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Factors Influencing Utilization of Rain Water Harvesting Technologies for Improved Food Security in Kauwi Sublocation Kitui County, Kenya

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A B S T R A C T

Despite the known advantages of the rain water harvesting technologies, studies show that the utilization rate at community level continues to be lower than expected. The current study focused on socio-economic factors influencing the utilization of rain water harvesting technologies in Kauwi sub-location, Kitui County, Kenya. The study adopted a survey design. Random sampling was used to identify the villages while households were systematically selected. A total of 160 households comprised the study's representative sample size from which interviews were conducted. From the results, 60% of the variation of utilization of earth dams was explained by the outcome variables (Nagelkerke R^2=0.6). Scrutiny of the results indicated that labour source ($p<0.1$, B=2.66) and access to credit ($p<0.1$, B=5.44) were the significant factors influencing earth dam utilization. The study concluded that different factors influenced utilization of different technologies differently. Findings of this study will help farmers in prioritizing factors that influence decision on utilizing rain water harvesting technologies.

Introduction

Water is an essential natural resource, vital for any development to take place. However, studies indicate not more than one percent of the water is freely available for social needs including agricultural production in the entire world (Alberto Boretti and Lorenzo Rosa, 2019). FAO (2011) indicated that the demand for water had increased worldwide rapidly, causing a gap amid provision and fulfilling the various human needs, and real supply and access to best water quality, mostly in low to medium-income countries.

Arid and semi-arid regions (ASARs) worldwide are facing water scarcity challenges, especially for domestic, industrial, commercial and agricultural purposes. Rain-fed agriculture is the most common farming practice in arid and semi-arid lands. However, it has been challenged by acute shortage of water and the uncertain climate. Farmers are met by rainfall that is low on average annually and changing rainfall distribution both temporally and spatially (Luvai *et al.,* 2014)

The arid and semi-arid areas of Kenya are characterized by insufficient water for household use, crop and livestock production (Jaetzold *et al.*, 2007). Due to low rainfall and its irregularity and variability in distribution, low fertilizer uses and poor overall crop management, smallholder farmers obtain very low yields on average (Jaetzold *et al.*, 2007). The unreliable rainfall for agriculture results in food insecurity in the regions. Various suggestions including rain water harvesting technologies have been put forth for farmers relying on water for crop production concerning how they can maximize production with minimum available water (Jothiprakash & Sathe, 2009). Despite the known advantages of the rain water harvesting technologies, the utilization rate at community level continues to be lower than expected, hence the focus of the study on factors influencing the utilization of the technologies. The information generated by the study would help farmers to ensure that decision they make on capitalizing on rain water harvesting technologies have been prioritized among other farming techniques. Further, the study would add to the empirical literature relating to rain water harvesting thus increasing the acceptability of the study by the researchers in society

Materials and Methods

Climate and topography of study area

The study area is as illustrated in fig. 1. The climate of the study area is in two climatic zones, arid and semi-arid but most of the County being categorized as arid. The County's temperatures are high throughout the year, ranging from 14°C to 34°C (GoK, 2009). September and October to January and February are the hot months and usually 26°C and 34°C are the maximum mean annual temperatures while the minimum mean annual temperature ranges between 14°C and 22°C. The coldest month is July with temperatures falling to as low as 14°C while the hottest month is that of September with temperature rising as high as 34°C (GoK, 2009). The rate of evaporation is high as the temperatures are high throughout the year. The rainfall pattern is bi-modal with two rainy seasons annually. The long rains come in the months of March to May. These are commonly very erratic and unreliable (Luvai *et al.,* 2014). The short rains forming the second rainy season occur between October and December and are more reliable. The other part of the year is dry. The annual rainfall ranges between 250mm-1050 mm per annum with long rains being 40% reliable while short rains 66% reliable (GoK, 2009). It is difficult to predict rainfall yearly. Seasonal rivers during the periods of rain are the major sources of surface water but after the rains, they dry up.

The soils are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storing capacity and low nutrient availability (Kibunja *et al.,* 2010). In most places, they have topsoil of loamy sand to sandy loam.

Social Economic Activity

The community's main economic activity is mixed crop and livestock production. This production system is determined on the agro-ecological zones. Arable farming is the main activity where they grow crops such as pigeon, maize, millet, cow peas, green gram, sorghum. They plant cash crops for commercial purpose such as green grams, cotton, coffee and sunflower. They rear livestock such as goats, sheep, donkeys, chicken and bees (GoK, 2009).

Map of study area

Research Design and Sampling procedure

This study adopted a descriptive research design. To get a representative sample size of 160 households, 10% of the total population (1600 households) of the study area was sampled. Kauwi Sub- Location was clustered into 23 villages that were all homogenous and 50% of the villages were then randomly selected. The sample size was obtained proportionately according to the number of households of each village. The tenth respondent was selected systematically from each village as a study sample for the purpose of being interviewed.

Data Collection Instruments

Personal observations and household survey interview schedule were adopted for this study.

Data analysis

The econometric model employed was logistic regression model which analyzed factors influencing adoption of rain water harvesting technologies. This model was chosen because it was simple in estimation hence lends itself to a meaningful interpretation. The details of the model are outline below.

Logit Model

$$Pi = F(\alpha + \beta xi) = \frac{1}{1+e^{-\alpha+\beta xi}}$$

$$Pi = \left[1 + e^{-(\alpha+\beta xi)}\right] = 1$$

Where $\alpha+\beta x_i = \log\left[\frac{P_i}{1-P_i}\right]$

And $\frac{P_i}{1-P_{i......}}$ is the likelihood ratio, whose log gives the odds that a technique is adopted.

Where: α is the constant of the equation

β is the intercept term

The regression can be expressed as

$\text{Log}(p_i/(1-p_i)) = \alpha + \beta 0 + \beta 1 * x1 + ... + \beta_n * x_n$

Where, i denotes i^{th} farmer, (1……364); Pi the probability of adoption by the farmers, and (1- Pi) is the probability of non-adoption. Where β0 is the intercept term, and $\beta_1, \beta_2, \beta_3 ... \beta_n$ will be the coefficients associated with each explanatory variable $X_1, X_2, X_3 ... X_n$. The details of the variables are given in Table 1.

Results and Discussion

Demographic Characteristics of Respondents in Kauwi sub-location

The demographic characteristics of the respondents presented in this section include gender, education, age, marital status, occupation, sources of labour, group membership, title deed ownership, credit access and income distribution of the households that participated in this study.

The results in Table 2 indicated that 40.25%of the household heads were males, while only 20.75% were females Majority of the heads of households were monogamously married 56.6% whereas 8.10% were single, 4.5%polygamous married, 1.1% divorced and 17.21%widowed. In addition, the results showed that most of the household heads were full time farmers 73.45%, 34.21% were business people, 27.16%casual labourers, and 7.45%had formal employment.

Further, data presented in Table 1 indicated that 12% of the respondents obtained their sources of labour from members of the family, 30.18% hired labour and 7.4% obtained labour from other sources.

The results showed that 22.12% of the household heads had no education at all, 82.57% had primary level of education, 43.26% had secondary level of education, 15.19% had tertiary level of education. From the results, it was evident that most of the household heads had primary level of education. Household heads that belonged to farmers' group membership were 21.13% and 13.86% belonged to no group. Those who accessed credit was 55.34%and 10.65%did not access any credit. Finally, 68.42%house heads had title deeds.

Influential factors of the utilization of rain water harvesting technologies in the Kauwi Sub-location

This study aimed at studying how different factors influenced individual rain water harvesting technologies in Kauwi Sub-Location. The significance level was at 5% and 1% significance level. The most significant rain water harvesting technologies included earth dams 60%, rooftops 58%, trash lines 48%, sand dams 46% and Zai pits and 45% rain water harvesting technologies (Table 3). This was because they had large Nagel kerke value compared to the rest of the technologies.

From the study area, earth dams were the most significant rain water harvesting technologies where 60% of the variation of its utilization was explained by the outcome variables. The variables that significantly influenced the utilization of this technology at 5% level of significance included labour source ($p<0.05$, B=2.66) and access to credit ($p<0.05$, B=5.44). This technology is labour and cost intensive during its initial construction face and maintenance face. Both family and hired labour increased the chances for utilizing this technology. This is because there was more labour that made work easier and there was shared responsibility. Access to credit made it possible for the households to access the funds necessary for purchasing of installation materials. This was in line with Mangisoni *et al.,* (2019) who found that access to credit enabled small holder farmers to access finance that would later be used to buy installation materials and pay for labour in the initial face and the maintenance face of the RWHTs.

Rooftop rain water harvesting technology was the second most significant rain water harvesting technology where 58% variation of its utilization was explained by the predictor variables. Occupation of household head ($p<0.01$, B=0.93), years involved in farming ($p<0.01$, B=-0.11), type of soil ($p<0.01$, B=-1.17) and off farm income ($p<0.01$, B=0.00) were the most significant factors at 1% significant level. It was very much unexpected that male was more likely to utilize this technology. Most female were responsible in utilizing rooftop rain water harvesting technologies as they were responsible in collecting water for domestic and livestock use. However, this could be due to the fact that the males were the decision makers and responsible for making various households' decisions. This finding was contrary to that of Ibrahim (2013) who found females to be highly associated with rooftop rain water harvesting technology. Those who were employed were more likely to utilize this technology compare to the unemployed. Employed persons could earn additional income that would be used in buying storage tanks for rooftop rain water harvesting.

On the other hand, employed persons were less likely to practice rooftop rain water harvesting to fulfil agricultural needs since the income earned could enable them in purchasing the needed agricultural products. This finding agreed with that of Cheserek *et al.,* (2013) who found out that employed persons would afford storage tanks for rooftop rain water harvesting technologies.

From the table 4.4, trash lines were the third most significant rain water harvesting technology where 48% (Nagelkerke R^2=0.48) of the variation of the utilization of this technology was explained by the outcome variables and 92.1% of the cases were correctly predicted. At 5% significant level, only one predictor variables influenced its utilization, the type of soil ($p<0.05$, B=-2.27). Trash line involved piling crop residues along contours in order to control erosion and help in improving water infiltrating into the soil. However, clay had high infiltration rate due to its high infiltration rate no erosion would be experienced due to run off thus this negatively influenced utilization of trash lines in the study area.

Table.1 Description of explanatory variables that predict probability of small holder farmers' utilizing rain water harvesting technologies in Kauwi Sub- Location

Variables	Description of variables	Hypothesized influence on adaptation
X_1	Age of the household head	+/-
X_2	Gender of household head	+/-
X_3	Education level of the household head	+
X_4	Years in Farming	+
X_5	Occupation of HH	+
X_6	Household size	+
X_7	Access to credit	+
X_8	Labour source	+
X_9	Land size	+/-
X_{10}	Type of soil	+/-

Table.2 Demographic Characteristic of Household Heads in Kauwi Sub-location

Demography	Value	Percentage (%)
Gender	Male	40.25
	Female	20.75
Marital status	Single	8.10
	Monogamously Married	56.62
	Polygamous married	4.5
	Divorced/ separated	1.1
	Widowed	17.21
Occupation	Fulltime farmer	73.45
	Business person	34.21
	Casual labourer	27.16
	Formal employment	7.4
Source of labour	Family labour	12
	Hired labour	30.18
	Others	7.4
Level of education	None	22.12
	Primary	82.57
	Secondary	43.26
	Tertiary	15.9
Group membership	No	13.86
	Yes	21.13
Title deed ownership	No	68.42
	Yes	31.58
Credit Access	No	10.65
	Yes	55.34

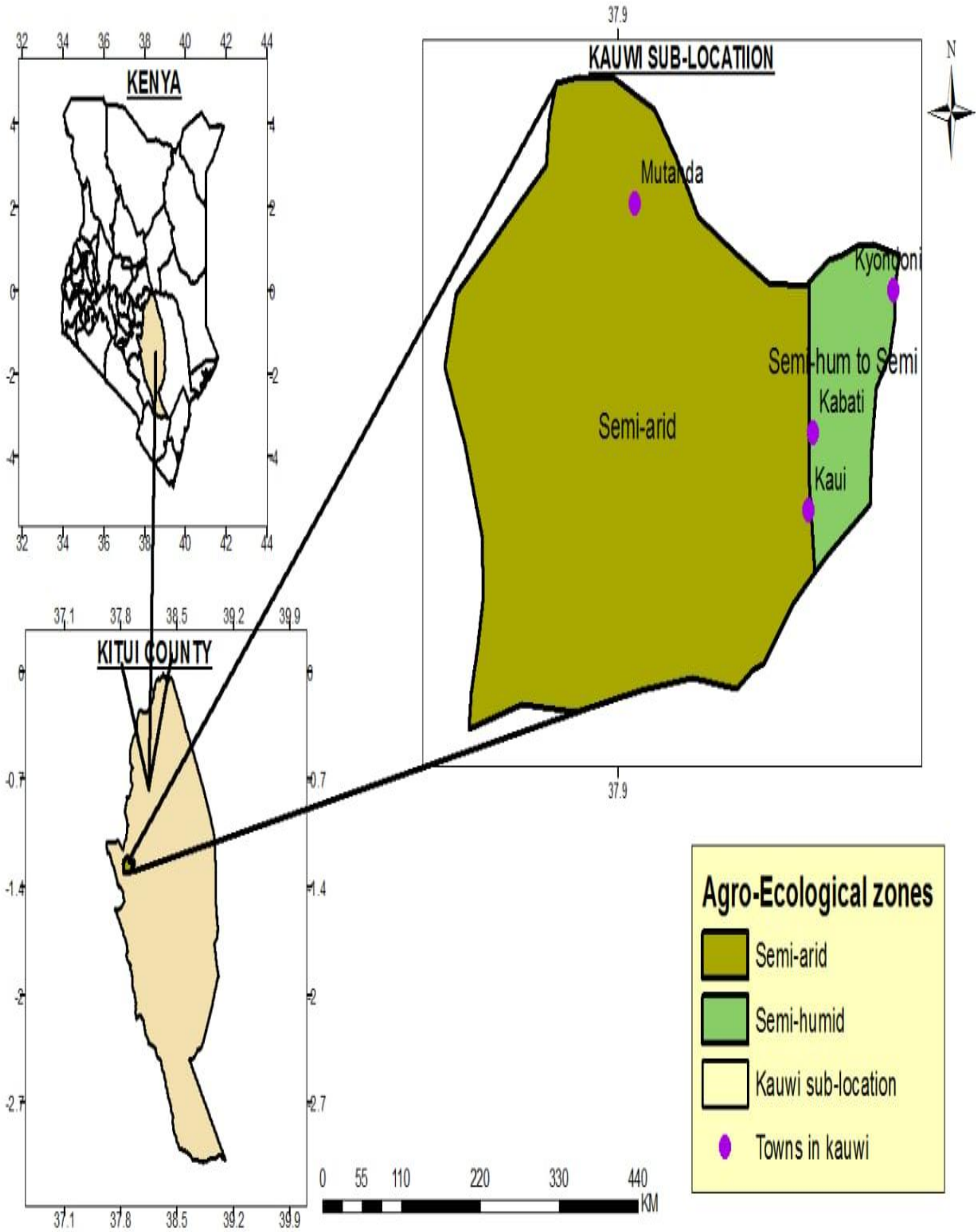
Table.3 Factors Influencing Utilization of Rain Water Harvesting Technologies

Parameters	Zai	Grass strips	Trash line	Sand dam	Contour bund	Earth Dam	rooftop	Fruit tree	exotic tree	indigenous trees
Gender of household head	-0.96	0.02	1.63	-2.31**	0.28	-4.19	2.49***	0.18	-0.41	-0.59
Age house hold head	-0.11**	-0.01	-0.00	-0.04	0.02	-0.16+	0.05	-0.01	-0.02	-0.04+
Education level household head	-0.72	0.14	1.20	0.21	-0.69	0.25	0.18	0.45*	0.55+	-0.26
Occupation of household head	0.45	-0.37	-0.07	-0.40	0.49	0.29	0.93***	-0.01	-0.37	-0.29
House hold size	-0.03	-0.05	0.35	-0.43**	0.18	0.50	0.40	0.07	-0.12	-0.15
Labour source	-0.35	-0.08	-1.89	0.71	-0.96	2.66*	2.16**	0.80**	0.55	2.03*
Land size here and else	0.56**	0.08	-0.01	0.43+	0.11	0.07	-0.25	-0.04	0.02	-0.02
Land size here	-0.50+	0.02	0.21	-1.06**	-0.17	0.58	0.45*	0.23**	-0.28+	0.26
Years in farming	0.02	-0.02	-0.05	0.07+	-0.03	-0.05	-0.11***	-0.02	0.01	0.01
Type of soil	-0.24	-0.83**	-2.27**	-0.99**	-1.02**	2.20	-1.17***	-0.80**	-0.14	1.00
Sale of surplus	0.00	0.00	0.00	0.00	0.00+	0.00	0.00	0.00	0.00	0.00
Off farm income	0.00	0.00	0.00	0.00	0.00	0.00	0.00***	0.00	0.00	0.00
Access to credit	-1.19	0.71	-0.54	0.08*	1.24	5.44**	-0.62	0.59	-0.97+	0.18
Loan borrowed last year	0.00+	0.00	0.00	0.00	0.00**	0.00	0.00	0.00	0.00	0.00
Amount of credit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Constant	4.89	2.41	1.92	7.09*	0.96	-5.61	-7.04***	-0.89	1.64	2.44
Percentage correct	93.1	77.3	96.1	92.2	88.3	94.5	81.3	68.8	67.7	76
Hosmer	0.19	0.12	0.98	0.67	0.39	1	0.69	0.80	0.57	0.94
Nagelkerke	0.45	0.25	0.48	0.46	0.31	0.60	0.58	0.27	0.33	0.30

Significance values are as follows: 0 - 0.001 '***', 0.001 - 0.01 '**', 0.01 - 0.05 '*', 0.05 - 0.1 '+', 0.1 - 1.0 ” (no symbol), R Core Team (2017).

Values in the table are the B odds.

Fig.1 Map of study area



The variation of utilization sand dam rain water harvesting technology as explained by the predictor variables was 46%. The predictor variables that were significant at 5% level of significance included gender ($p<0.05$, B=-2.31), household size ($p<0.05$, B=-0.43), land size here and elsewhere ($p<0.05$, B=-1.06) and type of soil ($p<0.05$, B=-0.99). This was very much unexpected considering the fact that males have been assumed to be household heads who are associated with making final decisions at household level. This study was contrary to Mekenon, 2017 who found that male were the final decision makers at household level and would therefore influence their decision into utilizing this RWHT. A unit increase in land size reduced the probability of utilization of this technology. A unit increase in land size resulted in decreasing odds in utilization of sand dam RWHT. This could be attributed to the fact that households who had large parcels of land could grow diverse types of crops. Diversifying the crops increased their chances of getting more produce since they believed that in case one crop failed then at least one of the many would not fail. Those who had small parcels were likely to use this technology in order to maximize on the produce. This finding was in line with that by Julius H. Mangosoni, (2019) who found that households with small parcels of land were more likely to utilize rain water harvesting technologies in order to make maximum use of their minimal available land. Clay soil type is difficult to rupture when compared to sand soil. Small holder farmers prefer the soil that easily ruptures for construction of rain water harvesting technologies. This finding was in line with that by Mekenon (2017) who found out that small holder farmers preferred to install rain water harvesting technologies in soils that were easy to rupture while installing the technologies.

For the *Zai* pits rain water harvesting technologies, the factors that significantly influenced utilization at 5% significance level was age ($p<0.05$, B=-0.11) and land size here and elsewhere ($p<0.05$, B = 0.56) owned by the household head. The results indicated that 45% of the variation of the utilization of the *zai* pits technology was explained by the predictor variables (Nagelkerke R^2=0.45) and 91.1% were correctly classified cases. A unit increase in age meant decrease in the odds of utilization of this technology. This was ascribed to the fact that, with increasing age, the people became less energetic. For technologies that needed much energy in its construction then meant that older people would shun away from such hence decreasing in odds of its utilization. This study agreed with that by Tesfaye, (2013) where he found that older people are less likely to adopt new technologies since they have little energy needed for the construction of such technologies. Land size here and elsewhere influenced the utilization of *Zai* pits. Where, in every unit increase inland size, the odds of utilizing his technology increase. This was so much unexpected as people with large parcels were found to diversify on what they were growing in the crop field. They expected not to lose from the various crops grown in the farm. If one failed, then the other would not. This was contrary to findings by Mangisoni *et al.,* (2019) who found that households with small parcels of land were more likely to utilize rain water harvesting technologies in order to make maximum use of their minimal available land.

Recommendations

The study found out that specific technologies were significantly influenced by different factors differently. The type of soil influenced all the selected rain water harvesting technologies. Based on the findings, it was evident that household size and labour source were the main factors that influenced utilization. Households whose household size was large were more likely to utilize the technologies as well as those who had more labour. Those with little labour source were likely to use hired labour in order to utilize the various rain water harvesting technologies. The findings also revealed that number of farming years highly related to the utilization of rain water harvesting technologies. This is because farmers who had been in farming for many years had more experience on crop failure due to water shortages hence knew the advantage of investing in rain water harvesting. It was recommended that small holder farmers should be keen on the various factors. They should utilize those technologies that are affordable and appropriate to them. For instance, a technology where a farmer has several factors at his disposal influencing it, then the farmer can appropriate it. This way, most favourable technology shall be used and agricultural productivity increased hence increase food security.

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