Original Research Article

Modelling the Determinants of Using Matengo Pits in Adapting to the Impacts of Climate Change and Variability: The Case of Mbinga District, Tanzania

Abstract

Aims: This study was undertaken to find out what determines the adoption of Matengo pits in order to adapt to the impact of climate change and variability.

Study Design: The study adopted a quantitative research design. The design allowed collection of a wide range of numerical data, covering the socio-economic characteristics of the respondents and their households, farm characteristics and institutional factors. These data were important in finding out the determinants of using Matengo pits.

Methodology: The study was conducted in Mbinga District, south-western Tanzania, because of the predominance of the pits. Three wards, which constituted about 10% of all 28 wards, were randomly selected and one village from each ward was selected to represent the other villages. Data were collected using structured interviews with systematically selected respondents from the sampling frame, which comprised all the heads of farmer households. A logistic regression analysis was conducted to find out the determinants of practicing Matengo pits.

Results: The findings indicated that slope of the land was the most important factor that determined the use of Matengo pits. This was based on the *Wald* value of 42.846, which was greater than all the other *Wald* values and the *p-values* of 0.000 at a 95% confidence level. Other significant determinants of using Matengo pits were sex of the household head *(p-value = 0.000)*, farming experience (*p-value* = 0.002), knowledge of Matengo pits as a strategy for adapting to climate change and variability (*p-value* = 0.004) and the size of a household (*p-value* = 0.014).

Conclusion: Matengo pits dominated the steep slopes of the study area, where they were introduced for soil conservation purposes. Low practicing of the pits were observed in the low land areas because some farmers had no knowledge about the usefulness of Matengo pits in their areas. Besides, the strategy is adopted differently by different sex, whereby male headed households were mostly practicing Matengo pits than their female counterparts. This is attributed to difficulties involved in digging the pits among the females and low income to employ other people to dig the pits. Further, farming experience and knowledge about the usefulness of the pits in adapting to climate change and variability increased the rate of practicing the strategy. Regarding the size of a household, small household size reduced adoption due to small labour force to engage in digging the pits.

In view of these findings, it is argued that knowledge of the usefulness of Matengo pits for adapting to the impacts of climate change and variability and availability of financial resources can help to overcome the barriers to practicing Matengo pits. As such, the Government, Non-Governmental Organisations and Community-Based Organisations should provide education about the usefulness of the pits and fiscal resources to motivate more famers in the district and other areas to adopt Matengo pits so as to improve their adaptive capacity, food security and the general socio-economic development.

Key words: *Climate change and variability, Matengo pits, Determinants and Logistic regression*

1. Introduction

Climate change takes place at unprecedented rates; thus, it has deleterious effects on natural, social and economic systems [1,2]. Agriculture is amongst the highly affected sectors, especially in developing countries due to over-dependence on rainfall [3]. It is worth noting that agriculture is the backbone of the economies of many developing countries [4,5,6]. Thus, climate change and variability affect crop production, food security, economies and general livelihoods of people in many such countries.

Various empirical studies have been undertaken to find out the strategies used to adapt to the effects of climate change and variability in farming systems as well as their sustainability in the face of the current and projected climate change. Mixed farming, changing planting date, the cultivation of early maturing crops, terracing, rainwater harvesting and irrigation are among the on-farm adaptation strategies adopted in various countries [7,8,9]. However, these strategies do not bear the desired results owing to the high rates of change in the earth's climate systems. Indeed, studies have indicated that many adaptation strategies fail or are projected to fail owing to the increase in climate change [10,11]. In order to have sustainable livelihoods, farmers ought to adopt innovative strategies; effective in the current and future climate change [10,11].

Using Matengo pits, locally known as *ngolo*, is one of the strategies that can withstand climate change. It is a unique, traditional farming strategy used by the Matengo people who live in the south-western highlands of Tanzania, particularly in Mbinga District. The technique has been used in the district since the 19th century and has, therefore, been used for more than 200 years [12]. In practice, the technique involves digging pits of approximately 1.5m square by 0.5m deep all aver the farm, thus forming ridges on which crops are grown [12]. The ridges are fertilised using grass or remnants of previous crops.

Traditionally, Matengo pits meant for soil conservation, the reduction of soil erosion and land management. Essentially, these were the reason for the introduction of the strategy on the steep slopes of Mbinga District [13,14,15]. However, recent studies have indicated that this is the best strategy for adapting to the impacts of climate change, especially drought [16]. According to these authors, water/moisture can stay in the pits for some days, thus enabling seeds to germinate even if there is no rain for days at the beginning of the rainy season. Moreover, Matengo pits can help to reduce the effects of dry spells (dry days between rainy seasons) on crop development and production. Dry spells cause soil water deficiency, thereby leading to plant water stress, crop withering and poor or no harvests. Matengo pits are useful in adapting to this climatic condition because the water in the pits can help crops to grow even during such conditions. As such, Matengo pits are useful for crop production during climate change-induced droughts.

Therefore, although Matengo pits have been used for different purposes in Mbinga District, their usefulness with regard to adaptation to climate change and variability cannot be overemphasised. It is important, therefore, that more farmers in the District and other places adopt this strategy. The strategy can help increase crop production, food security and the general economic development of farmer households and countries. However, without an understanding of the determinants of its adoption, the strategy may not be adopted. Adoption of a strategy (technology) may be determined by attitudes towards using that technology which is a function of its perceived usefulness and perceived easy to use [17] (Figure 1).

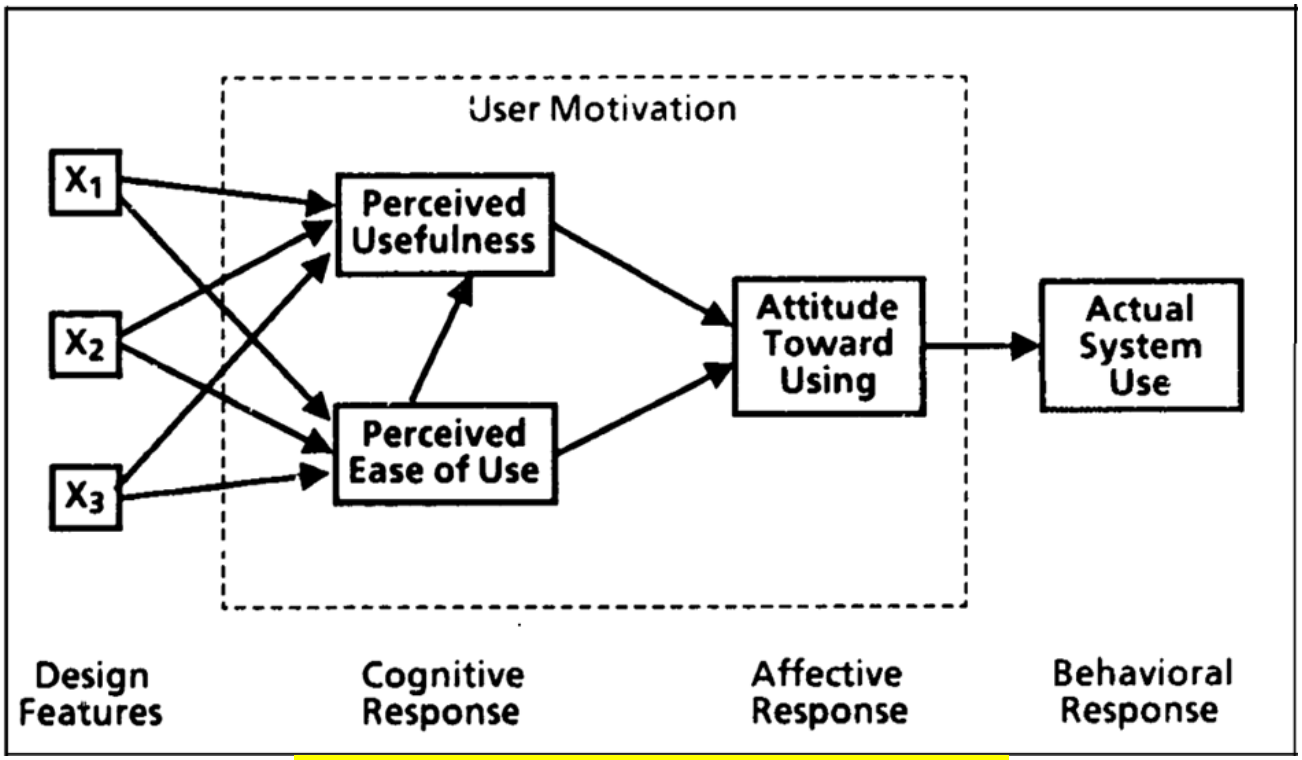

Figure 1: Technology Acceptance Model (Source: [17])

In the same line of argument, Rogers in his diffusion of innovation theory posit that rate of acceptance of innovation or technology is determined by the perceived attribute of that innovation which include its relative advantage, complexity to understand and use, compatibility with the existing values, trialability and observability (18). Moreover, types of innovation–decision, communication channels, the nature of social systems and the extent of change agents' promotion efforts are also proposed to be the determinants of innovation/ technology acceptance [18]. This theoretical frameworks provides an understanding of the determinants of acceptance of technologies. However, to foster adoption of specific technologies, there is a need for empirical studies to ascertain the determinants of adoption of the technologies in question. This study was conducted to find out the determinants of acceptance of Matengo pits, focusing on Mbinga District.

2.0 Material and Methods

2.1 Study Area

This study was conducted in Mbinga District, Ruvuma Region, Tanzania. This area was selected owing to the predominance of Matengo pits.

2.2 Study Approaches and Design

The study adopted a quantitative design to collect a wide range of numerical data to find out the determinants of using Matengo pits. The data were collected using a questionnaire survey. The questionnaire was used to interview the sampled household heads.

2.3 Sample and Sampling Procedures

Three wards, which constituted about 10% of all 28 wards of Mbinga District, were randomly selected. The selected wards were Mikalanga, Kambarage and Mpapa. One village was selected from each ward. The villages were Ilela, Matekela and Mitawa. The Village Executive Officer of each village was consulted and requested to provide a list of farmer households; the lists were compiled to produce a sampling frame. The sampling frame was useful for determining the sample size and selecting a representative sample. The three villages had a total of 3,148 farmer households. Table 1 presents the number of farmer households in each village.

Table 1: Number of Farmer Households per Village

Ward	Village	Number of Households
Mikalanga	Ilela	1,368
Kambarage	Matekela	914
Mpapa	Mitawa	866
	Total	**3,148**

The sample size was determined on the basis of a 95% confidence level and a 5% (0.05) precision level. The population for this study was finite and so the sample size was determined using the equation for determining a sample size for a finite population proposed by Kothari (2004). The equation is given below.

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2\,(N-1) + z^2 \cdot p \cdot q}$$ [19].

Where;
n = sample size
z = standard variate at a given confidence level (which is 1.96 at 95% confidence level)
p = sample proportion
$q = 1 - p$
N = size of the population (number of farmer households)
e = precision (acceptable error).

Data for the calculation were:
$z = 1.96$, $p = 0.2$ (population varies in terms of using Matengo pits or otherwise),
$q = 0.8$,
N = 3, 148,
e = 5% (0.05).

Inserting data into the equation:

$$n = \frac{(1.96)^2\,(0.2)\,(0.8)\,(3148)}{(0.05)^2\,(3148) + (1.96)^2\,(0.2)\,(0.8)} = 228$$

Thus, 228 respondents were interviewed. The number of respondents from each village was determined using proportionate stratified sampling, which allowed for the sampling of a proportional number of respondents from each village, according to the size of its population. The following equation of proportionate sampling proposed by Kothari was used to obtain the sample:

$$P_i = \frac{N_i}{N} n$$ [19].

Where P_i = the proportional sample of each village,

N_i = the number of households in each village,

N = the total households forming the sampling frame and

n = the sample size.

The computations and sample size for each village are given in Table 2.

Table 2: Proportional Sample for Each Village

Village	Number of Households	Sample Size for Each Village
Ilela	1,368	1,368/3,148 x 228 = 99
Matekela	914	914/3,148 x 228 = 66
Mitawa	866	866/3,148 x 228 = 63
Total	**3,148**	**228**

Thus, 99 household heads were selected from Ilela village, 66 from Matekela village and 63 from Mitawa village. These household heads were systematically selected from the sampling frame.

2.4 Data Types and Data Collection Methods

The main data for this study included various variables believed to be the determinants of adopting Matengo pits. The data included the characteristics of the household heads: age, sex and level of education. The characteristics of the households were: household size, income, knowledge of Matengo pits, farm characteristics, including farm size, crops grown as well as institutional factors such as access to information on climate and access to agricultural extension services. These were quantitative data and were collected using a questionnaire. The questionnaire was administered to the sampled household heads. The questionnaire was translated from English to Kiswahili because most of the respondents were conversant in Kiswahili and not English. Then, findings from Kiswahili were translated back to English language.

2.5 Data Analysis Techniques

Logistic regression was used to analyse the determinants of adopting Matengo pits using IBM-SPSS Statistics. Logistic regression (binomial logistic equation) is appropriate for examining the relationship between the number of independent variables and a binary dependent variable (dependent variable on a dichotomous scale) [20,21]. The following model was used in doing the analysis:

$$Y_i = \beta_0+\beta_1X_1+\beta_2X_2+ \ldots\ldots \beta_9X_9$$

Where Y_i = a dichotomous dependent variable

β_0 = Y-intercept

$\beta_1 - \beta_9$ = a set of coefficients to be estimated and

$X_1 - X_9$ = hypothesised explanatory/independent variables.

In this study, using Matengo pits was a dependent variable, which was specified as *using Matengo pits* = 1 and *otherwise* = 0. Basing on the technology acceptance model [17], the diffusion of innovation theory [18] and the empirical studies on determinants of adoption of climate change adaptation strategies [22,23], the study hypothesised the explanatory variables indicated in Table 3.

Table 3: Explanatory Variables and Expected Signs

Variable	Description	Expected Sign	Reason for the Expected Sign
X_1	Sex of the household head (*1=M, 0=F*)	+	More male-headed households are using Matengo pits than their female-headed counterparts due to the intensive labour requirement.
X_2	Age of household head	+	More aged people are involved in farming and use adaptation strategies than youths.
X_3	Level of education of the head of household	+/-	Some farming strategies are preferred by educated people while others are not.
X_4	Household size	+	More family members require services that necessitate adopting good adaptation strategies and increase man power to involve in Matengo pits.
X_5	Farming experience	+	Experience increases the possibility of adopting farming strategies.
X_6	Slope of land *(1= Steep, 0=flat/gentle slope)*	+	Matengo pits are mostly used on steep slopes because of their traditional role in soil conservation.
X_7	Access to information on climate (1=*much*, 0=*limited*)	+	Access to information on climate motivates people to adopt adaptation strategies.
X_8	Knowledge of Matengo pits *(1= Yes, 0=No)*	+	Knowledge is an important factor in adoption decision process [18].
X_9	Knowledge of Matengo pits as a climate change adaptation strategy *(1= much, 0=limited)*	+	Knowledge is an important factor in adoption decision process [18].

3.0 Results and Discussion

Results of the logistic regression analysis are presented in Table 4. The overall fitness of the model as a tool for analysing the data was tested using the Hosmer-Lemeshow test of goodness-of-fit and was found to be appropriate for analysing the data collected for this study. Decision on the significance of the determinants was based on the significance level, as indicated by the Sig.column in the logistic regression output (Table 4). Since the results are reported with a 95% confidence level, the significance value must be 0.05 (5%) or less, in the case of the significant independent variables. Besides, the Wald estimates give the importance of the contribution of each variable, such that the variable with a higher Wald value is the most important one. Table 4 show results of the logistic regression analysis.

Table 4: Results of the Logistic Regression Analysis on the Determinants of Using Matengo Pits

Hypothesised Independent Variable	B	Wald	df	Sig.	Exp(B)
Sex of the household head	1.934	12.191	1	.000	6.918
Age of the household head	-.024	.052	1	.820	.976
Education of the household head	1.010	1.686	1	.194	2.747
Household size	.306	6.029	1	.014	1.358
Farming experience	.348	9.271	1	.002	1.416
Slope of land	4.596	42.846	1	.000	99.055
Access to information on climate change	-.294	.214	1	.644	.746
Knowledge of Matengo pits	3.723	3.103	1	.078	41.377
Knowledge of Matengo pits as an adaptation strategy to climate change and variability	2.047	8.199	1	.004	7.746
Constant	-12.886	15.135	1	.000	.000

($Y_i = \beta_0+\beta_1X_1+\beta_2X_2+ ...... \beta_9X_9$)

Table 4 indicates that the significant determinants of using Matengo pits are the sex of the household head, the size of the household, farming experience, the slope of land and the knowledge of Matengo pits as a strategy for adapting to the impact of climate change and variability. The *p-values* for those variables were 0.000, 0.014, 0.002, 0.000 and 0.004, respectively. Among these, the slope of land was the most important determinant with a *Wald value* of 42.846, which was the greatest of all the *Wald values*. This was followed by the sex of the household head, farming experience, knowledge of Matengo pits as a strategy for adapting to the impact of climate change and variability and the size of a household. By contrast, the age of the household head, the level of education, access to climate information and general knowledge of Matengo pits were statistically insignificant at a 95% confidence level. The following discussion is on the significant determinants of using Matengo pits.

3.1 Slope of Land

The slope of land had significance influence on the adoption of Matengo pits. The pits were mostly used on steep slopes because of their traditional role in soil conservation. Studies have shown that Matengo pits were introduced on the steep slopes of Mbinga District to reduce soil erosion and soil conservation [14,15,16]. Thus, the technique is used more on steep slopes than in flat or gently sloping areas.

3.2 Sex of the Household Head

Another significant determinant of using Matengo pits was the sex of the household head. Male-headed households were more likely to use Matengo pits than those headed by female heads. Female-headed households found it difficult to adopt Matengo pits owing to the difficulty in digging the pits. The majority of the female-headed households who used the pits were found to have other characteristics, which motivated them to adopt the strategy. The characteristics included the size of a household; a big household had enough work force or a high income with which to engage other people to dig the pits for them. These findings concur with some previous studies which reported differences between male- and female-headed households in terms of using strategies for adapting to climate change and variability [23,24]. Both studies have shown that female-headed households were less likely to employ adaptation strategies than male-headed households because of the traditional social barriers that prevent females from having easy access to land, capital and other important resources.

3.3 Farming Experience

Farming experience was the third most important determinant of using Matengo pits; it had a *Wald value* and a *p-value* of 9.271 and 0.002, respectively. It was found that more experienced farmers were more likely to adopt Matengo pits than their less experienced counterparts. Closely related to farming experience was the age of respondents. Some studies associate age and farming experience; age represented farming experience and affected adaptation to climate change impacts [22]. On the contrary, this study found that age was an insignificant explanatory variable. This may be due to the fact that the study used farming experience and age as independent explanatory variables and the fact that what influenced the use of Matengo pits was the duration in which one had engaged in farming (farming experience) more than age. This means that those who were experienced in farming were most likely to use Matengo pits, regardless of their age.

3.4 Knowledge of the Usefulness of Matengo Pits

Knowledge of the usefulness of Matengo pits as a strategy for adapting to the impact of climate change and variability positively influenced the adoption of the strategy. From a theoretical viewpoint, Rogers postulated that knowledge is important in the adoption decision process [18]. People adopt technologies whose existence and usefulness they know about. Studies have reported that Matengo pits were a useful strategy for adapting to the impact of climate change and variability [16]. This study further noted that the technique helped to conserve moisture for some days or weeks, thus supporting crop germination and reducing water stress under dry conditions during various stages of crop development. The current study has found that the farmers with knowledge of the usefulness of Matengo pits were more likely to adopt the strategy than those without or with less such knowledge.

3.5 Household Size

The size of a household was the least important explanatory variable in the adoption of Matengo pits. This finding concurs with the finding of Deressa, who reported that, although the increase in the size of a household did not significantly increase the probability of adopting the strategy by the farmers in the Nile basin in Ethiopia, the positive sign indicated that large households were highly likely to adapt to climate change impacts [21]. In the present study, although the *Wald values* indicates that the size of a household was the least important explanatory variable, its influence as a factor for adoption of Matengo pits cannot be ignored. A large household provides the labour force required in using Matengo pits. In addition, the large number of household members increases the demand for life necessities, which encourages the adoption of strategies, including Matengo pits, which are likely to increase production.

4.0 Conclusion

This study sought to find out the determinants of using Matengo pits so as to foster adoption of the pits for sustainable adaptation to climate change and variability. The logistic regression analysis done has shown that the slope of land, the sex of the household head, farming experience, knowledge of Matengo pits as a strategy for adapting to climate change and variability and the size of a household were the significant determinants of using the pits at a 95% confidence level. Matengo pits are mostly practiced at the steep slopes due to their traditional role of preventing soil erosion and soil conservation. Farmers from low land areas do not find it necessary to adopt the pits. This is especially the case with those whose knowledge about the usefulness of Matengo pits in adapting to climate change and variability is minimal. Thus, the Government (particularly the local government authorities), Non-Governmental Organisations and Community-Based Organisations in Mbinga District and other areas need to provide education about the usefulness of Matengo pits in adopting to climate change and variability. Other significant factors, including size of the household and sex of head of the household can be addressed by provision of financial resources. These measures may increase farmers' appeal to the strategy in question hence increasing its adoption and contribute positively on efforts to adapt to the impacts of climate change and variability.

Consent

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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