EISSN: 2707-0425

East African Journal of Science, Technology and Innovation, Vol. 3 (2): March 2022

Barriers and Enablers of adoption of Rain Water Harvesting Technologies at County Levels: A Case of Matungulu Sub-County, Machakos County Kenya

[1]WEKESA P M., [1]NZIOKA J M., [1]MUTUNE J M*

[1]Wangari Maathai Institute for Peace and Environmental Studies, University of Nairobi, Nairobi, Kenya.

***Corresponding Author**: pwekesa@uonbi.ac.ke

Abstract

Rainwater harvesting technology is among the oldest methods of fetching water among households. The demand for water use has grown globally outpacing population growth, and increasingly, many regions are currently reaching levels which water services are unsustainable, especially in Arid and Semi-Arid Lands (ASAL) regions. Inadequate water for domestic and agricultural use has had negative impacts on households in ASAL areas. There has been however introduction of rainwater harvesting technologies that seeks to solve the effects of water scarcity in these areas. Adoption of these technologies depend on factors that hinder/encourage households to adopt them. Matungulu Sub-County is such area that requires adoption of these technologies. Focus group discussions, interviews with key informants, and structured questionnaires were used to collect data. Descriptive and inferential statistics were used in data analysis. This involved calculation of arithmetic mean, standard deviation, percentages, frequencies and Analysis of Variance. The study identified 5 rainwater harvesting methods; Surface rainwater harvesting, Rooftop rainwater harvesting, Catchments, First flush and Filter. Findings indicated that overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents agreed that incentives from the county government significantly promoted water-harvesting technologies. This was confirmed by a positively strong and significant correlation between integration of Rainwater Harvesting Technologies in the county development agenda. Results of this survey indicate that mostly household heads finance rainwater technologies and County Government initiatives have not been adequately felt. The study findings indicate that the major barriers to adopting rainwater technologies are costs and a lack of expertise on the adoption of these technologies. To ensure the sustainability of rainwater harvesting technologies, the study recommends the development of clear monitoring systems on water collection in the County. Additionally, there is a need to strengthen funding and sensitization on the best technologies to enhance water harvesting.

Keywords: *Governance mechanisms; Machakos; Matungulu; Rainwater harvesting technologies; Water technologies*

Received: 25/10/21
Accepted: 15/03/22
Published: 31/03/22

Cite as: *Wekesa et al., (2022)* Barriers and Enablers of adoption of Rain Water Harvesting Technologies at County Levels: A Case of Matungulu Sub-County, Machakos County Kenya. *East African Journal of Science, Technology and Innovation 3(2).*

Introduction

Throughout generations, people have been living in water scarce areas where collection of rainwater from rooftops and rainwater runoff from the hills were major sources of domestic water. This water collection technique, though simple, enabled early farmers to practice agriculture in the Middle East, North Africa and even Mexico (Pacey and Cullis, 1986).

Competing demands for water from agriculture, domestic use, climate change and population growth is putting pressure on water resources. The effects of climate change directly affects the rainfall patterns across the globe (Markandya, Cabot-Venton, and Beucher, 2015). This has been the concern of experts who have predicted that with increasing effects of global warming and changing rainfall patterns, there is likely to be a reduced harvested water. This will result in some regions getting more rain at the expense of others leading to extreme weather conditions (Ntale *et al.,* 2005).

The international Resource Panel (IRP), (2016), reported that under current trends, global water demand will exceed supply by 40 percent by the year 2030. This is reflected by the recognition by the United Nations that there is need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015).

The global effects of climate change as well as increasing water scarcity, coupled with population growth, demographic changes and urbanization pose greater challenges on water supply systems (WHO, 2019). Other alternatives of water sources for drinking, irrigation as well as other domestic uses will therefore, continue to evolve, with an increasing reliance on groundwater and alternative sources, rainwater harvesting and recycling of wastewater (Sapkota *et al.,* 2018).

Many studies have been conducted on barriers and enablers of rainwater harvesting technologies, however, very little has been documented on the Kenyan case. According to Suzenet *et al.*, (2002) key barriers to adoption of rainwater harvesting technologies are: "lack of information and knowledge; economic and financial constraints; absence of incentives; institutional and regulatory gaps; house-builder attitudes." Developers' attitudes is domiciled on failure to implement or adopt technologies that support water harvesting and recycling in designs of new homes (Goodhew *et al.,* 1999).

The main objective of the study was to provide an understanding of the barriers and enablers of utilizing rainwater-harvesting technologies in the study area and to interrogate the extent to which Machakos County Government implements and integrates water-harvesting technologies in its programs, planning, and budgeting among households in Matungulu Sub-County in Kenya. This study would provide critical data on the household adoption of rainwater technologies that can be used to develop key strategic plans on how to promote the use of RWHT through cost-effective community initiatives to complement the county government efforts.

Literature Review

Documentary data shows that heavy rains are experienced in the study area during the months of March, April, and May as well as in October, November and December. These are the most appropriate times for effective rainwater harvesting to enhance water availability during the dry seasons (Figure 2).

Kimani, Gitau and Ndunge, (2015) revealed in their study that there are basically three types of rainwater harvesting technologies in use in Makueni County; Macro-catchment technologies, micro-catchment technologies and rooftop harvesting technologies.

Macro-catchment technologies are concerned with collecting run-off water from roads, hillsides and postures. An example of macro-catchment technology is the earth dam. Micro catchment technologies involve collection of run-off water close to the areas where they are needed. Examples are pits, contour tillage and bunds among others. These are mostly used to irrigate crops with medium water needs. Rooftop harvesting technologies are used to collect rainwater from rooftops and are able to collect relatively clean water which can be used for domestic purposes. (Kimani, Gitau,and Ndunge, 2015).

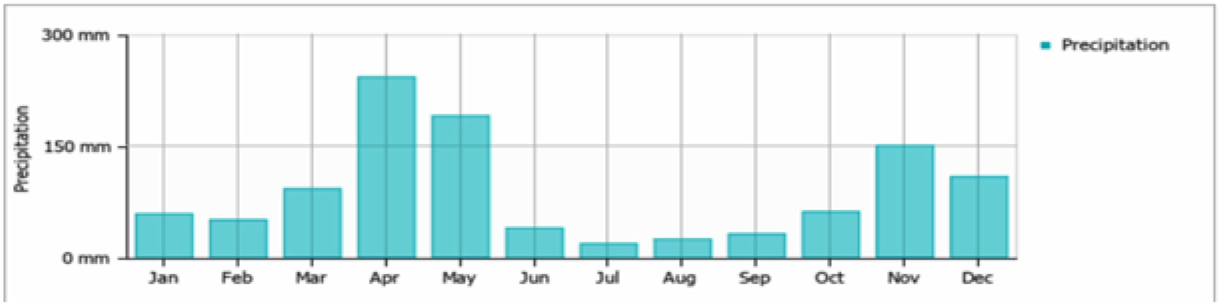

Figure 2. Average rainfall precipitation

Several studies were conducted to identify barriers to sustainable water management in Canadian urban cities. The Canadian Water and Wastewater Association (CWWA) in a report indicated that there were no regulatory barriers to water re-use but the problems were occasioned by lack of regulations and guidelines on water harvesting and utilization in urban households (Chantelle, Khosrow and John, 2010).

In Iran, experts have elicited views that lack of specialized administrative structures for rainwater harvesting is perceived as one of the most important barriers among city residents in various Iranian cities. There is also a significant level of inadequate perception among residents towards water conservation which plays a significant part in adoption of rainwater technologies in Iran (Sheikh, 2020).

Marsalek *et al.*, (2002) in their study noted that there was need to have water quality standards, end-use guidelines, and technology performance standards as a measure to address the regulatory gap. The study of Brandes and Ferguson (2004) focused more broadly on "demand-side management and attitudinal barriers, financial barriers, data/information barriers, and administrative barriers. Issues such as the myth of abundance, low and subsidized water prices, lack of comprehensive cost-benefit models, an engineering bias that favours centralization, and fragmented administration, are particularly relevant to RWH".

For many years, Non-Governmental Organizations and other community based as well as faith based groups and networks have been in the forefront in agitating for adoption and use of rain water harvesting. However, lack of scientifically verifiable information for use by policy makers in designing strategies for water harvesting and mapping areas of potential implementation of rainwater harvesting technologies have hindered the progress (Mati *et al.*, 2006).

Sheikh, (2020) identified the key enablers for rainwater harvesting technologies as implementing common strategies that center on developing of common policies, strategies and regulations that provide financial incentives, training and extension activities, collaboration with other agencies providing the same water harvesting services, mandatory regulations as well as encouraging the public to adopt rain water harvesting technologies.

Materials and methods

The study area

The study was conducted in Matungulu Sub-County, Machakos County. It borders Nairobi, Kiambu, Embu, Kitui, Makueni, Kajiado, Murang'a and Kirinyaga (MCIDP, 2015). Machakos County comprises eight (8) constituencies also referred to as Sub- Counties including Machakos Town, Masinga, Kangundo, Yatta, Mavoko, Matungulu, Kathiani, and Mwala Sub-Counties (MCIDP), 2015) (Figure 1).

The local climate of Matungulu Sub-County is semi-arid with a few hilly terrains (MCIDP, 2015). The annual rainfall of the Sub-County is unevenly distributed and unreliable averaging between 500 mm and 1300 mm. The short rains are experienced in October and December and long rains come from March to May. July is the coldest month while October and March are the warmest months with temperatures varying between 18˚C and 29˚C throughout the year. The total population of Matungulu Sub-County is 199,211 people, with 64,257 Households. It covered an area of 577.5 square kilometres with a population density is 215 persons per square kilometre dominated by the Akamba people (MCIDP, 2015).

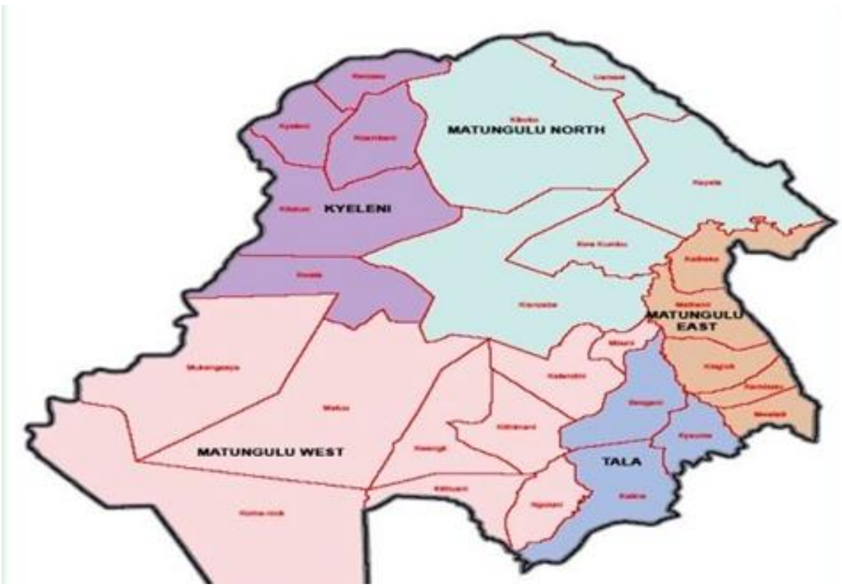

Figure 1. Map of Matungulu Sub-County
Source: IEBC

Sampling procedure
Probability sampling technique was used to identify sample population. This type of systematic sampling was adopted because it gives all elements in the study population an equal chance of being selected in the sample. The sample size for this study was 384, which was calculated using Fisher's formula:

$$n = Z^2 pq/d^2$$

Where n = sample size, Z=Confidence level, p = 50%; q = 1-p while d = significance level (0.05)

To select households from all villages in the sub – county for interview, simple random sampling method employed using the prepared list acquired after assigning random numbers to the households, a random sample of 384 households was selected using table of random numbers. 384 questionnaires were distributed to the selected sample size. Fifteen key informant interviews were also conducted to get in-depth information on rainwater harvesting technologies. Further two sessions of focus group discussions were conducted to get more views from the respondents.

Data analysis
Descriptive statistics were used in data analysis through the use of the Statistical Package for Social Sciences (SPSS version 22 software). This involved calculation of arithmetic mean, standard deviation, percentages, frequencies and Analysis of Variance.
Both primary and secondary data was used. Structured questionnaires was used to collect primary data which included respondents biodata, RWT adopted, Barriers and enablers and policy issues on rainwater harvesting.

Secondary data were obtained from statistical abstract reports, government publications such as the Machakos County Integrated Development Plan, 2015, Population and

Housing Census Reports, Ministry of Agriculture Annual Reports and Food and Agricultural Organization (FAO) publications. These data was used to complement the primary data and to confirm the study findings.

A total of 384 households were considered in the study out of a total of 64,257 households residing in the area under study. The sample was calculated at 95% confidence level, using Fisher's formulae, where (n) referred to the sample size (where the population being targeted was more than 10,000), (Z) was the standard normal deviation at the desired confidence level (Z level is 1.96 at 95% significance level), (p) is equal to 50 per cent, (q) is 1 – p while (d) is statistical significance level (0.05).

$$n = Z^2 pq/d^2$$

$$n = 384 \text{ Households}$$

The analyzed data were then presented in tables and figures.

Simple linear regression model was used to test the hypothesis in order to meet the requirements of the objective as follows.

Test of Hypothesis

H_0: Barriers and enablers do not significantly influence the effects of rain water harvesting technologies among households.

H_1: Barriers and enablers significantly influence the effects of rain water harvesting technologies among households in Matungulu Sub-County, Kenya.

The null hypothesis was tested using the simple linear regression model as stated below.

$Y_1 = a_1 + \beta_1 X_1 + e_1$ Where:

y = Impact on House Household Livelihoods

a_1 = Constant

β_1 = Beta coefficient

X_1= Barriers and Enablers

e_1 = error term

The outcomes were as presented as follows in table 3

The results showed that the model explanatory power between barriers and enablers and the impact on household livelihoods determined by the 'R Square'. This established that only 0.1% of the changes in the impact on household livelihoods can be explained by barriers and enablers. This was not significant.

Linear regression was selected in order to understand the relationship between Barriers and enablers and the rainwater harvesting technologies

Results

From the study, results indicated that majority of respondents were male representing 61% of the total respondents. This is an indication that there is a bias towards the male gender in matters relating to rainwater harvesting. However, results showed that through the age groups, there was a balanced representation of respondents.

At 75%, farmers represented majority of the respondents to the study followed by self-employed, employed and business people at 11%, 8% and 2% respectively. Agriculture is the main economic activity in Matungulu and therefore the sample distribution gives the study a good stand basing on the relevance of the respondents towards achieving the objectives of the study.

The study revealed that majority of households engaged in rainwater harvesting, representing 98% of the respondents however, this practice was done in small quantities that cannot sustain long-term use of the harvested water (table 1). The study identified 5 rainwater harvesting methods; Surface rainwater harvesting, Rooftop rainwater harvesting, Catchments, First flush and Filter.

Table 1. Utilization of household rainwater harvesting technologies

Household RWT	Frequency	Percent
Yes	371	98
No	8	2
Total	**379**	**100**

Table 1. Statistics

Composite Means/Std. Dev & Variance for the Key Objectives		Barriers and Enablers	Water Harvesting Technologies	Integration of RHT in County Development Agenda	Impact on Household Livelihoods
N	Valid	379	379	379	379
Mean		2.92	4.02	4.04	4.18
Std. Deviation		.503	.549	.699	.566
Variance		.253	.302	.489	.321

Financing Rainwater harvesting systems

The respondents were asked on whom was the main source of capital in purchasing or constructing the rainwater harvesting method and the results were presented as below in table 2.

Table 2: Main Source of Capital

Main Source	Frequency	Percent
Head of Household	327	86
Community	27	7
Self-help Group	20	5
County Government	4	1
Both Self and Spouse	1	1
Total	**379**	**100**

Table 2: main source of capital.

The study findings indicate that the head of household was the main source of capital in the purchase of rainwater harvesting method representing 86% of the respondents while 7% of the respondents said it was the community. On the other hand, 5% of the respondents indicated that it was carried out by the self-help group while only 1% each of the respondents agreed it was done by the county government and both self and spouse. This was a clear indication that majority of household heads were the main source of capital towards purchasing the rainwater harvesting method.

Barriers to Utilization of Rain Water Harvesting Technologies

The opinion results were measured using a 5-point Likert-scale ranging from (1) = Strongly Disagree (SD), (2) = Disagree (D), (3) = Undecided (U), (4) = Agree (A) and (5) = Strongly Agree (SA) as shown in Figure 3.

Cost of rainwater harvesting technologies

The study results show that majority of respondents at a composite mean of 4.7 on Likert scale believe that cost is the major prohibiting factor hindering adoption of rainwater harvesting technologies. This include cost pf purchase, cost of installation and cost of maintenance. They agree that cost vary depending on the technology adopted, which include boreholes, water tanks, wells and dams.

Further, a composite mean of 4.3 believed that the high cost of rainwater harvesting technologies was because of heavy taxation and lack of support from the government. The county government especially has not put in place policies to provide adequate financial incentives to support rainwater-harvesting technologies.

Additionally, the study revealed that the household head was responsible for purchase of rainwater harvesting technologies at 87% of the respondents. Other sources of capital included self-help groups, community and spouse at 4%, 3% and 2% respectively.

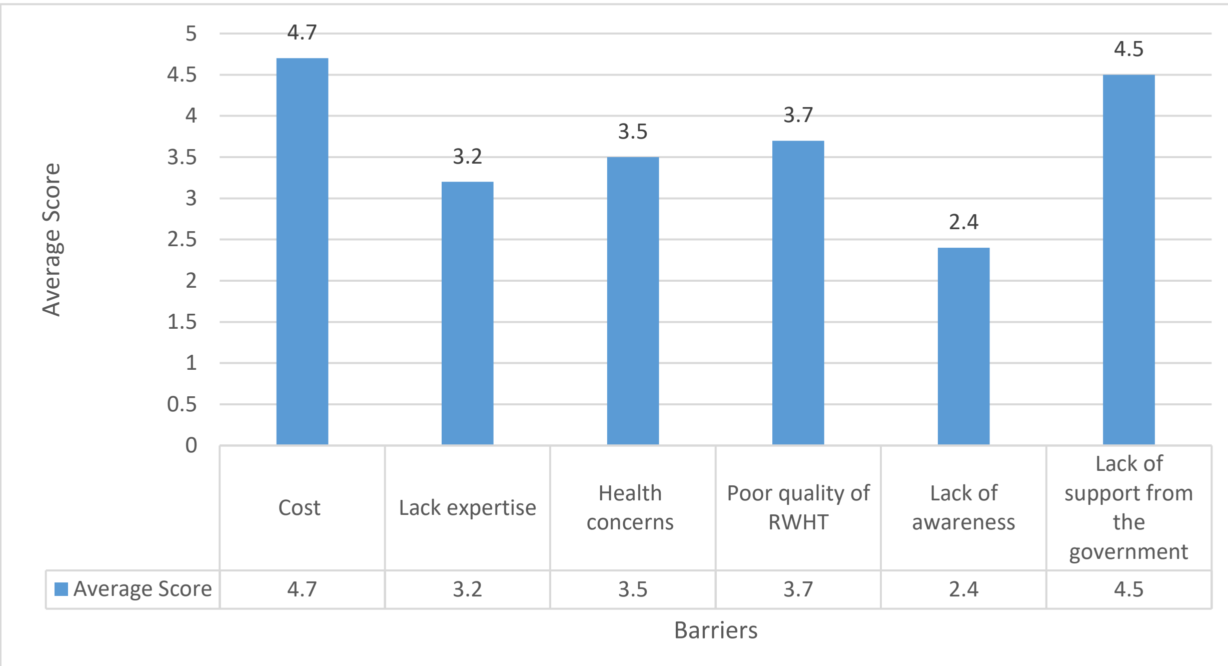

Figure 3. Barriers to adoption of rain water technologies

knowledge of the technologies: A composite mean of 3.2 of the respondents believe that lack of expertise to adopt and implement these technologies is one of the major barriers. The respondent imply that while some technologies can be easily installed, others need experts to design and build these systems. 75% of respondents indicate that most of the time, local masons and plumbers, who are not adequately trained are used in designing and building rainwater harvesting technologies, leading to poor designs and increased risk to residents.

Quality of rainwater harvesting systems. The respondents noted that some of the rainwater harvesting technologies purchased only lasted for a short time before they were replaced or need repairs. A composite mean of 3.7 of respondents believed that this was because of the poor design by locally used technicians and also from effects of extreme weather conditions that accelerate their deterioration. However, 24% of respondents believed that technologies were of good quality but the way in which it was installed was the problem, leading to reduced lifespan.

Awareness on Rainwater Harvesting technologies: Respondents were requested to indicate the level of awareness of the available rain water harvesting technologies and how they were installed and used. A composite mean of 2.4 of the respondents were able to list at least one rainwater harvesting technology. This indicated that there was a good level of awareness on rainwater harvesting technologies. However, 78% of the respondents were not aware on how to effectively install and manage these technologies

Government support: A composite mean of 4.5 of the respondents indicated agreement that County Government does not provide adequate support for rainwater harvesting technologies. Respondents were further asked to indicate the level of agreement on certain aspects of support from the county government on adoption of rainwater harvesting technologies. Data was measured in a Likert scale and results indicated that the county government did not do enough to provide support in relation to adoption of rainwater harvesting technologies. These aspects included provision of training, financial support, incentives, developing clear policies on use of rainwater, water treatment and developing projects for sustainable water harvesting.

Enablers of rainwater harvesting technologies

Respondents were requested to indicate their level of agreement to specific statements on the enablers of adoption and use of rainwater harvesting technologies. The results were measured using a 5-point Likert-scale ranging from (1) = Strongly Disagree (SD), (2) = Disagree (D), (3) = Undecided (U), (4) = Agree (A) and (5) = Strongly Agree (SA) as shown in Figure 4.

Results indicate that water scarcity was a major contributing factor for adoption of rainwater harvesting technologies with composite mean of 4.7. This was followed by self-initiatives, community/group initiatives, affordable water harvesting technologies, frequent campaigns by community based organizations and support from county government at composite means of 4.2, 3.7 3.1, 2.4 and 1.5 respectively

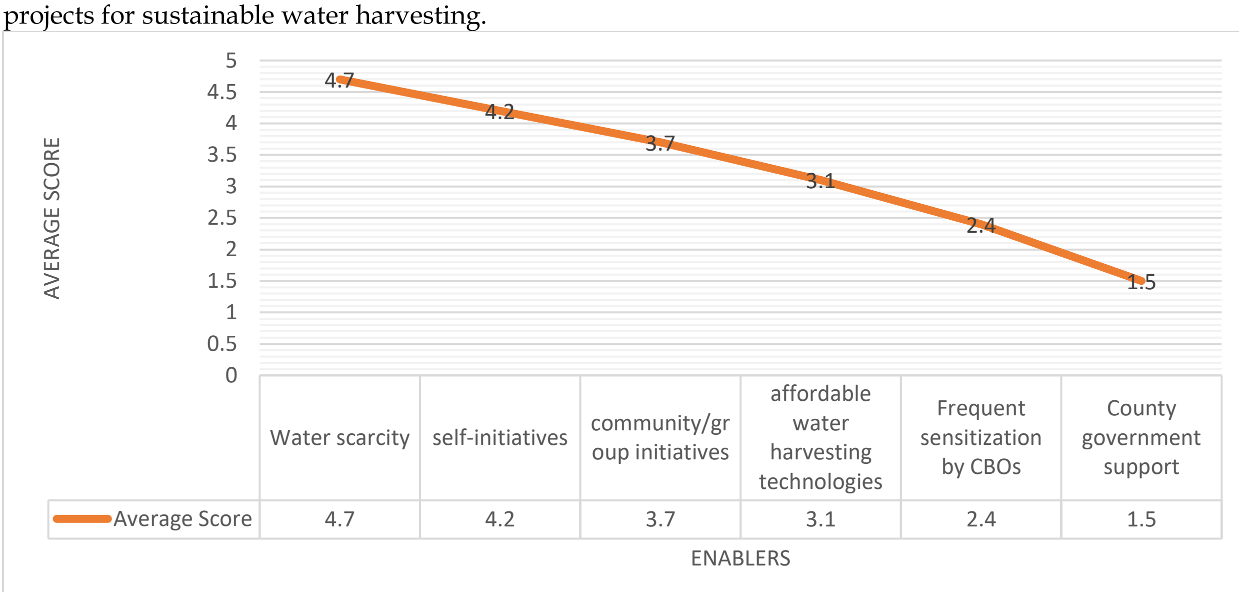

Figure 4. Enablers to adoption of rainwater harvesting technologies

Impact on Household Livelihoods

The ANOVA results in table 4 showed an F Value of 0.490 reflecting a significance level of .484[a] meaning the test statistic was not significant at that level. This showed that barriers and enablers did not have a statistical significant impact on household livelihoods at 95% confidence level.

Table 3. Model Summary for Barriers and Enablers and Impact on Household Livelihoods

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.036[a]	0.001	-0.001	0.566

a. Predictors: (Constant), Barriers and Enablers

Table 4. Analysis of Variance of Barriers and Enablers and Impact on Household Livelihoods

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.157	1	0.157	0.490	0.484[a]
	Residual	121.089	377	0.321		
	Total	121.246	378			

a. Predictors: (Constant), Barriers and Enablers

b. Dependent Variable: Impact on Household Livelihoods

Discussion

Global Water Institute, (2013) stated that Kenya's biggest challenge currently was the growing water shortage and dwindling rivers, hence there was the need to diversify water harvesting and storage mechanisms that improved the threatened supplies. In addition, there was a lot of water wastage due to the untapped rainwater that led to soil erosion and siltation of water bodies. This is supported by the Average rainfall monthly data presented in the monthly rainfall precipitation data.

The United Nations (UN) recognizes the need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015). In Kenya, a water crisis occurs when there is a situation of inability by the government to supply clean, safe drinking water to its population (UNESCO, 2018). The study identified key barriers to utilization of RWT as; Cost, lack of expertise, health concerns, poor quality RWHT, lack of awareness and lack of support from the government.

The study identified the cost of purchasing rainwater technologies, cost of installation, maintenance and lack of financial support as a major barrier to adoption of rainwater harvesting technologies. This agrees with case studies done by Kim *et al.,* (2016), who found out that the cost of a rainwater harvesting system is economically prohibitive for most individual households. It also supports the findings of Suzenet *et al.,* (2002) that key barriers to adoption of rainwater harvesting technologies are: "lack of information and knowledge; economic and financial constraints."

Health concerns arising from use of untreated rain water was identified as a major barrier in this study. This confirms the findings by WHO/UNICEF that in developing countries in Africa, Asia and Latin America, satiation services are still un-established or poorly funded. This is evidences by the prevalence of hygiene related diseases in these regions (WHO/UNICEF, 2017). These findings are also reinforced by Smets (2009) noted in his study that access to clean and safe drinking water in industrialized countries is cheaper compared to developing countries. On average, households in industrialized countries spend about 1.1% of their income for their water and sanitation bill. Poor households generally spend an average 2.6% of their income. Smets,

(2009) further notes that improving access to affordable water requires paying attention to the affordability index and taking measures to reduce it such as differentiated pricing, targeted aid programmes, cross-subsidy systems, etc. Many developing countries have implemented such measures.

Lack of expertise to design and build rainwater harvesting systems was noted as another barrier. This supports studies which have found out that lack of knowhow among the publics to increase demand for rainwater harvesting which will in turn promote the idea of progressive policy development. This bottom-up approach will ensure that regulations that stifle progress in rainwater harvesting technologies are removed. The study also recommended the availability of strong leadership to guide in policy development and encourage the existing interested groups to adopt the technologies (Chantelle *et al.*, 2010).

The study identified poor quality rainwater harvesting technologies as one of the barriers. This is supported by the study by Marsalek *et al.,* (2002) who noted that there was need to have water quality standards, end-use guidelines, and technology performance standards as a measure to address the regulatory gap.

Awareness of the availability of RWHT is important in adoption for wider use. The study confirms the findings of Matthew and William (2010), who noted that increased interest in RWH was exemplified when a rainwater harvesting website hosted by the authors received over 2000 unique visitors over 3 days when a local news channel broadcasts information on rainwater harvesting systems. The majority of respondents indicate that they received information on Rain Water Technologies from the radio, indicating that for these technologies to be widely integrated into society, County Governments must design their campaigns to utilize the broadcast media. Self-help groups and village barazas also play a key role in community awareness.

The study confirms the findings by Kim *et al.,* (2016), that rainwater harvesting is not a high priority for beneficiary developing countries or of high priority in water management policies. This explains the reason for the poor adoption of these technologies in Kenya. However, findings call for new thinking regarding RWHTs as suggested by Lockwood and Smits (2011) who propose a self-supply initiative initiated by individual families or groups. The findings of the study also seem to confirm that the main source of funding of water harvesting technologies is the household heads as per the findings of Kim *et al.,* (2016), that it is expensive to construct rainwater systems and donor agencies and countries concentrate on financing centralized water supply system. The findings confirm that the government plays a minimal role in financing small-scale water harvesting technologies.

The study findings indicate that motivation to adopt rainwater harvesting technologies centres around water scarcity, affordability, and the need for reliable water supply for domestic and livestock. Support from County Government only accounts for 11% of the motivation factors. This strengthens the findings of Lade and Oloke, (2015), that the greater attractions of an RWH system are accessibility, low cost, and easy maintenance at the household level. RWH enhances water supply by mitigating the temporal and spatial variability of rainfall and provide water for basic human needs and other small-scale productive activities. RWH and storage have proved to be affordable and sustainable. This indicates that more needs to be done by the County Government for its efforts to be felt.

The County Government of Machakos recognizes the need for adequate access to water and has embarked on a comprehensive water program which has the following components: water resource mapping, drilling, equipping and reticulation of boreholes, weir and dam construction, rehabilitation of existing water projects, rainwater harvesting and strengthening of governance structures for water service providers and community water projects (CIDP, 2018). Among the objectives of the County Integrated Development Plan, 2018 is to establish pro-poor subsidy programs in poor resource settings (free water) and to strengthen governance in water service providers (WSPs) for sustainable provision of water services for domestic, industrial, and agricultural purposes to ensure the conservation of environment. The findings of this study highlighted the cost of RWT as one of the barriers to adopting rainwater technologies, therefore, necessitating subsidy programs for Rain Water Harvesting technologies.

Conclusion

Results of this study indicate that the cost of purchasing rainwater technologies was a major barrier to its adoption. Even though the county government through its integrated development Plan has spelled out plans for the water sector, the lack of adequate budgets has hindered its implementation. Lack of expertise was identified as another barrier to adopting rainwater harvesting technologies. This indicated that the County government needs to develop strategies for training installation experts for rainwater harvesting technologies to support the rural community to meet their water needs. This should go hand in hand with sensitization of the community on the available rainwater harvesting technologies in the market.

The study also identified lack of support from the government on rainwater harvesting technologies. Support comes in various ways which include training opportunities, subsidies on the cost of rainwater harvesting technologies and creating collaborative engagements with industry.

This study provides critical data on the household adoption of rainwater technologies that can be used to develop key strategic plans on how to promote the use of RWHT through cost-effective community initiatives to complement the county government efforts. However, further studies need to be done to ascertain the quality and the effects of the use of rainwater for domestic purposes to void the prevalence of diseases in the communities.

Rainwater harvesting technologies give hope to curbing water shortages in arid regions of Machakos County. However, the adoption of the rainwater harvesting technologies depends on the dynamics of governance mechanisms which the county uses to ensure that policies and incentives trickle down to the residents. Notably, Machakos County Government programs, planning, and budgeting do not significantly influence the effects of rainwater harvesting technologies among households. Further, there is a need for the County Government of Machakos to have a framework that would ensure that the rainwater harvested upholds good quality and is safe for human consumption through a mechanism of testing the quality of such water. To ensure the sustainability of the rainwater harvesting technologies, the County Government of Machakos requires a clear monitoring system on the total amount of water collected in the county in terms of litres or gallons and its adequacy in serving the local communities.

In addition, Machakos County Government can strengthen its funding, training, awareness creation, and sensitization of its residents on the best technologies of rainwater harvesting to enhance water availability and sustainability.

Acknowledgment

The authors are grateful to institutions and individuals who provided data and information for this research. These include Machakos County Water Resource Authority (WRA) Office officials. Much gratitude and thanks also go to our research assistants led by Ann Arochi Wang'anya and Francis Nzomo Kimweli for preliminary data preparation and coding. We also thank Mr. Simon K. Bett (University of Nairobi) and Dr. Bessy Kathambi from Wangari Maathai Institute for Peace and Environmental Studies (WMI) who provided insight and expertise that assisted the research. We thank the anonymous reviewers for their patience and time in helping improve the quality of this article.

References

Brandes, O. & Ferguson K. (2004). The future in every drop: The benefits, barriers, and practice of urban water demand management in Canada. POLIS Project on Ecological Governance, University of Victoria, Victoria, BC. 65 pp.

Chantelle L., Khosrow F. & John F. (2010) Identifying Barriers to Widespread Implementation of Rainwater Harvesting for Urban Household Use in Ontario, Canadian Water Resources Journal, 35:1, 93-104, DOI: 10.4296/cwrj3501093

CIDP. (2013). Machakos County Integrated Development Plan. Government Printer.

Global Water Institute, 2013. Without Strategic Water Security, Farmers Will Migrate in

Goodhew, S. M. R., Fitzgerald, D., & Southcombe, C. (1999). Water efficient dwellings; do UK housebuilders recognise a need?. *Journal of Financial Management of Property and Construction*.

International Resource Panel (IRP) 2016. *Policy Options for Decoupling Economic Growth from Water Use and Water Pollution*.

Jones, M. P., & Hunt, W. F. (2010). Performance of rainwater harvesting systems in the southeastern United States. *Resources, Conservation and Recycling*, *54*(10), 623-629.

Kim, Y., Han, M., Kabubi, J., Sohn, H. G., & Nguyen, D. C. (2016)., CB-RWH for drinking water supply in developing countries Water Science & Technology: Water Supply, 2016: 16(4), 1110-1121.

Kimani, M. W., Gitau, A. N., & Ndunge, D. (2015). Rainwater harvesting technologies in makueni county, Kenya. *International Journal of Engineering and Science*, *5*(2), 39-49.

Lade, O., & Oloke, D. (2015). Rainwater harvesting in Ibadan City, Nigeria: Socio-economic survey and common water supply practices. *American Journal of Water Resources*, *3*(3), 61-72.

Lockwood, H., & Smits, S. (2011). *Supporting rural water supply: moving towards a service delivery approach*. Practical Action Publishing.

Machakos County Integrated Development Plan, (2015). Retrieved on 28th August, 2019, from www.machakosgovernment.com/

Markandya, A., Cabot-Venton, C., & Beucher, O. (2015). Economic assessment of the impacts of climate change in Uganda.

Marsalek, J., Schaefer, K., Exall, K., Brannen, L., & Aidun, B. (2002). *Water Reuse and Recycling. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba: CCME Linking Water Science to Policy Workshop Series* (No. 3, p. 39). Report.

Mati, B., De Bock, T., Malesu, M., Khaka, E., Oduor, A., Meshack, M., & Oduor, V. (2006). Mapping the potential of rainwater harvesting technologies in Africa. *A GIS overview on development domains for the continent and ten selected countries. Technical Manual*, *6*, 126.

Ntale, H. K., Naturinda, D. N., Rubarenzya, M. H., & Kyamugambi, K. (2005). The rainwater harvesting strategy for Uganda.

Pacey, A., & Cullis, A. (1986). Rainwater harvesting. *The collection of rainfall and runoff*.

Parsons, D., Goodhew, S., Fewkes, A., & De Wilde, P. (2010). The perceived barriers to the inclusion of rainwater harvesting systems by UK house building companies. *Urban Water Journal*, *7*(4), 257-265.

Sapkota, M., Arora, M., Malano, H., Moglia, M., Sharma, A., & Pamminger, F. (2018). Understanding the impact of hybrid water supply systems on wastewater and stormwater flows. *Resources, Conservation and Recycling*, *130*, 82-94.

Search for Wetter Lands. Retrieved on December 12, 2020 from: www.gwiwater.org

Search for Wetter Lands. Retrieved on December 12, 2020 from: www.gwiwater.org

Sheikh, V., (2020). Perception of domestic rainwater harvesting by Iranian citizens. Sustain. Cities Soc. 60, 102278.

Smets, H. (2009). Access to drinking water at an affordable price in developing countries. *Options Méditerranéennes, A n°, 88*.

Suzenet, G., Tal, A., & Boymanns, D. (2002). Sustainable water management for the city: technologies for improving domestic water supply. *Built Environment (1978-)*, 138-151.

UNEP (2015). United Nations Environmental Programme Annual Report 2015.

UNESCO (2018). UN World Water Development Report, Nature-based Solutions for Water. Retrieved on 10th September, 2019, from: https://en.unesco.org/commemorations/worldwaterday/2018

WHO/UNICEF (2017). Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2017. https://doi.org/10.1111/tmi.12329

World Health Organization. (2019). National systems to support drinking-water: sanitation and hygiene: global status report 2019: UN-Water global analysis and assessment of sanitation and drinking-water: GLAAS 2019 report..