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Effects of Rainwater Harvesting Technologies on Sustainable agricultural Production in Ntutsi and Mijwala Sub-counties, Sembabule District

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Abstract

Despite the benefits of rainwater harvesting technologies on enhancing sustainable agricultural production, farmer still face the number of huddles in implementing such technologies like lack of knowledge, limited space, and limited capital and among others. Rain water harvesting technologies were thought of to sustain agricultural production but its relevance among farmers remains un-documented. The study was about the effects of rainwater harvesting technologies on sustainable agricultural production in Ntutsi and Mijwala Sub-counties, Sembabule District. The specific objectives were to; ascertain the methods of rain water harvesting use for sustainable agricultural production, identify the benefits of rain water harvesting technologies on agricultural production, identify the factors influencing the adoption of rain water harvesting technologies and investigate the challenges faced in implementing water harvesting technologies. The study adopted a cross sectional survey design. Data was collected from 248 farmers. Data management and analysis was done using SPSS version 20 to generate both descriptive and regression statistics. The study identified different rain water harvesting methods use for sustainable agricultural production such as; ridges/tied ridges/furrows, water pans/ponds, sand dams and sub-surface dams as well as rooftop catchments. The study also discovered that technologies like ridges/tied ridges/furrows (x^2 = 8.305, p=0.005), road runoff water harvesting (x^2 = 6.048, p=0.001), and a combination of practices (x^2 = 4.120, p=0.042) had a significant influence on agricultural production. The study also confirmed that gender [AOR = 2.569; (95% CI: 1.239 - 5.327); p = 0.011], level of education [AOR = 1.441; (95% CI: 0.656 - 3.164); p = 0.003], and farm size [AOR = 2.060; (95% CI: 1.021 - 4.154, p = 0.044] were the significant factors influencing the adoption of rain water harvesting technology for sustainable agriculture production in the area.

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The study further confirmed that unavailability of labour [AOR = 0.978; (95% CI: 0.169 - 54.570, p = 0.001), lack of knowledge on water harvesting [AOR = 0.333; (95% CI: 0.104 - 34.088, p = 0.005], were some of the challenges faced in the implementation of rain water harvesting technologies. It therefore recommends that farmers be linked to financial institutions since they do not have the capital to invest in RWHTs. This will enable farmers to adopt not only one but many RWHTs.

Keywords: rain water harvesting technologies; sustainable agricultural production; Sembabule; and Uganda.

1. Introduction

Globally, agriculture continues to be a fundamental instrument for sustainable development and agricultural production, [1]. yet, ‘rain water harvesting technologies remain pervasive, costly and inequitably distributed, severely limiting farmer’s ability to compete in global supply and production markets’ ([2, 3]in his study on the potential of rainwater harvesting to reduce pressures associated with poor rainfall patterns and water shortage, showed that there are significant opportunities available to upgrade rain-fed agriculture also in water scare savannah agro-systems. He stressed the need for strong attentions directed to upgrading rain fed agriculture amongst the smallholder farmers. Upgrading rain-fed agriculture in Arid and Semi-Arid Lands especially in ‘developing’ countries requires a focus on rainwater management targeting drought and dry spell mitigation ([4]).

In Africa, rain water harvesting technology therefore has the potential of contributing to mitigate rainfall fluctuations, and thereby stabilize yields over time and increase overall yield levels [5]. He further pointed out that water harvesting is an important but not exclusive tool to achieve sustainable increase in agricultural productivity in Semi-Arid and dry humid savannahs. It needs to be integrated with other management strategies particularly soil fertility management, but also tillage, timing of operation, pest management and choice of cropping systems.

In Sub-Saharan Africa, rainfall is the major source of agricultural water supply for most of the subsistence farming system ([6]). However, its distribution is unreliable particularly for the semi-arid and dry sub humid areas that crop production as well as animal rearing has become risky enterprise and the lives of the people extremely precarious because people’s lives depends on animal and crop enterprises. National governments and international organizations have been picking up one and throwing another approach to ensure the reliability of the availability of water for agriculture [7].

Critchley, [8]indicated that there are successful situations of rain water management programs as part of sustainable land management to increase in-situ water availability and increase aquifer recharge in the Blue Nile River Basin.

Ugandan economy is agricultural-based and it has been demonstrated that access to rain water management interventions can reduce poverty levels by approximately 22% [9]). These interventions can also provide a buffer against production risks associated with increasing rainfall variability due to climate change. While various studies have highlighted the potential of rain water management interventions to increase agricultural productivity and improve livelihoods in Ethiopia, in practice adoption rates of these interventions remain low. Rainwater harvesting systems that is on cropland water conservation to enhance soil infiltration and water holding capacity tends to dominate [10]

This paper indicates that even though rainwater harvesting practices can yield positive results through effective increase of soil moisture for crops in water scarce areas, each system still has limited scope due to hydrological and socio-economic limitations that make agricultural production unsustainable in Uganda [11]. The limitations revolve around practiced farming systems, population pressure, formal and informal institutions, land tenure, economic environment and social structures [12]

2. Statement of the problem

Poor distribution of rainfall due to dry spells together with low nutrient input during critical crop growth stages lead to low yields or crop failure; hence there is a need for dry spell mitigation by improving water productivity through water harvesting in Sub-Saharan Africa ([13].

In Uganda, serious food shortages due to unsustainable agricultural production has been attributed to erratic rain fall received in several rural parts of Uganda as a result of crop failure due to dependence on rain fed agriculture and this is sometimes caused by limited knowledge on utilization of rain water harvesting technologies among smallholder farmers ([14]).

In Ntutsi and Mijwala sub-counties, the only water resource available is rainfall as a local source and this is why utilization of rain water harvesting is extremely necessary but farmers have failed to realize that rain water harvesting could make agriculture production unsustainable ([15]). This had prompted the researcher to carry out a study on the effect of rainwater harvesting technologies on sustainable agriculture production In Ntutsi and Mijwala sub-counties, Sembabule district.

3. Research objectives

The overall objective of the study was to investigate the effects of rainwater harvesting (RWH) technologies for sustainable agriculture production in Ntutsi and Mijwala sub-counties, Sembabule district.

The specific objectives were to; to ascertain the methods of rain water harvesting for sustainable agricultural production, to identify the benefits of rain water harvesting technology on sustainable agricultural production, to identify the factors influencing the adoption of rain water harvesting technology for sustainable agriculture production and investigate the challenges faced in implementing water harvesting technologies in the study area.

4. Conceptual framework

This is a three factor model that presents the relationship between the study variables as shown below;

Independent Variable **Dependent Variable**

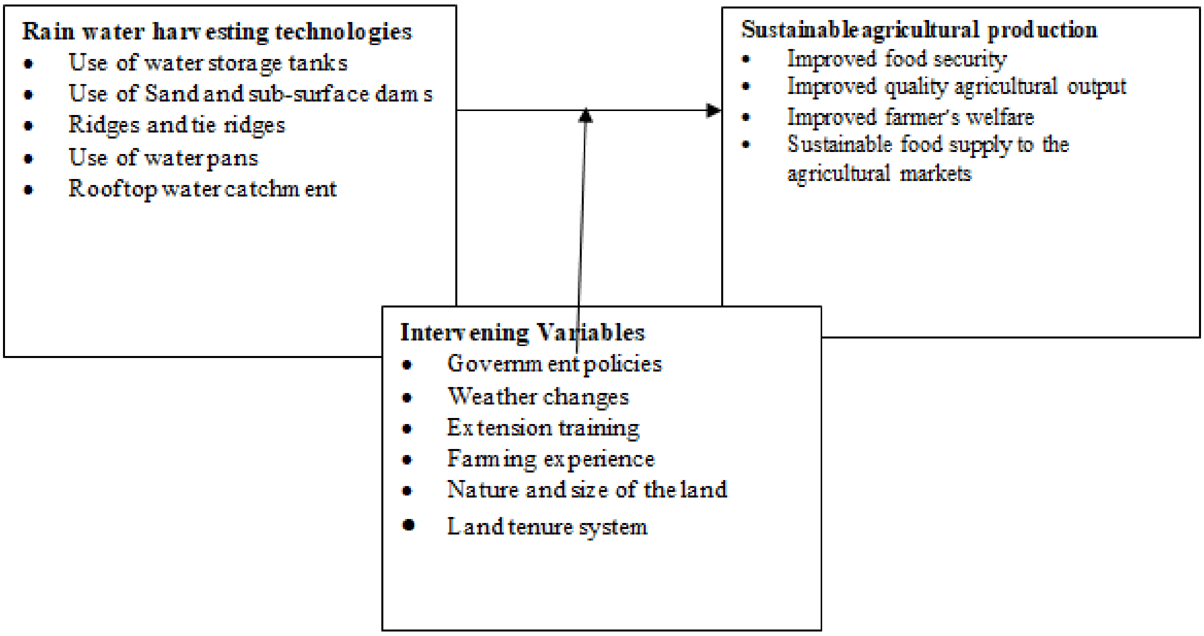

Figure 1

5. Methodology

The study was conducted on effects of rain water harvesting technologies on sustainable agricultural production in Ntutsi and Mijwala sub-counties in Sembabule district. Agriculture is the major economic activity of the people in district is agriculture with livestock and crop farming being the backbone of the area. The agro-climatic conditions in Sembabule present conducive environment for pasture growth which has favored the dairy sector all the year. The animals raised include: Ankole cattle, Exotic cattle breeds, Hybrid cattle - mixtures of exotic and Ankole breeds and crops grown included, maize, sweet potatoes, bananas, cassava, and among others. The area experiences two rain seasons that is from February - May and mid-August – October which has made hard for farmers to feed the animals during the dry seasons. The area experiences lengthy dry periods than the wet periods. During the rainy season, grazing pastures are in plenty, crop production is always at the peak, however in the dry seasons farmers experience a sharp decline in agricultural production.

A cross-sectional survey design employing qualitative and quantitative approaches was used to capture information from farmers and other key informants. This approach enabled the researcher to study a single discrete social unit) in depth. It also enabled flexibility by giving him an opportunity to deeply understand the respondents' opinions.

A sample of 248 respondents (including utilizers and non-utilizers of rain water harvesting technologies) was selected using single population proportion formula with 95% level of confidence and 5% margin of error. Other key informants were selected on purpose. The sample size for the study was determined by using simple random table developed by Krejcie and Morgan 1970.

The sample population was selected using simple random sampling and purposive sampling. Simple random sampling was used specifically for farmers who were involved in the rainwater harvesting and those farmers that had not adopted the technology. Purposive sampling was used for key informants who were limited to extension workers and local leaders simply because they were believed to be having adequate technical information about the study.

A semi-structured questionnaire was used to collect quantitative data from different farmers. The questionnaires were checked for completeness, coded and entered into SPPSS version 21 software package for cleaning and analysis. Interviews were used as a tool for qualitative data.

The data collection through questionnaire was analyzed using Excel and SPSS computer program. Both descriptive and regression statistics were generated and used to interpret the study findings. All the results were presented in tables.

6. Results

Table 1: Socio-demographic description of the respondents (n=248).

Variable	Category	Frequency	Percentage
Gender	Male	151	60.9
	Female	97	39.1
Marital status	Never married	64	25.8
	Married	163	65.7
	Widowed	05	02
	Divorced	16	6.4
	Minimum	Maximum	Mean ± SD
Age in years	17	69	35.84 ± 8.229
Educational in years	2	16	10.72 ± 4.169

According to the findings in Table 1 above, more than a half (60.9%) of the respondents were male and 39.1% were female. Results also indicated that the majority of the respondents were married 65.7%, and 25.8% were single, 6.4% were divorced and 2% were widowed. Mean age distribution among respondents were 35 years with the youngest aged 17 and the oldest 69.

Most respondent's surveyed belonged to productive age of 27 - 35 years which is a young vibrant productive group hence justifying their active involvement in agricultural production to sustain their livelihoods. Average number of years in school were ten (senior three) with a minimum of two and a maximum of 16 years (university degree). A bigger part of the study respondents had attained secondary education.

Table 2: Common rain water harvesting methods adopted in the study area (multiple responses).

	Category	Frequency	Percent
Valid	Water pans/ponds	63	17.3
	Ridges/tied ridges/furrows	80	22
	Road runoff water harvesting	105	28.8
	Underground water storage tanks	31	8.5
	Sand dams and sub-surface dams	49	13.5
	Rooftop catchments	36	9.9
	Total	364	100.0

As can be seen from table 2. Majority (28.8%) of the respondents mentioned road runoff water harvesting, 22% talked of ridges/tied ridges/furrows, 17.3% water pans/ponds, 13.5% talked of sand dams and sub-surface dams, 9.9% talked of rooftop catchments while the least number of respondents 8.5% talked of underground water storage tanks.

Table 3: Benefits of rain water harvesting technology on sustainable agricultural Production in the study area (multiple responses).

	Category	Frequency	Percent
	Supply of water for irrigation	55	17.7
	Support livestock life and survival	48	15.5
	Support of crop growth and survival	89	28.7
	Soil moisture and water conservation	67	21.6
	Enrichment of soil with nutrients	51	16.5
	Total	310	100.0

As indicated in table 3 above, 28.7% of the respondents quoted that rain water harvesting technologies are sources of water that supports crop growth and survival, 21.6% stated that they back up soil moisture and water conservation, 17.7% revealed that they supply water for irrigation mainly in dry periods, 16.5% said they enrich soil with nutrients and 15.5% stated that they provide water for animal life and survival.

Table 4: Correlation matrix between rain water harvesting technologies and agricultural production.

	Agricultural production	
RWHTs	Chi-Square	p-value
Water pans/ponds	2.317	0.314
Ridges/tied ridges/furrows	8.305	0.005
Road runoff water harvesting	6.048	0.001
Underground water storage tanks	5.480	0.065
Sand dams and sub-surface dams	3.519	0.471
Rooftop catchments	4.985	0.026
Combination of practices	4.120	0.004

Results of the correlation analysis between rain water harvesting technologies and agricultural production measured at 5% level of probability are presented in table 4 were. At bivariate level, ridges/tied ridges/furrows

(x^2 = 8.305, p=0.005), road runoff water harvesting (x^2 = 6.048, p=0.001), rooftop catchments (x^2 = 4.985, p= 0.026), and a combination of practices (x^2 = 4.120, p=0.042) presented a significant association with agricultural production. Other technologies like water pans/ponds, underground water storage tanks, sand dams and sub-surface dams showed no significant association with sustainable agricultural production.

Table 4: Results of the logistic regression model of utilization of rain water harvesting technologies in relation to highlighted factors.

Variable	**Value**	**AOR (95% CI)**	**p-value**
Gender	Male	2.569 (1.239 - 5.327)	0.011
	Female	1	
Age	In years	0.856 (0.312 - 2.351)	0.763
Level of education	Years in school	1.441 (0.656 - 3.164)	0.003
Wealth status	Poor	0.384 (0.169 - .871)	0.022
	Rich	1	
Access to credit	Yes	0.509 (.241 - 1.079)	0.078
	No	1	
Labour	Yes	2.685 (1.507 - 4.782)	0.001
	No	1	
Household members' perception	Yes	0.882 (0.422 - 1.845)	0.738
	No	1	
Training and extension services	Yes	0.588 (0.367 - .940)	0.127
	No	1	
Farm size	In acres	2.060 (1.021 - 4.154)	0.044

Source: computer output (SPSS) analysis, 2021

As indicated in Table 5, nine factors were hypothesized and only five (5) variables remained statistically significant including; gender, level of education, wealth status, labour and farm size.

Gender of the household head increased the probability of adopting rain water harvesting technologies for sustainable agriculture production. Male headed households farmers were 2.6 times likely to adopt rain water harvesting technologies than female headed households [AOR = 2.569; (95% CI: 1.239 - 5.327); p = 0.011].

Level of education of the household head equally increased the log odds of the probability of adopting rain water harvesting technologies for sustainable agriculture production in the area. Educated farmers were 1.4 times more likely to adopt rain water harvesting technologies than the uneducated [AOR = 1.441; (95% CI: 0.656 - 3.164); p = 0.003].

Unlike education level, wealth status reduced the log odds of the probability of adopting rain water harvesting technologies for sustainable agriculture production by 0.384. Poor households were 0.4 times less likely to adopt rain water harvesting technologies compared to rich households [AOR = 0.384; (95% CI: 0.169 - 0.871); p = 0.022]. The earlier stated null hypothesis for wealth status was in this case rejected.

Labour availability increased the probability of adopting water harvesting technology adoption by 2.685. Households with access to labor were 2.7 times more likely to adopt rain water harvesting technologies compared to households without labour [AOR = 2.685; (95% CI: 1.507 - 4.782, p = 0.001]. The earlier specified null hypothesis that there was no significant association between labour and adoption of rain water harvesting technologies was rejected.

Farm size increased the log odds of the likelihood of farmers adopting rain water harvesting technologies for sustainable agriculture production by 2. Households with bigger pieces of land were 2 times more likely to adopt rain water harvesting technologies compared to those with fragmented plots [AOR = 2.060; (95% CI: 1.021 - 4.154, p = 0.044].

Table 5: Parameter estimates for the challenges associated with the implementation of water harvesting technologies.

Variables	Value	AOR (95% C.I)	P-value
Unavailability of labour	Yes	0.978 (0.169 - 54.570)	0.001
	No	1	
Knowledge on water harvesting technologies	Yes	0.333(0.104 - 34.088)	0.005
	No	1	
Inadequate capital	Yes	0.676 (0.150 - 76.330)	0.003
	No	1	
Lack of technical expertize	Yes	1.808 (0.818 - 28.267)	0.142
	No	1	
Lack of resources to use	Yes	2.122 (0.103 - 6.113)	0.235
	No	1	
Fragmented type of plots (small sized land)	Yes	0.943 (1.121 - 45.518)	0.001
	No	1	
Change in rainfall patterns	Yes	0.322 (0.103 - 3.514)	0.130
	No	1	
High maintenance costs	Yes	0.858 (0.218 - 3.267)	0.004
	No	1	

Source: computer output (SPSS) analysis, 2021

Results of the logistic regression model of challenges associated with the implementation of water harvesting technologies in Ntutsi and Mijwala sub-counties were presented in table 6.

The log odds explained the probabilities of the outcome as a result of a limiting explanatory variables. Significant challenges were interpreted at 95% confidence interval and 5% level of significance.

Of the eight (8) challenges postulated, only five (5) challenges remained significant and these included; unavailability of labour [p = 0.001], inadequate knowledge on water harvesting technologies [p = 0.005]. Inadequate capital, [p = 0.003]. Fragmented type of plots (small sized land) [p = 0.001] and high maintenance costs [p = 0.004].

7. Discussions

Results of the correlation analysis indicated that rain water harvesting technologies like ridges/tied ridges/furrows, road runoff water harvesting, rooftop catchments, and a combination of practices had a significant impact on agricultural production in Ntutsi and Mijwala sub-counties. A positive and significant correlation was observed between using ridges/tied ridges/furrows in harvesting rain water and agricultural production at 5% level of significance. This implied that an increase in the volume of water harvested through ridges/tied ridges/furrows increased production by 8.3 units. This study finding is in agreement with [16]) who pointed out that micro-catchment practices have a high potential for combining water harvesting with soil conservation. Micro-catchment rain-water harvesting, provides a good means for changing from soil conservation based on just runoff control to integrating soil water conservation and water harvesting for sustainable agricultural production.

Combining different rain water harvesting technologies had a positive significant relationship with maize production and yields at 5% level of significance. A unit increase in water harvested through a combination of different water harvesting technologies positively increased agricultural production by 4.12 times at (p-value = 0.004). This study finding was comparable to findings by [17]which stated that rainwater harvesting uses a wide range of techniques for concentrating, collecting and storing rainwater and surface runoff for different uses by linking a runoff producing area with a separate runoff-receiving area. In this sense, RWH collects rainwater runoff and stores it for future use, be it for agricultural, domestic or drinking purposes. As such, RWH encompasses all RWH techniques that collect and harvest runoff from roofs or ground surfaces.

Results of study also indicated that there are factors influencing the adoption of rain water harvesting technology for sustainable agriculture production in Ntutsi and Mijwala sub-counties. Nine factors were identified and only five (5) variables remained statistically significant including; gender, level of education, wealth status, labour and farm size.

Level of education of the household head equally increased the log odds of the probability of adopting rain water harvesting technologies for sustainable agriculture production in the area. Educated farmers were more likely to adopt rain water harvesting technologies than the uneducated. This is because education is very critical in technological adoption and use, production decision making and information seeking behavior of the farmers. This study finding was in agreement with ([18]) who revealed that education increase farmers‟ ability to obtain, and analyze information that helps him to make appropriate decision. Many empirical evidences indicate that the higher the level of education, the greater is the possibility for farmers to become aware of the uses of water harvesting practices for securing food self-sufficiency. Wealth status reduced the log odds of the probability of adopting rain water harvesting technologies for sustainable agriculture production. Poor households were less likely to adopt rain water harvesting technologies compared to rich households. Poor households on the hand prefer either not to adopt the rain water harvesting techniques or adopt the less expensive ones. This study finding concurs with [19]who argued that low-wealth farmers are often reluctant to adopt technologies because they need stable income especially when the returns to adopt are unclear or will only bear fruits in the future.

Labour availability increased the probability of adopting water harvesting technology adoption. Households with access to labor were more likely to adopt rain water harvesting technologies compared to households without labour. From the findings, majority of participants reported rainwater harvesting technology as a tedious task and labour demanding in terms of construction. This study finding concurs with Araya, [20]) who stated that farmers can reject newly introduced soil and water conservation technologies even when they are aware that adoption of the measures protects and improves productivity of their lands depending on several socioeconomic and institutional factors that can be barriers to technology adoption. Farm size increased the chances of farmers adopting rain water harvesting technologies for sustainable agriculture production. Households with bigger pieces of land were more likely to adopt rain water harvesting technologies compared to those with fragmented plots. This is because with a large farm size, a farmer could experiment new technologies on a portion of land without worrying about endangering the family food security. This study finding is in agreement with [21]who mentioned that rain water harvesting technology requires land, one of the scarcest resources, for runoff generation and storage construction. His study revealed the positive and significant impact of farm size on utilization of rain water harvesting technology.

The study further identified different significant challenges faced in implementing water harvesting technologies. Significant challenges were identified at 95% confidence interval and 5% level of significance. Of the eight (8) challenges postulated, only five (5) challenges remained significant and these included; unavailability of labour, inadequate knowledge on water harvesting technologies, inadequate capital, fragmented type of plots (small sized land) and high maintenance costs. Unavailability of labour was a significant challenge associated with the implementation of rain water harvesting technologies for sustainable agriculture production. From the findings, majority of participants considered the rainwater harvesting technology to be a tedious task and yet most households studied comprised of fewer members. This study finding concurs with [22]who stated that usually labour requirements for rain water harvesting structures are high. Despite the effectiveness of some water conservation techniques, adoption by farmers has been poor mainly because of several factors among them high labour intensity.

Knowledge on water harvesting technologies presented as significant challenge towards the implementation of rain water harvesting technologies for sustainable agriculture production. Farmers with low knowledge on water harvesting technologies were less likely to implement water harvesting technologies compared to those with knowledge. This finding is in line with [23]who argued that despite the effectiveness of some water conservation techniques, adoption by farmers has been poor mainly because of several factors among them is poor knowledge on water harvesting technologies.

Inadequate capital was a significant predictor in farmer’s implementation of rain water harvesting technologies for sustainable agriculture production at 5% level of significance. Using rain water harvesting technologies for agricultural production require a lot of investment in terms of materials, labour and equipment used in construction which most households in the study area may not afford. This study finding concurs with [24]who argued that low-wealth farmers are often reluctant to adopt technologies because they need stable income especially when the returns to adopt are unclear or will only bear fruits in the future.

Farm size had a significant influence on farmer's implementation of rain water harvesting technologies for sustainable agriculture production at 5% level of significance. Farmers with fragmented type of plots (small sized land) were less likely to implement RWHTs. High maintenance costs acted a significant challenge in farmer's implementation of rain water harvesting technologies at 5% level of significance. The higher the costs, the lower the chances that implement RWHTs. To support this findings [25]argued that in spite of having willingness to pay, people may not be able to install rainwater harvesting system because of lack of affordability. The question of affordability arises particularly when the focus group is low income people. [26]in his study also mentioned that high costs of maintenance are a problem faced in the implementation of rainwater harvesting in developing countries. This threatens the sustainability of many rainwater harvesting projects.

8. Conclusion

The study confirmed that road runoff water harvesting, ridges/tied ridges/furrows, water pans/ponds, sand dams and sub-surface dams, rooftop catchments and underground water storage tanks are the common rain water harvesting methods adopted in Ntutsi and Mijwala sub-counties. The study also concludes that there is a significant relationship between specific rain water harvesting technologies and sustainable agricultural production. For example road runoff water harvesting technology increased agricultural production by 6 times at p-value of 0.001. These technologies were beneficial in supplying water which supports crop growth and survival, soil moisture and water conservation, water for irrigation in dry periods as well as water that supports animal life. The study concludes that gender of the household head, level of education, wealth status, labour availability and farm size are the key significant factors influencing the adoption of rain water harvesting technology for sustainable agriculture production in Ntutsi and Mijwala sub-counties. The study further concludes that unavailability of labour, lack of knowledge on water harvesting, inadequate capital, farm size and high maintenance costs are the main significant challenges faced in implementing water harvesting technologies in the study area.

9. Recommendations

There is need for constructing community owned water harvesting facilities to heighten community ownership of the projects than depending on individually owned water harvesting projects which are not sustainable.

There is a need to link farmers to financial institutions because farmers do not have the capital to invest in rain water harvesting technologies.

Relevant agencies should put more emphases on education and awareness creation to increase the adoption of reliable and sustainable water harvesting practices. Farmers need to be educated about the importance of rain water harvesting technologies in sustainable agriculture production. Provision of incentives to companies/agencies that are embracing and promoting rain water harvesting technologies is paramount.

Capacity building is needed to empower farmers with necessary skills and knowledge required in utilizing rain water harvesting technologies for agricultural production. This can be achieved through periodical education and training arrangements at both household and community level.

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References

[1] P. Lameck, Water harvesting technologies, Nairobi Kenya, 2012.

[2] Barry et al., Global suppy and production of markets, kenya, 2015.

[3] Rockström, Rainwater Harvesting, germany, 2012.

[4] Gatundu, Rain water management, Kenya, 2013.

[5] E. E., traps and transformation, sub sahara Africa, 2009.

[6] N. Hatibu, Economics of rain water harvesting, dodoma Tanzania, 2012.

[7] A. a. C. W. Braul, Conservation farming, Zimbabwe, 2011.

[8] C. R. a. A. S. W., Water Harvesting for plant production, sub sahara Africa, 2012 .

[9] H. (Kutch, Principle of forms of water concentrating culture, Germany, 2012.

[10] Kihara and Muni, Evaluation of RainWater harvesting system, Nairobi, 2012.

[11] 2. Kihara and Muni, Evaluation of rainwater harvesting system, Nairobi, 2012.

[12] C. Gatundu, Policy legislative framework for community based natural resojurce management, Nairobi, 2013.

[13] Komariah and Masateru, Water productivity and water harvesting, Sub-Saharan Africa, 2013.

[14] Mugerwa, Harvesting technologies, south Africa, 2010.

[15] Thomas, Agricultre production unsustainable, Kenya, 2011.

[16] Kimeu, Micro rain water Harvesting, Kenya, 2008.

[17] FAO, Irrigation water delivery Model, Roma Italy, 2013.

[18] G. P.H., Technological Adoption, Kenya, 2016.

[19] J. Rockstrom, Water harvesting upgrading, kenya, 2011 .

[20] C. a. G. K. ,. Gachene, Soil fertility and land production, Sweden, (2013.

[21] D. Kirori, Ground Water development, Kenya, 2017.

[22] Gleick P.H., Basic water requirements, Kenya, 2016 .

[23] P. 2. Kimeu, Community surface water harvesting, kenya, 2008.

[24] Muni., Evaluation of water harvesting system, Kenya, 2012.

[25] Nyabenge., Rain harvesting potential, Kenya, 2016.

[26] D. Mburu, Role of sand dam in water supply, kenya, 2013.