EVALUATION OF TYPES AND FACTORS INFLUENCING ADOPTION OF RAINWATER HARVESTING TECHNIQUES IN YATTA DISTRICT, KENYA

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The utilization and critical mass adoption of appropriate rainwater harvesting techniques is an important prerequisite for agricultural development, particularly in semi-arid areas. Against this backdrop, a study was undertaken to evaluate the factors influencing adoption of rainwater harvesting techniques among households in Yatta district, Kenya. A semi-structured questionnaire was used to collect data from 60 households. Logistic regression was used to evaluate different factors influencing adoption of rainwater harvesting techniques. Most of the farmers were aware of a variety of water harvesting techniques, with roof water harvesting (45%) and dams (36.1%) being rated high, and were willing to adopt them within their local context. The regression model showed the education level of household head, experience of water shortage, and awareness of water harvesting techniques and age of farmers as having a significant and positive influence on adoption of water harvesting techniques. For effective implementation and subsequent adoption of rainwater harvesting technologies, farmers would require technical knowhow and skills, capital, raw material and organizational support. In addition, farmers need to be mobilized and trained on the use of rainwater harvesting techniques and sensitized on the potential socioeconomic benefits of adopting them.

Key words: Adoption; rainwater harvesting techniques; logistic analysis; semi-arid areas; Yatta district.

1. Introduction

Kenya is classified as a water scarce country with annual water supplies below 1000m^3/person (Rockström *et al.*, 2009). The situation is predicted to worsen drastically within the near future. In order to increase water availability to people, rainwater harvesting (RWH)[1] technologies are implemented in various places according to their potential and suitability (KRA, 2010). RWH uses a wide range of techniques for concentrating, collecting and storing rainwater and surface runoff for different uses; agricultural, domestic or drinking purposes, by linking a runoff producing area with a separate runoff-receiving area (Mbilinyi *et al.*, 2005). The three main forms of water collection that

[1] Rainwater harvesting (RWH) is a method of collecting and storing rainwater for agricultural production areas as well as other domestic use (Hatibu and Mahoo, 2000).

make up RWH are water collection, rooftop harvesting and micro-catchments (Mbilinyi *et al.*, 2005; Critchley and Siegert, 1991).

In Kenya, there are different types of RWH techniques which have been implemented throughout the country as a strategy to enhance water availability (KRA, 2010). RWH techniques can be applicable in all agro climatic zones (Rebeka, 2006). However, it is more suitable in arid and semi-arid areas (ASALs) where the average annual rainfall is between 200 and 800 mm. In such condition, rain-fed crop production is challenging without using rainwater harvesting techniques. This implies that water harvesting and storage would be vital to ensure water availability especially during prolonged dry season and drought (Mugerwa 2007, Enfors 2009, and RELMA, 2007). The factors that influence the adoption of rainwater harvesting techniques by resource poor farmers in the ASALs have however not been fully evaluated, and accordingly appropriate recommendations made, for critical mass adoption and consequently increased agricultural development and rural incomes. This scenario necessitated the current study to evaluate the factors influencing adoption of rainwater harvesting techniques in Yatta district - a semi arid area of Kenya.

2. Research methodology

2.1 Study area

The survey was carried out in Yatta District in the lower Eastern Province of Kenya. The district lies between longitudes of -0.8^{0}W,-1.27^{0}E, and latitudes of 36.66^{0}N, 37.10^{0}S and altitude from 1000 to 1600 metres above sea level (Kang'au *et al.,* 2011). The district falls under agro-climatic zones IV and V, which, is classified as ASALs (Jaetzold and Schmidt, 2006).

The District has a semi-arid climate with mean annual temperature varying from 17ºC to 24ºC and experiences bimodal rainfall with long rains commencing end of March to May (about 400 mm) and short rains from end of October to December (500 mm). The major sources of surface water are seasonal rivers during the rainy season, which dry up immediately after the rains. Most of the areas are generally hot and dry leading to high rates of evaporation. The majority of the farmers in the District are small-scale mixed farmers with low investment for agricultural production (Macharia, 2004).

2.2 Study approach

2.2.1 Farm Household selection

Systematic sampling procedure was use in this study. This involved obtaining a list of farmers from the divisional agricultural office in Yatta District and 60 farmers were randomly selected from the list. The determined sample size was regarded as adequate for inferences to be made about entire population considering the time available and the costs involved in the survey as well as the homogeneity of the target population in the study area. The selected farmers were visited to ascertain their socioeconomic status and willingness to participate.

2.2.2 Data collection and analysis

Data collection: A semi-structured questionnaire involving a face-to-face interview was administered to the household heads for all selected households to gather information on household demographic characteristics and water harvesting techniques related issues.

Data analysis: This study used qualitative methods of data analyses. The collected data was coded, entered and checked for consistency before keying into the SPSS software for further processing and analysis to generate descriptive statistics; means as well as percentages of factors influencing adoption of water harvesting techniques.

Logit model: A logistic regression model with an entry selection process was used to analyze and estimate influence of independent variables (factors that are influencing adoption) on the dependent variable (adoption of a particular technique). The logit model was chosen because the properties of estimation procedures are more desirable than those associated with the choice of a uniform distribution (Pindyck and Rubinfeld 1998). In the logit regression model, parameters are determined through maximum likelihood estimation (MLE) procedure. The probability that a technique is adopted can be specified as:

$$P_i = F(\alpha + \beta x_i) = \frac{1}{1 + e^{-(\alpha + \beta x_i)}}$$ ……………………………….. Eq. 1

Where P_i is the probability that the technique will be adopted given x_i, where x is a vector of explanatory variable and e is the natural logarithm.

Equation (1) can be rewritten as:

$$P_i = \left[1 + e^{-(\alpha + \beta x_i)}\right] = 1$$ ………………………...………….. Eq. 2

Where $\alpha + \beta x_i = \log\left[\frac{P_1}{1 - P_1}\right]$ and $\frac{P_1}{1 - P_1}$ is the likelihood ratio, whose log gives the odds that a technique is adopted. Whereby: α is the constant of the equation and β is the intercept term

The regression can further be expressed as:

$\text{Log}(p_i/(1-p_i)) = \alpha + \beta_0 + \beta_1 * x_1 + ... + \beta_n * x_n$ ………………...………….. Eq. 3

Where;
i denotes i^{th} farmer, (1……60); P_i the probability of adoption by the farmers, and $(1- P_i)$ is the probability of non-adoption. Where β_0 is the intercept term, and $\beta_1, \beta_2, \beta_3 ... \beta_n$ are the coefficients associated with each explanatory variable $X_1, X_2, X_3 ... X_n$ the estimation form of logistic transformation of the probability of farmers' decision to adopt the technique.

3. Results and discussions

3.1 Characterization of water harvesting techniques

3.1.1 Farmers' awareness of rainwater harvesting techniques

About 60% of the farmers were aware of the possible water harvesting techniques that existed within their local context and this is because of the perennial water shortages experienced.

Nonetheless, low income and education levels of the farmers may have curtailed the chances of implementing and/or adopting the water harvesting techniques.

Equally, a good proportion of farmers (40%) were not aware of the rain water harvesting techniques and this may be attributable to inadequate dissemination of information and skills with regard to rain water harvesting techniques. Similar empirical studies have recognized that, awareness exposes someone to information and therefore creates knowledge, which is a very important stage in the adoption of rain water harvesting techniques (Masuki *et al.,* 2005).

The distance to be covered, on average 1.4 km to the nearest point of water, in the event of water scarcity further amplified the awareness of and the need for the water harvesting techniques. The distance covered in search of water was relatively far from the community. This and thus made people, especially women and children, suffer and spend a lot of energies and time as well as walk long distances to collect water during water scarcity. According to UNFCCC (2002) in dry periods, the water resources, water supply and demand are greatly challenged by water scarcity and as a result women and children have to travel long distances to collect water for their livelihoods purposes.

3.1.2 Type of water harvesting techniques practiced by households

About (45%) of the farmers in Yatta district practiced roof water harvesting techniques (Photo 1) followed by sand dams (36.1%, Photo 2) with minority of the farmers (1.6%) adopting water pans (Table 1).

The considerable application of roof water tanks by most farmers in this area is attributed to the fact that most of them were supported to buy the tanks by non-governmental organizations (NGOs). This is in addition to the ease of implementation of the said technique by rural farmers. Nelly (2010) found that, many roof water tanks have been implemented by NGOs in rural areas of Kenya because these tanks were regarded to be of the best quality and increasing water quantity and availability at the implemented sites.

The second most widely practiced water harvesting technique was the sand dams and the ease of its construction, prospects for communal use and suitability of the natural landscape for its construction may have endeared the technique to the farmers. This is in addition to its provision of a large amount of water for people, livestock and plants during the dry season. Similar studies have found that sand dams indirectly benefit up to thousands of people, as the use of the stored water is never restricted to the people who built the technique (Jacob, 2011). Moreover, the sand dam has potential to provide a large amount of water for up to 1,200 people, animals, tree nurseries and vegetable gardens (Jacob, 2011). This is also shared by UNFCCC (2002) who found that in Sakai and other parts of Kenya, constructed sand dams were reliable sources of water for people, livestock and plants during the dry season. The dams also trapped sand that prevent evaporation and caused water to percolate underground, where it became available for future use.

Adoption of other techniques such as terracing (3.3%), water pans (1.6%) and boreholes (14%) were found to be low in this area. This however is not the case in other places of Kenya such as Lare division of Nakuru County, where adoption of water pans technique is pronounced (KARI, 2000). This may be due to the relatively flat topography and inherent soil type that allowed for water retention in this area. On the other hand low adoption of borehole could be attributable to the high cost of its construction and technical knowledge required. This is also supported by ICRC (2010) who reported that borehole construction is quite complex and requires engineering skills.

3.1.3 Preference of water harvesting techniques across age groups

The probable adoption of water harvesting techniques varied across age groups (Table 2). The farmers aged between 50-60 years preferred roof water harvesting tanks (33.3%), sand dams (40.9%), and water pans (100%). Terraces were popular for farmers aged between 30-40 years (50%) as well as 40-50 years (50%), while, farmers who were aged above 60 years preferred to use boreholes (62.5%).

The adoption of the various water harvesting techniques and their uniqueness to the different age groups (Table 2) is assumed to be due to their good understanding and experience of their environment and the benefits of the respective techniques.

Other studies have also alluded to experience as being important in the adoption of technologies of the water harvesting technologies (Babbie, 1973).

The middle aged farmers (30-40 and 40-50 years) preferred to use terraces compared to older farmers probably because this technique is laborious and requires energetic and young farmers to implement. According to Chianu and Tsujii (2004), targeting young farmers when promoting adoption and a systematic increase in farmers' educational attainment can increase the probability of water harvesting technology adoption.

Furthermore, the size of the farm would also have a bearing on the water harvesting technique to be adopted. The average farm size was found to be 2.65 acres per household which seems to be slightly small compared to the average smallholder farm holding in the district. This suggests that, if farmers had big farm sizes, they would be willing to increase adoption of the various water harvesting techniques. This view is similarly shared by Makonnen et al. (2011) who stated that in Ethiopia, the absence of land use policy and government payments in the face of dwindling farm size had become a critical problem for success of water harvesting techniques.

3.1.4 Education level, experience with water shortage and sources of income

About 66.7% of the males had studied up to lower primary school, while (46.4%) of female had reached upper primary school (Table 3). The majority (60%) of the farmers had experienced water shortage. The source of income of the majority (58.3%) of the farmers was reported to be from agricultural activities (Table 3).

The low education levels of the interviewed households may have significantly contributed to the low or non-adoption of water harvesting techniques. This is because, education would expose one to information and therefore creates awareness and enhances adoption of water harvesting systems. Hatibu (2003) noted that farmers with a higher level of education were likely to adopt water harvesting systems earlier, therefore shortening the adoption of the techniques.

The majority of farmers had experienced water shortage of which was expected in view of the fact that, the rainfall of the area is erratic and poorly distributed within the seasons. The experience of water shortages is further a pointer to the greater chance of adopting and practicing water harvesting techniques. UNFCCC (2002) reported that smallholder farmers who live in ASALs of Kenya are more likely to adopt rainwater harvesting techniques due to long period of water shortages and drought. The farmers (about 40%) who reported to have not experienced water shortage were mainly those implementing one or two of the water harvesting techniques reported (Table 2). According to Critchley and Gowing, (2006), there is a remarkable improvement in the level of farmers' awareness on utilization of water harvesting techniques in Kenya. The number of farmers requesting the technologies is growing every year and are willing to excavate their site and to subsidize the necessary local materials by themselves due to experiences of water shortage.

The source of income for majority of farmers was the farm and about 53% of the farmers entirely depended on farming activities for survival and generation of income and/or depended on farming activities to supplement their main sources of income. According to Kirsten and Moldenhauer (2006), agricultural activity is one of the many possible sources of employment and income for farm households across the world. This, together with the low levels of education, may perhaps explain why the adoption of the water harvesting technologies is low. The meagre agricultural income may not be enough to implement some of the water harvesting techniques vis-à-vis the other competing uses; health, education and nutrition, of the farm income.

3.2 Support provided to the community to harness water harvesting techniques

About 66.7% of the farmers reported that various organizations had helped them put up water harvesting structures and had also build their capacity in water harvesting techniques. About 33% of the farmers however indicated lack of assistance from organizations in the construction of water harvesting structures.

Of the farmers reporting receiving some form of support, about (30%) of them reported that sand dams were promoted by NGOs followed by Regional Land Management Unit (RELMA) and Constituency Development Fund (CDF) respectively (Table 4). About 28% of the farmers reported that the roof water tanks were promoted by *International Fund for Agricultural Development* (IFAD) followed by (20%) of the farmers who reported that roof water tanks were promoted by the United Nations Children's Fund (UNICEF) and RELMA.

These study supports the findings of ABD (2009) who reported that there were several water harvesting techniques in the arid and semi-arid land of Kenya that had been promoted by many international organizations and institutions (FAO, IFAD and RELMA) to augment water availability for many purposes such as food production. The support given by the various organizations and institutions in the implementation of the water harvesting techniques is nonetheless not unique to the study area but is a country wide initiative. According to Barghouti and Le Moigne (1990), NGOs with few private sectors, played a significant role in supporting farmers when it came to implementing and adopting water harvesting techniques all over Kenya. These organizations were well appreciated by farmers and were considered to be most effective compared to government driven programs.

3.3 Evaluation of factors influencing adoption of water harvesting techniques

Using the logistic regression model, the factors; education level, experience of water shortage, farm size, awareness of water harvesting techniques, source of income, age of farmers, organization involvement and distances of water source (section 3.1-3.2) were modeled in order to explain their influence on farmers' adoption of water harvesting techniques (Table 4).

The education level, experience of water shortage, farm size, awareness of water harvesting techniques, age of farmers, and income source (Table 4) had a significant bearing on the adoption of water harvesting techniques. The model showed that the education level had the highest positive influence on adoption of water harvesting techniques followed by experience of water shortage, farm size and awareness of water harvesting techniques in that order. The lowest influence was age of farmers that had positive effect on adoption of the harvesting techniques followed by farming as source of income that was significant and negatively related to adoption of water harvesting techniques. Organizations, distance to water sources, and farm income had no influence on the adoption rate of water harvesting techniques.

Education level was significant and positively related to adoption of the techniques. The exp (β) value associated with education level attained by the head of a household was 47.5. This suggests that the more educated the farmers' are the more likely to adopt rainwater harvesting techniques than less educated farmers. In most adoption studies, farmers with higher levels of education attainment are more likely to adopt or to practices rainwater harvesting techniques compared to less educated farmers (Chianu and Tsujii, 2004).

Farmers' experiences of water shortage had a positive effect on adoption of the water harvesting techniques. The exp (β) also shows that, for 1-unit increase in farmers' experiences of water shortage, log-odds of adoption (the probability of adoption) would increase by a factor of 33.7. Farmers who had experienced water shortage had a greater possibility to adopt water harvesting techniques than those who had not experienced water shortage. UNFCC (2002) reported that smallholder farmers who live in ASALS of Kenya had adopted rainwater harvesting techniques due to long period of water shortage and drought.

Farm size was found to be significant (5% α) with negative impact on adoption of rainwater harvesting techniques. The exp(β) value associated with farm size was 0.798. Farmers whose farms were larger were therefore less likely to adopt the water harvesting techniques. This however contradicts research findings by Buyinza et al. (2008) who reported that farmers' who had bigger farms were more likely to adopt rainwater harvesting techniques. This could be attributed to average farm size of the entire district which was found to be relatively small.

Farmers' awareness of water harvesting techniques had a positive impact on adoption of the techniques. The exp (β) showed that the odds of a farmer who was aware of rainwater harvesting techniques was 24.65 times likely to adopt compared to those who were not. This suggests that farmers who are more aware about the techniques had a greater chance to adopt water harvesting techniques. Similar empirical studies had found that farmers with a positive attitude were keen on implementing agricultural technologies that incorporated an element of water harvesting technologies (Herath and Takeya, 2003).

Farming as the main *source of income* had a negative impact on adoption of rainwater harvesting techniques. The exp (β) value associated with farming as the main source of income was 0.091. Hence, with1-unit increase in income from farming, the odds for adoption decreases by 0.091. However, among the factors that affected the adoption of rainwater harvesting techniques the majority (58.3%) of farmers had reported that the farm was the main source of their incomes. This implies that farmers who mainly relied on income from farms had less likelihood of adopting the water harvesting techniques than those who had other sources of income apart from farms.

However, Herath and Takeya (2003) noted that the role of farm income on the decision to adopt is unclear. Hence, it is difficult to predict the sign of farming as source of income.

Related studies have also found that farmers' income level was an important factor affecting adoption of water harvesting techniques (He *et al.*, 2007). Other experiential findings among smallholder farmers in arid and semi-arid areas have also underscored the importance of diversified farm income sources as a strategy to enhanced adoption of water harvesting techniques (Rutten, 1992).

The *farmers' age* was found to be significant and positively related to adoption of water harvesting techniques. This indicates that the probability of adoption of rainwater harvesting techniques is higher among older farmers than among younger farmers. The average age of farmers was found to be 51. 8. According to Babbie (1973), as the farmer gets older he/she tends to intensify adoption of the technologies in his/her farm. This can be attributed to the experience of the farmer in farming activities, which other studies have found to be important in adoption of technologies.

4.0 Conclusion and implications

The current study was undertaken to better understand how efforts to promote rainwater harvesting technologies could be focused. It emerged that the adoption of rain water harvesting techniques varied with age, level of education and income. This therefore implies that for successful adoption of water harvesting techniques the supporting organization should take into account this factors and concerted efforts made to enhance capacity building on water harvesting techniques among smallholder farmers. Farm incomes should as well be diversified and other support mechanisms put in place with a view of increasing the level of adoption of the rain water harvesting techniques.

The estimation result of the binary logistic regression indicated that, educational level of household heads, experiences of water shortage, farm size, awareness, farming as source of income and household's age were the most important factors that influenced household's decision to adopt rainwater harvesting techniques. This further reinforces the need to take into consideration these factors for successful implementation, targeting and subsequent adoption of water harvesting techniques in Yatta district.

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Photo1: RWH using plastic tanks

Photo2: RWH using Dams

Table 1: Type of water harvesting techniques practiced by households

	Frequency	Percent
Roof water tanks	27	45
Sand dams	22	36.1
Runoff from terraces	2	3.3
Water pans	1	1.6
Boreholes	8	14
Total	60	100.0

Table 2: Age categories and preferred water harvesting techniques

Techniques	30 - 40		40 - 50		50 - 60		Above 60	
	Count	%	Count	%	Count	%	Count	%
Roof tanks	7	25.9	6	22.2	9	33.3	5	18.5
Sand dams	5	22.7	6	27.2	9	40.9	2	9.09
Terraces	1	50	1	50	0	0	0	0
Water pans	0	0	0	0	1	100	0	0
Boreholes	1	12.5	1	12.5	1	12.5	5	62.5

Table 3: Education level, experience with water shortage and sources of income

Frequency	Percent	
	Percent (Male)	Percent (Female)
Educational level of farmers		
Never went to school	0	14.3
Lower primary school	66.7	10.7
Upper primary school	33.3	46.4
Secondary school	0	25.0
Certificate	0	3.6
Experience with water shortage		
Experienced water shortage	36	60
Not experienced water shortage	24	40
Income source of farmers		
From farm	35	58.3
Not from farm	25	41.7

Table 4: organizations promoting various water harvesting techniques

	UNICEF	RELMA	NACO	IFAD	NGOs	CDF	FAO
Boreholes	15.5	0	6.7	10.6	5.0	5.0	10
Water pans	0	0	3.3	0	0	0	3.3
Wells	15.5	0	1.7	1.7	10	0	1.7
Sand Dam	0	25.5	0	0	30	24	7.5
Roof tanks	20	20	1.7	28	15	10	0
NA	30	17	63.2	7.7	0	44.3	41.6

Table 4: Logistic Regression Analysis of factors influencing adoption of rainwater harvesting techniques

Variable	B	S.E.	Wald	Exp(β)
Constant	-18.119	5.578	10.550	.000
EDUC	3.860	1.342	8.272**	47.48
EXPWS	3.518	1.242	8.022**	33.71
FRMZ	-0.225	.091	6.077**	.798
AWR	3.205	1.313	5.955**	24.65
FSOINC	-2.400	1.218	3.882**	.091
AGE	0.076	.039	3.721**	1.08
ORG	-1.740	1.161	2.246	.175
DIST	-0.287	.484	.351	.751
INKSH	0.952	.515	3.420**	2.59

***Significant at 5%; Chi-square = 50.242**; -2 Log likelihood = 32.869; N= 60, Cox & Snell R^2=.567; Nagelkerke R^2=.756.*
Where:
EDUC denotes Education background of the household heads; EXPWS is the Experiences of water shortage; FRMZ is the Farm sizes; AWR is the Awareness of water harvesting techniques; FSOINC is the farming as source of income; While, AGE is the Household's age

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