for the farmers. Inefficient Irrigation Management Committees were the least problematic in the scheme. The test statistic for the Friedman test is statistically significant ($P< 0.05$).

Table 2 shows that the mean adoption for the micro irrigation system was 0.31 (31%). The 2-tailed test revealed that there is no statistically significant difference ($P>0.05$) between the test value (0.35) and the mean adoption of micro irrigation (0.31). Results from multiple regression analysis showed that duration of the farmer in the scheme, area under maize crop, use of micro irrigation, level of credit, labour and level of fertilizer use have a significant ($P<0.05$) impact on maize output. However, income levels, gender, age and agricultural training attained by household head have negative partial regression coefficients and ($P<0.05$) as in Table 3.

From Table 4, age, gender, marital status and agricultural training attained by household head significantly ($P<0.05$) influenced the farmer's decision to adopt micro irrigation technology.

Table 5 shows that 67% of the trained farmers adopted the technology and 33.3% of the untrained farmers adopted micro irrigation. Gender of household head had a significant influence ($P<0.05$) on the adoption decision with 66.7% of females adopting and 33.3% of males adopting as in Table 5. The duration of farmer in the scheme, household size and level of education attained by the farmer did not significantly influence the adoption decision ($P>0.05$) as shown in Table 4.

DISCUSSION

Late supply of inputs (maize seed, fertilizers and chemicals) is the main production constraint. This may be attributed to poor infrastructural development (road and telephone networks) in the areas where the schemes are situated, making transportation of the inputs to the farm difficult. Furthermore, the smallholder irrigation farmer gets second preference to their commercial counterparts when it

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comes to input allocation by input suppliers. With the acute shortage of these inputs at the national level, smallholder irrigation farmers with their poor management skills are always faced with the problem of inputs.

Participation of NGOs in smallholder irrigation schemes has enabled innovations in agriculture to reach farmers. Inefficient irrigation systems were pinpointed as a major constraint. The dominant methods employed are the conventional flood and isolated cases of sprinkler which have low efficiencies of as low as 45%. This is supported by studies conducted in Honduras where yields for cereals were found to be significantly lower for farmers utilising flood irrigation as compared to those using micro systems [16].

The location of many smallholder irrigation schemes in areas of poor and erratic rainfall means that water scarcity is a prevalent problem in these schemes. Also coupled with poor natural resources management in these areas, major supply dams are silting at an alarming rate. Water scarcity has also called for the need to commercialise the water supply system in Zimbabwe. This has given birth to the Zimbabwe National Water Authority (ZINWA) to supply and monitor water use and charging and hence a shift from the subsidised rates farmers used to enjoy. This might have negative consequences on the economic viability of the schemes. On the other hand, since water in the schemes is delivered by costly assets, there needs to be some service cost recovery mechanism and charging farmers for water use. This reduces the burden on government fiscal capacity and allows funds to be channeled to other more rewarding projects.

The non-significant difference as indicated by the t-test shows that there is low uptake of the system in smallholder irrigation schemes. The low uptake may be due to under performance of the schemes which leaves the farmer without enough capital reserves to invest in innovations available on the market. The tendency in most smallholder irrigation schemes for most farmers has now turned to be subsistence production [16]. As such, most farmers do not see the need to invest heavily in expensive technologies. Though the repayment period had been spanned over 10 years depending on the yield levels, most farmers at Hama Mavhaire did not take up the micro irrigation kits. This might have been propelled by the conservativeness of farmers especially the elderly who do not want to try out new technologies due to the risks associated with such decisions.

From the results, a farmer's duration in the scheme has a significant (P<0.05) impact on maize production probably due to the farming experience acquired over time by the farmer. This experience may enrich the farmer on the major production aspects such as a sound knowledge of agronomic practices, soil type and the pests as well as the disease outbreaks common in the area. The coefficient for duration is 0.185 and is positive meaning that *ceteris paribus*, having two farmers, a farmer with an additional year in the scheme has a yield 18.5% higher than the counterpart.

Credit has a catalytic effect on productivity in most sectors of the economy, the agriculture sub-sector included; in other words, credit is important for farmers in a country like Zimbabwe, where they (famers) are among the poorest members of society. This is especially true for women, who generally lack clear title to land or other assets that lenders require as collateral.

This study showed a significant ($P<0.05$) contribution of credit to maize output as depicted by a positive coefficient of 0.182. This is mainly due to the increased access to inputs and availability of requisite capital for farm operations as well as the ability to invest in innovations leading to enhanced production and yields.

Nutrient availability is central to sound plant growth. Furthermore, irrigation development and increased fertilizer use have driven agricultural productivity for the past 50 years [16].The *ceteris paribus* effect of fertilizer use on maize yields is given by the coefficient of level of fertilizer use. This means that a 1% increase in level of fertilizer use leads to a 437% increase in maize out put. However, farmers have to be aware of the optimal levels of fertilizer use and guard against diminishing marginal returns to fertilizer use. Since water is largely removed as a growth limiting factor in irrigated farming systems, appropriate fertilizer and manure application can lead to quantum-leap yield increases as shown for the South-Asian Rice-Wheat Consortium.

A priori expectations were that older farmers have higher yields than their young counterparts as the former are usually hard workers and experienced farmers [16]. In this study, however, age does not have a significant ($P>0.05$) impact on the maize outputs mainly because young farmers are usually pioneers and the elderly are laggards when it comes to innovation take-up. As such, young farmers are employing updated methods of production such as latest technologies and appropriate levels of fertilizer, and insecticide use. Micro irrigation systems have efficiencies of up to 90 %. This study reveals that adopters have yields up to 274% higher than the non adopters of micro irrigation. This might further be attributed to the low labour requirements for micro irrigation users due to the mechanism of the micro set up, which has light tubes and require less manpower to operate. Revelations from the study are that access to credit must be enhanced for smallholder irrigation farmers to allow them to access inputs such as fertilizers and make use of the available technologies such as micro irrigation. Also extension services to enlighten the older farmers coupled with field trials to allow evaluation and observability and appreciate the greater relative advantage, might create an enabling set-up for use of micro irrigation to boost maize yields.

The adoption of micro irrigation for maize production was measured as to whether a farmer adopted or not. It is important to note that the dependent variable in the logistic regression model is not adoption but the probability to adopt. It then follows that the coefficients of the independent variables represent the change in the probability of adoption given a unit change in the corresponding independent variable.

Results in Table 4 show that effect of age has the predicted negative sign. This means that the odds of adoption of the micro irrigation technology decrease as the farmer gets older. This is supported by studies where findings were that as farmers get older, they tend to be more conservative and risk averse and are less likely to take up new ideas and innovations [16]. This, however, may also be greatly influenced by the position of the farmer in the social cycle with those in high caste groups also having great chances of adopting. The coefficient of training shows that farmers who are trained have higher chances of adopting micro irrigation than the untrained farmers. This may be due to the ability of trained farmers to obtain and use information available on the relative advantages of the available technologies over the conservative technologies. Training also generates confidence among the farmers resulting in higher rates of adoption. Gender also has a strong bearing on the adoption decision and women who do much of the farming in the communal setup always tend to opt for low labour intensive farming methods. In the study, results show that young female farmers have higher chances of adopting micro irrigation as compared to older males.

CONCLUSION

The ranking of inefficient irrigation systems as the second major constraint may be viewed as an indicator that farmers do acknowledge the derailment being imposed upon production by the systems they are using. Results also indicate that most of the constraints are gravitating around the water issue. As such, there is need for a plan that will bring all the stakeholders into a coherent framework for action to address the water problem in smallholder irrigation schemes. However, at the 5% level of significance, it can be concluded that there is low uptake of micro irrigation technology (an efficient irrigation system) by the farmers in smallholder irrigation schemes. These efficient systems can enhance maize productivity in the schemes. To try and address the low adoption problem, focus can be placed on agricultural training to capacitate the farmers and enable them to utilize the micro irrigation system and boost production for those embarking on the maize enterprise. In addition, adapting technologies to the level of farmers' willingness to change their habitual way of farming could have helped improve micro irrigation adoption. Some farmers complained that they had not adopted micro irrigation, as the projects were difficult and time consuming.

Table 1: The ranking of constraints

Constraint	Late delivery of inputs	Inefficient irrigation systems	Shortage of water	High water charges	Marketing problems	Inefficient IMCs
Mean rank	2.43	2.78	2.85	2.93	4.53	5.48

IMCs: Irrigation Management Committees

Table 1.1:   Test statistic

n	Chi-square	df	Sig
67	166.708	5	0.000

Level of significance = 0.05

df: Degrees of Freedom

n: Number of respondents in the study

Sig: Significance

Table 2: Comparisons of mean adoption

One sample test

Test value=0.35

Adoption of micro irrigation	mean	t	Df	Sig(2-tailed)
	0.31	-0.64	66	0.524

Level of significance = 0.05

df: Degrees of freedom

Sig: Significance

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Table 3: Relationship between maize yield and different independent variables

Variable	B (Coefficient)	Significance
Constant	-3.808	0,353
Duration	0.185	0.047
Area	61.267	0.006
Adoption	2.741	0.002
Credit	0.182	0.009
Labour	1.946	0.046
Income	-1.047	0.299
Fertilizer	4.372	0.000
Gender	0.568	0.706
Age	-0.442	0.660
Training	-0.607	0.712

Level of significance = 0.05

Dependent variable is the maize out put (in 50 kg bags)

B: Partial regression coefficient

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Table 4: The relationship between adoption and different independent variables

Variable	Age	Duration	Training	Household size	Education	Gender	Marital status	Constant
Coefficient	-0.14	-0.04	4.165	-0.014	0.427	2.775	1.963	-10.814
Significance	0.049	0.617	0.002	0.942	0.516	0.018	0.006	0.015

Level of significance = 0.05

Dependent variable is log (Probability "adoption")

B: Partial regression coefficient

Table 5: Percentage of adopters and non-adopters according to training and gender

Variable	Response	Non-adopters (%)	Adopters (%)
Training	No	78.3	33.3
	Yes	21.7	66.7
Gender	Male	76.1	33.3
	Female	23.9	66.7

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