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Rainwater Harvesting Technologies in Makueni County, Kenya

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ABSTRACT: *Rainwater harvesting has been in existence for many years and has positively impacted life, agriculture and economy. Despite these known benefits of rainwater harvesting, Makueni County's population is slowly adopting rainwater harvesting technologies. Water scarcity still remains a major constraint to life and economic development in the County. The aim of this paper is to evaluate rainwater harvesting technologies and the factors contributing to adoption of the technologies in the ASAL areas with Makueni County being the case study. The study was conducted in Wanzauni and Itetani locations in Tulimani division, Mbooni West district, Makueni County within Kenya's Eastern Region which lies within the arid and semi arid ecological zones of Kenya. A total of 160 household questionnaires were administered, focus group discussions and key informants interviews done during data collection exercise. The data was analyzed using Statistical package for social scientists (SPSS). Various rainwater harvesting technologies (RWHTs) are used within Makueni County including macro-catchment (earth dams, sand/sub-surface dams), micro-catchment (Zai pits, strip catchment, tillage, contour and semi-circular bunds) and rooftop rainwater harvesting technologies with rooftop catchment being the most commonly used technique. However, adoption of these RWHTs in Makueni County is slow irrespective of their potential to improve livelihoods. A logistic regression analysis was conducted to predict factors affecting adoption of RWHTs within 160 households in Makueni County. Some of the factors found to have statistically-significant positive effect on the adoption of RWHT are gender, literacy levels, social and economic status and technological know-how on RWHT. Ways of promoting the adoption of RWHTs such as capacity building and training, poverty alleviation through enhancement of income generation activities, enhanced formation of community groups aimed at water development activities, and improved designs incorporating mechanized technologies in favour of women and children, are recommended.*

KEYWORDS: *Rainwater Harvesting (RWH), Rainwater Harvesting Technologies (RWHT), Adoption, Arid and Semi-Arid Areas (ASALs), Makueni County.*

I. INTRODUCTION

Rain is the primary source of water known in the hydrological cycle, while rivers, lakes and ground water are all secondary sources. In present times, there is heavy dependency on such secondary sources of water and in the process, it is forgotten that rain is the ultimate source that feeds all these secondary sources (CSE, India 2003).

Rainwater harvesting (RWH) is making optimum use of rainwater at the place where it falls so as to attain self-sufficiency in water supply without being dependent on remote water sources (UN-HABITAT, 2004). It is the intentional collection, storage and management of rainfall and other various forms of precipitation from different catchment surfaces (Wanyoyi, 2002).

Rainwater harvesting is an ancient practice and has been in parts of the world for over 4000 years (Worm and Hattum, 2006). Rainwater harvesting in Asia dates back to 10^{th} Century (Global Development Research Center, 2002) and is also popular in rural Australia, parts of India, Africa and parts of the United States. It was widely used for the provision of drinking water in the rural areas in Europe and Asia. Since 1990s, urban RWH has also been on the rise in various parts of the world. For example, Singapore which has limited resources in terms of land and water has turned heavily to rainwater harvesting. About 48% of its land is used as water catchment area (Appan, 1997). Consequently, about 86% of its population live in high-rise buildings. Water collected from roofs in the urban areas is harvested and stored for non-potable uses. This has saved about 4% of the water used in Singapore. Despite the recent developments in expansion of rainwater catchment systems in Africa, adoption of RWH is slower as compared to other continents.

According to Mati (2007), various rainwater harvesting technologies have been in use for millennia and new ones are being developed all the time. These can be classified as:

- **Macro-catchment technologies** - This is a system that involves the collection of runoff from large areas which are at an appreciable distance from where it is being used. These technologies handle large runoff flows diverted from surfaces such as roads, hillsides, pastures. Hillside sheet/rill runoff utilization, rock catchments, sand and earth dams are examples.
- **Micro-catchment technologies** – those that collect runoff close to the growing crop and replenish the soil moisture. Micro-catchment technologies are mainly used for growing medium water demanding crops such as maize, sorghum, groundnuts and millet. Examples of these technologies are *Zai* pits, strip catchment tillage, contour bunds, semi-circular bunds and meskat-type system.
- **Rooftop harvesting technologies** - Have the advantage to collect relatively clean water.

For small-scale catchments, rainwater harvesting can be categorized according to the type of catchment surface used and, by implication, the scale of activity (Nissen-Petersen, 1999) as presented in Fig 1.

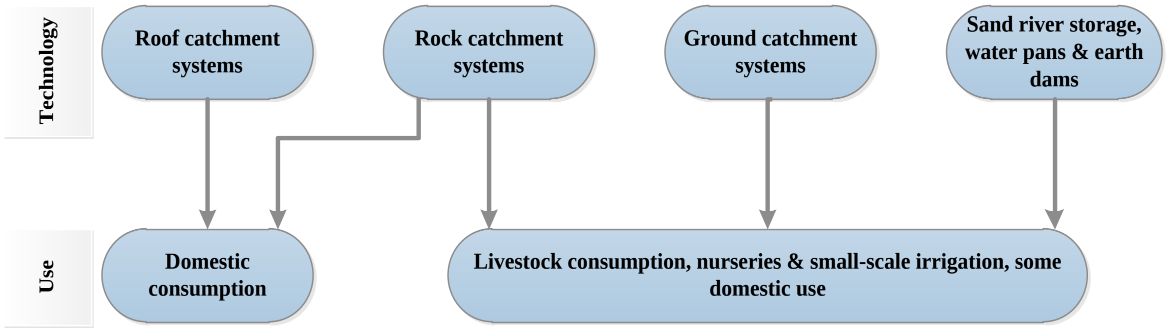

Figure 1: Small-scale and medium-scale rainwater harvesting systems and uses (Gould and Nissen – Petersen, 1999)

Overdependence on secondary sources of water coupled with the increasing climate change, has made water to be a scarce resource in the world with about 783 million people in the world (11% of the world's population) having no access to safe water. Lack of safe water and sanitation costs sub-Saharan Africa around five (5) percent of its Gross Domestic Product each year. Kenya being in the sub-Saharan Africa it’s no different. Like other Arid and Semi Arid (ASAL) parts of Kenya, Makueni County located within the Eastern Region of Kenya has over the years been ravaged by decades of hunger and starvation. The County is characterized by hot and dry climate for most of the year. Temperature ranges between 12^0C and 32^0C. Two rainfall seasons with an average annual rainfall ranging from 150 to 650 mm are experienced with the long rains occurring in March/April and the short rains in November/ December (Makueni County’s Integrated Development Plan (CIDP), 2013).

Rainwater harvesting has been in existence for many decades as a way of augmenting available water resources in the world. In the years of its existence, rainwater harvesting has positively impacted life, agriculture and economy. Despite these known benefits of rainwater harvesting, Makueni County’s population is slowly adopting rainwater harvesting technologies. Water scarcity still remains a major constraint to life and economic development in the County. Although clean and safe water is a treasured commodity, many people in Makueni County do not have access to it. People from the hilly places in the County rely on springs and shallow wells to get their water for domestic use whereas in the low lands they mainly use boreholes, sand dams and earth dams as their sources of water.

The aim of this paper is to evaluate rainwater harvesting technologies and the factors contributing to adoption of the technologies in the ASAL areas with Makueni County being the case study.

II. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Mbooni West district, Makueni County within Kenya’s Eastern Region which lies within the arid and semi arid ecological zones of Kenya. The County experiences two rainy seasons, namely; the long rains occurring in March/April while the short rains occur in November/December. The hilly parts of Mbooni and Kilungu receive between 800-1400mm of rainfall per year which has high potential for crop production. There are extremely high temperatures of 35.8^0C which are experienced in the low-lying areas of the County leading to high evaporation which worsens the dry conditions (Makueni CIDP, 2013). Normally, the rains are sometimes unreliable, erratic and inadequate.

The County is characterized by water scarcity, low food production and high poverty levels. It is prone to frequent droughts that are usually worse in the low lying areas which receive little amount of rainfall, averaging 500mm which is hardly enough to sustain crop production and the only economic activity which many the local people rely on is small stock rearing. Drought is a major cause of poverty in the area and the most vulnerable are women, children, the aged and the disabled. Drought recurs after every 2-3 years. As a result, the scarce resources set aside for development programmes within the area are at times diverted towards the provision of famine relief to the local people. This has had a negative impact on the development efforts in the district.

The County has two major rivers; Athi River which is permanent and Thwake River which is a semi-permanent. These two rivers are the major sources of water within the County. According to the Makueni County's Integrated Development Plan (CIDP) of 2013, there are other seasonal rivers which provide water to the population during rainy seasons or shortly after the rains. Other sources of water include four (4) protected springs, 117 boreholes, 289 water pans, 118 sand dams and 159 earth dams. The County's current water demand is about 22,113m^3/day against an average water production of 13,607m^3/day from the developed sources. This implies that there is a huge deficit of unmet water demands of about 8,506m^3/day (about 38.5% of the County's population).

Makueni County is predominantly inhabited by the Kamba community and its 2015 population is projected at 961,738 consisting of 468,298 males and 493,442 females (KNBS, 2013). There are high levels of poverty within the County which stand at 64.3% (KIHBS, 2006). About 67% in the rural areas and 33% in urban areas of the County's population live below the poverty line. Literacy levels within Makueni County are relatively high standing at 77.59% as compared to the literacy levels in Kenya which stand at 71.41% (Makueni CIDP, 2013).

Subsistence farming is a major socio-economic activity within Makueni County. It is practiced under rainfed agriculture and with the erratic rainfall patterns experienced within the area, sustainable food production has been a nightmare in Makueni County. Other socio-economic activities include beekeeping, small-scale trade, sand harvesting and charcoal burning. Access to health care in the County is low. With reference to the Economics of Poor Sanitation in Kenya (WSP), Makueni County loses 638 million Kenya Shillings each year due to poor sanitation, poor health care access time, premature death, health care costs and productivity. Some of the diseases prevalent in the area are malaria, pneumonia, diarrhoea, stomach-ache and upper and lower respiratory diseases.

2.2 Household Sampling Methods

A total of 160 households were selected from Wanzauni and Itetani locations in Tulimani division, Mbooni West district using simple random sampling technique. In addition key informant interviews and focus group discussions were done in these areas.

2.3 Data Collection and Analysis

The data collection exercise employed both primary and secondary data collection methods and was done by administration of household questionnaires which had questions related to socio-economic characteristics including gender, age, educational level, occupation, family size, land sizes, housing type, main sources of water, accessibility, utilization, management and preservation, rainwater harvesting, food and nutrition, water shortage related problems and their effects on health, hygiene and sanitation and human security. Focus Group Discussions and interviews with key informants were also conducted among the leaders from the area

Statistical package for social scientists (SPSS), qualitative data analysis computer programme was used to analyse data for this research. The package was collated with the qualitative data then used to produce descriptive statistics that have been used in the presentation of the findings in this report.

2.4 Logit Model

A binary lostic regression model (logit model) was used to determine and analyse factors affecting the adoption of rainwater harvesting technologies in ASAL areas. The Logit Model was chosen because it's simpler in estimation than the Probit Model (Pindyck and Rubinfeld, 1998) and that it is a standard method of analysis when the outcome variable is dichotomous (Hosmer and Lemeshow, 2000), where adoption of rainwater harvesting technologies is 1 and non-adoption is 0.

If X_i represents the set of parameters that affect adoption of rainwater harvesting technologies by i^{th} household (1……..160), then U_i is an indirect utility derived from the adoption decision and is a function of explanatory variables *(X)* and is expressed as shown in equation (1):

$$U_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \qquad \text{(1)}$$

Where;

β_0 is the intercept term

$\beta_0, \beta_1, \beta_2, \ldots\ldots \beta_i$ are the coefficients associated with each explanatory variable $X_1, X_2, X_3 \ldots\ldots X_i$

Therefore, the probability the i^{th} household adopts rainwater harvesting technology influenced by (X_i) factors is given by equation (2):

$$P_i = \frac{e^{U_i}}{1 + e^{U_i}} \qquad \text{(2)}$$

Where;

P_i is the probability that i^{th} household adopts rainwater harvesting technology

Taking the natural logs of the odds ratio (in favour of rainwater harvesting technologies) of equation (2), the prediction equation for the i^{th} farmer (as known as the Logit Model) is presented in equation (3):

$$Logit(P) = \ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \sum_{i=1}^{n} \beta_1 X_1 + \varepsilon \qquad \text{(3)}$$

Variables used in the Logit Model

The explanatory variables used in the logic regression model are as presented in Table 1:

Table 1: Logit model explanatory variables code hypothesis

Variable	Variable Code	Expected Effect
Gender of household respondent	B1	Women who are more concerned with water issues are expected to positively influence the adoption of rainwater harvesting technology (RWHT)
Age of household respondent	B2	Age is expected to positively correlate with adoption of RWHT
Marital status of household respondent	B3	Marital status is expected to positively affect adoption of RWHT
Education level of household respondent	B4	Education is expected to positively influence adoption of RWHT
Occupation of household respondent	B5	Occupation is expected to positively influence adoption of RWHT
Member of a social group (social status)	B6	Social status is expected to positively correlate with adoption of RWHT
Source of income for the household	B10	Source of monthly income is expected to positively affect the adoption of RWHT
Household family size	B11	This variable is hypothesized to correlate positively with adoption of RWHT
Household land size	B12	This variable is hypothesized to correlate positively with adoption of RWHT
Household house roofing material	B14	Roofing material of household house is expected to affect adoption of RWHT either positively or negatively
Distance from the household to existing water source	C2	Distance walked form homestead to the existing water source is hypothesized to positively correlate with the adoption of RWHT
Training information on rainwater harvesting	G1	Technological know-how on rainwater harvesting is expected to positively affect the adoption of RWHT

III. RESULTS AND DISCUSSIONS

3.1 Household Socio-Economic Characteristics

Among the 160 sampled households, 80 percent of those interviewed were females and 85% are married. The household questionnaires were administered to household heads or any other responsible adult person in the household at the time of the survey and majority (93%) of those contacted and interviewed were above 28 years of age. Sixty six (66%) percent of the households were headed by persons with primary level of education, while only five percent of the heads had post-secondary education. The average household size was six (6) persons and majority (84%) of the households owned less than three acres of land. About 68 percent of the households had permanent houses with 99 percent of the houses being iron sheet roofed. Farming is the main source of livelihood with 52 percent of the respondents engaged in subsistence agriculture.

3.2 Health, Hygiene and Sanitation

Ninety five percent (95%) of the respondents reported that they have toilet facilities in their homesteads and the remaining five (5) percent use their neighbor's toilets. Due to scarcity of water during dry spells, water borne diseases are common in the areas as people are unable to practice proper hygiene. Typhoid was reported as the main water borne disease affecting majority (81%) of the households. Other diseases reported were diarrhea and dysentery.

3.3 Food Security and Nutrition

The World Health Organization defines three aspects of food security: food availability, food access, and food use. Food availability is having available sufficient quantities of food on a consistent basis. Food access is having sufficient resources, both economic and physical, to obtain appropriate foods for a nutritious diet. Food use is the appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation. Due to unreliable rainfall coupled with poor farming practices as a result of high poverty levels, food production is low and is insufficient to sustain the household members. As a result, only 50% of the households rely on their own production for food with the rest purchasing food from the markets (49%) and insignificant percent (1%) receiving relief food. Those who purchase food spend an average of Kenya Shillings 300 per household per day on food.

3.4 Main Water Sources

About 81% of the households relied on rivers/streams for domestic, livestock and small –scale irrigation purposes. Other sources include boreholes/wells, dams and roof catchments. On the issue of water accessibility, the respondents indicated that they walk up to three (3) km and spending more than one (1) hour to and from the water source.

3.5 Extent of Use of RWHT and Practices in Makueni County

Rainwater harvesting concept has been exploited in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas (Otieno, 1994). Research, technological development and awareness creation have concentrated on the use of very basic methods and technologies. Various techniques on rainwater harvesting are being developed in Makueni County so as to address the problem of food insecurity. These include macro-catchment RWHT such as earth dams, water pans, sand dams, shallow wells, rock catchment structures; rooftop rainwater harvesting systems; and micro-catchment rainwater harvesting technologies for agricultural farming. Common micro-catchment rainwater harvesting technologies include *Zai* pits, strip catchment tillage, contour bunds, semi-circular bunds and meskat-type system.

3.5.1 Macro-Catchment RWHT

Sand Dams/Sub-Surface Dams

Sand/sub-surface dams are barriers constructed across sandy riverbeds to retain water within the trapped sand upstream; they store water in the sand, preventing run-off. The sand filters and cleans the water, and also tops up the ground water aquifer. Water from the sand/sub-surface dams is extracted through traditional scooped holes, or through a pipe that leads to a tank or an infiltration gallery leading to a sealed shallow well and is used for domestic, livestock and small-scale irrigation purposes. The water stored in sand/sub-surface dams is also protected from high evaporation rates and thus the water can last for long periods without drying up as compared to open water storage facilities. However, in some areas of the County, water from sand/sub-surface dams is considered salty due to geological characteristics within the areas. Despite the salinity, communities within these areas appreciate the dams as reliable sources of water as compared to lack of the rare resource. Sand/sub-surface dams require relatively low capital costs, labour and minimal maintenance costs and can last for many years. Records indicate that there are about 118 sand dams in Makueni County (Makueni CIDP, 2013). Some of these dams include;

The Matiani Sand dam; which was built in September 2011 funded by Water Services Trust Fund (WSTF). It has a capacity of about 120 m^3 and about 150 beneficiaries who use the water for domestic use, livestock and construction purposes and small scale irrigation. Occasionally, the sand in the dam is sold for construction purposes to commercial dealers at about Ksh. 5,000 per seven (7) tonnes lorry.

Figure 2: Matiani sand dam

The Syiuni subsurface dam which was built in 2009 by the National Water Conservation and Pipeline Company (NWCPC) and provides water to several villages including Muusini, Miw'ani, Malindi, Makakoi and Kyandavi. Its capacity is about 1600m^3 and was constructed using local sand, boulders and ballast. Moreover, the dam has other components installed including a pump house and pumping unit, PVC pipeline system, a water tower and a water kiosk. This project provides water for domestic usage, livestock and construction purposes. To sustain the project, it is run by a select committee drawn from the villages and the water is sold to the community at Ksh. 2 per a 20 liters jerry can. A small section of the community has individual water connections to the water tower with individual meters.

Figure 2: Syiuni subsurface dam

Water Pans

Water pans/ponds are small earth dams whose storage capacities do not exceed 20,000 m^3 and have a shallow depth of less than 5m. Water from pans is suitable for livestock and irrigation (Waswa and Mpinduzi, 2007). Makueni County has about 289 water pans. However, most of these pans don't survive an entire drought season due to high rates of evaporation, leaching and sedimentation. Methods of extracting water from these pans have also been an issue. Most of the community use water cans and calabashes to extract water from the pond and carry the water cans by back/or hand. Water from these pans is at high risks of pollution since most of them are not fenced and animals drink water from them directly. Water extraction cans and calabashes may also cause pollution within the water pans. Water from the pans is mainly used for livestock and domestic purposes in some areas.

Earth Dams

Earth dams are constructed to collect water from river valleys. Despite its poor quality, water collected from earth dams is used to cater for livestock and domestic purposes. Water from earth dams is also used for irrigation and other purposes such as construction. Earth dams have short life span due to high rates of evaporation and sedimentation (SASOL and Maji na Ufanisi, 1999). Dams' failure is common in the ASALs due to land degradation, heavy pressure from livestock and denuded groundcover. Evaporation from open water storage in ASALs can have a water loss that amounts to 0.9 - 1.4m within a period of 6 months (Falkenmark et al., 2001). There are 159 surface dams in Makueni County (Makueni CIDP, 2013). However, earth dams and other open water storage facilities including water pans/ponds within Makueni County face the problem of evaporation just as in all other open water storage facilities in ASALs. Erratic rainfall and shortages leading to frequent drought spell, high evapo-transpiration rates have resulted to unreliability and unsuitability of earth dams. The available open water storage including dams, pans and ponds, though common, cannot sustain water for a long time due to the high rates of evaporation.

3.5.2 Rooftop Rainwater Harvesting

From the study, about 60% of the residents of Makueni County harvest rain water at household level, with rooftop catchment being the most commonly used technique the communities use gutter-to-tank technology. All those who harvest water at their homesteads use gutter-to-tank technology. Rooftop rainwater harvesting has shown a high degree of reliability especially to the households who have invested in sizable rainwater harvesting systems. However, in some instances it is unreliable as most of the households lack adequate capacity water storage tanks. Various storage facilities are used as illustrated in Fig 4 where over 60 percent of the communities lack enough storage facilities. Most (over 60%) of them have storage facilities of less than 200litres capacity which cannot hold enough water throughout the year. Households that have invested in sizable rainwater harvesting systems ranging from 1 to 10 m^3 capacity, hardly suffer water shortage problems and waterborne diseases. Rooftop RWH technology yields good quality water and is mostly implemented at homesteads and schools. Water harvested from rooftops is mainly for domestic uses including drinking and household chores. However, households that have enough storage facilities have small kitchen gardens and the stored water is a source of drinking water for livestock. Pictures of the some of the rooftop rainwater storage facilities are shown in Figs 5, 6 and 7.

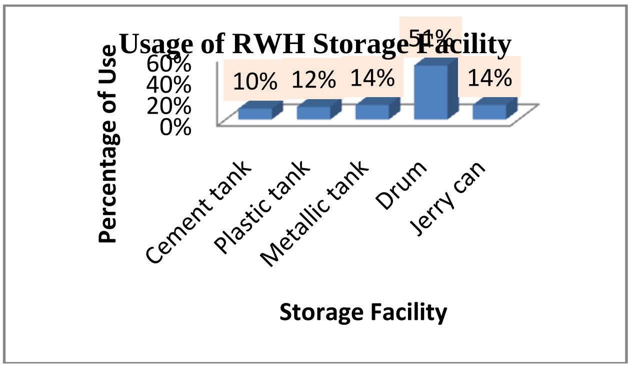

Figure 4: Rainwater storage facilities

Figure 5: Jerrycan storage facilities in Tulimani division

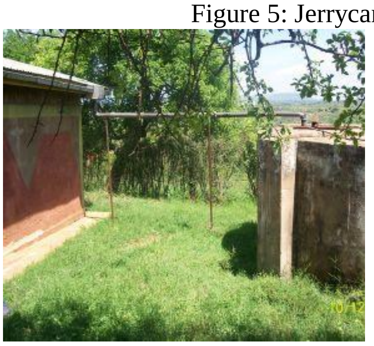

Figure 6: Cement tank in Tulimani division

Figure 7; Plastic tank donated by Lion's club in Kalamba division

3.5.3 Micro-Catchment RWHT

Micro-catchment RWHT provides high percentage of water per unit catchment areas hence plants grow well with little rainfall. It involves water conservation that maximizes soil infiltration and increased water holding capacity within the root zone and is one of the simplest and cheapest technologies. In Makueni County, micro-rainwater harvesting technology has been in use since early 1990s. Most commonly used technologies are *Zai*-pits, terracing (*Fanya juu*, *Fanya chini)* and strip catchment tillage, bunds (contour and semi-circular). Studies show that crops planted using this technology give high yields with very little rainfall. Tisdale (1985) reported that pitting (*Zai*-pits) concentrates rainwater in smaller area raising soil water content per unit volume of soil hence raising water level in soil which favours crop nutrient uptake leading to increased crop yields. In the short rains of 2009, a high yielding of maize crop was observed planted in pits in Kako division in Makueni (Kathuli, 2015).

3.6 Factors Affecting Adoption of Rainwater Harvesting Technologies

Issues of adoption of RWHT in Makueni County have continued to pose a challenge to new technologies irrespective of their potential to improve livelihoods. A logistic regression analysis was conducted to predict factors affecting the adoption of rainwater harvesting technologies within 160 households in Makueni County using gender, age, marital status, education and occupation of household head/respondent, social and economic status, household family and land sizes, roofing material of household house, distance walked from the homestead to the existing water source and technological know-how of the household head/respondent on rainwater harvesting as explanatory variables. Fitness test of the logit model used in this study was done using the Hosmer and Lemeshow statistics and was found to be within the ranges. The overall accuracy of the model was 82.9%, Chi-square of 30.068, *p*-value of 0.872 which is greater than .000, d.f of 8, Nagelkerke's R^2 of .702 indicating a significant difference between predicted and observed values of the dependent variables (*See Table 2*).

3.6.1 Socio-Economic Factors

Gender, Age and Marital Status of Household Head/Respondent

Women are more concerned with water issues are expected to positively influence the adoption of rainwater harvesting technology (RWHT). Most of the respondents (80%) were women since they are often likely to be found at home and are willing to participate on water and sanitation issues as compared to men. It is also their cultural role to be concerned with water issues within the Kamba community. Gender was statistically confirmed to positively influence the adoption of rainwater harvesting technologies within the ASAL areas. The odds ratio for gender is 2.038 implying that women can positively influence the adoption of rainwater harvesting technologies.

The odds ratio of age of the respondents is 0.863 implying that age has a statistically negative effect on the adoption of rainwater harvesting technology. Marital status affects the adoption of RWHT positively. Its odd ratio is 4.490 indicating that married people are likely to adopt RWHT more than the youth. This can be attributed to rights to making decisions and land ownership. Youths do not have right of their own farms/homesteads hence cannot make decisions on the RWH technology to be used.

Literacy Level

Highest education level attained by the household head has a statistical positive effect on the adoption of RWHT. The odds ratio of education level of household head is 5.909 implying that educated household heads are more likely to adopt rainwater harvesting technologies. This is in-line with previous studies such as Tesfaye, 2001, Lloyd, 2015, Florence, 2013 and Ibrahim, 2013 which have indicated positive effect on the adoption of RWHT.

Occupation and Income Sources

From the logical analysis results, occupation does not significantly affect the adoption of rainwater harvesting technologies. The odds ratio of occupation is 0.913. However, the income per household is a key contributor to the adoption of rainwater harvesting technologies. The odds ratio of household income is 5.257 implying that; the more income a household earns, the more likely the household will adopt rainwater harvesting technology. This might be the biggest contributor to the water scarcity in Makueni County since majority of the population are poor with over 70% of the County's population living below the poverty line. These household cannot afford construction materials to construct water storage facilities or buy the ready-made facilities. High household income implies a greater incentive for investment in rainwater harvesting technologies and ability to bear the risks that can be associated with its adoption (Lloyd, 2015).

Household Land

According to the Makueni CIDP (2013), the average land size for both small scale and large scale farming households is about 3.44 Ha and 30.4 Ha respectively with only 19.8% of all land owners having legal ownership documents (i.e. title deeds). Most households within the County rely on farming as a source of livelihood and therefore land ownership is an indicator of household welfare as it provides direct benefit to households and act as a resource of livelihood. Rights to a piece of land determine the nature of investments and developments to be done on the land. Rainwater harvesting being one of the developments/investments that can be done on a household land is threatened by lack of legal land ownership. This is statistically proven by the odds ratio of household land rights of 1.755 in Table 2.

Social Capital

Households that are members of a group including women groups and self help groups among others are more likely to adopt rainwater harvesting technologies. The odds ratio of for social capital is 1.521 implying that the social status of a household increases the probability of the adoption of RWHT by 1.521. Poverty is one of the setbacks towards the adoption of RWHT; many households within Makueni County cannot adopt RWHT because they lack enough capital and credit access. Members of a group or organization have greater chances of credit access hence invest in RWH projects as compared to those who don't belong to a social group or organization. Most of the water and rainwater harvesting projects in Makueni County are implemented through groups and associations so as to ensure sustainability, accountability and ownership amongst the community. This enhances the probability of those who belong to a group/organization to adopt RWHTs.

Table 2: Logit Model odds ratios of factors influencing adoption of rainwater harvesting technologies

Variable	**Exp (β)**
Gender of household respondent	2.038
Age of household respondent	0.863
Marital status of household respondent	4.490
Education level of household respondent	5.909
Occupation of household respondent	0.913
Member of a social group (social capital)	1.521
Household income	5.257
Household family size	1.220
Household land size	1.755
Household house roofing material	3.611
Distance from the household to existing water source	7.203
Training information on rainwater harvesting	2.674

Note:

Sample size = 160, Hosmer and Lemeshow Test: Chi-square = 30.068, p-value = 0.872, d.f = 8, Nagelkerke's R^2 = .702 and Overall model accuracy = 82.9%,

3.6.2 Technical Factors

According to KRA survey on community water projects (1998), the major cause of the projects' failures is due to lack of technical interventions. Assessment of the infrastructure showed that the communities were not fully involved in the planning and technology selection. Technical aspects of the projects including gutters selection and methods of fixation, fixing taps, tank construction valves and operation and maintenance guidelines are not fully understood nor issued to the community on the commissioning of the project.

Wanyonyi (undated) further identified the major technical constraints towards the adoption and success of rainwater harvesting systems as; inadequate guidelines on the construction of RWH systems especially in the rural areas, inadequate technological transfer to the beneficiaries (in cases of donor funded projects), lack of training programmes on rainwater harvesting for stakeholders (beneficiaries artisans), poor technical selection and usage of local materials in construction of RWH systems, improper sizing of rainwater storage systems, inadequate water quality improvement structures, control and usage for safety and health and limited technological transfer in rainwater harvesting at project level due to inadequate trained personnel in RWH.

Makueni County having most of the rainwater harvesting projects done as community projects is no better. Technical issues including lack of proper guidelines on how to construct RWH systems, improper sizing of the systems, lack of training on RWH, storage and management, poor local construction materials selection and proper site for locating RWH systems. About 93% of the respondents indicated that they had never been trained on rainwater harvesting, health and sanitation and food and nutrition. Erratic rainfall received within the County coupled with lack of data on rainfall intensities, event duration, water infiltration and data on soil storage properties, and improper training on rainfall data simulation lead to improper sizing of RWH storage facilities. High losses through seepage and evaporation make water pans/ponds and earth/surface dams never fill to their expected capacities.

Poor water extraction methods from the storage facilities as a result of improper designs lead to safety and health issues. People and animals get water directly from unprotected dams and ponds. This lead to pollution and in some cases drowning. The major common way of water extraction from sand dams is a drudgery method of scooping sand and fetching water from the holes using jerry cans.

Respondent's awareness of rainwater harvesting technologies and their technical aspects have statistically-significant positive impact on adoption of the technologies. The odds ratio of information on rainwater harvesting is 2.674 implying that households which have received training on rainwater harvesting have a greater chance to adopt RWHT than those who are not aware.

IV. RECOMMENDATIONS AND CONCLUSION

Rainwater harvesting has potential to make a significant contribution towards livelihoods in Makueni County by proper harvesting, storing and management of the little water that falls. Various rainwater harvesting technologies (RWHTs) are used within Makueni County including micro-catchment rainwater harvesting technologies (i.e. earth dams, sand/sub-surface dams, shallow wells, rock catchment structures, systems), rooftop rainwater harvesting and micro-catchment rainwater harvesting technologies for agricultural farming (i.e. Zai pits, strip catchment tillage, contour bunds, semi-circular bunds and meskat-type system, with rooftop catchment being the most commonly used technique with gutter-to-tank technology. However, there is slow adoption of RWHT in Makueni County irrespective of their potential to improve livelihoods. Results from logistic regression analysis conducted to predict factors affecting the adoption of rainwater harvesting technologies within 160 households in Makueni County showed that some of the factors considered have statistically-significant positive effect on the adoption of RWHT. These include gender, literacy levels, social and economic status and technological know-how on RWHT. To enhance adoption of RWHTs in Makueni County and other ASAL areas, the following is recommended:

- Water shortage affect rural women more since it's their cultural role to provide water. They are more concerned with rainwater harvesting projects as compared to men. Therefore, training and awareness creation on RWHTs amongst women should be enhanced.
- Literacy levels influence adoption of RWHTs and therefore school age going children should be encouraged to go to school. To promote better knowledge on RWHTs, rainwater harvesting should be introduced in school curriculum.
- Poverty which is a major setback to the adoption of RWHTs should be alleviated by promoting income generation activities to enhance adoption of RWHTs within the ASALs.
- Community groups focused on RWH promote adoption of RWHTs and should therefore be enhanced. Population within the ASALs should be encouraged to form community groups aimed at water development activities as a way of promoting adoption of RWHTs.
- Most of the rainwater harvesting technologies in Makueni County are labour intensive and cannot be mechanized yet considerable volumes of soil need to be excavated during construction. There is need for research into appropriate technologies to lessen the drudgery and address gender issues.
- Water loss through evaporation and seepage from open reservoirs is a challenge within the ASALs. Research on the ways of reducing this ought to be done.
- Awareness on rainwater harvesting technologies including designs, suitability and management need to be done within Makueni County.

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