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Contribution of Run-off Water Harvesting to Food Production in Kyannamukaaka Sub County, Uganda

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Abstract: *Surface run-offs continue to flow away from crop fields into wetlands, rivers and lakes. The paper examines the contribution of run-off water harvesting to food production including; identifying the techniques farmers use to harvest run-offs, assessing the benefits of harvested run-offs to farmers and investigating the limitations to harvest and use of run-offs by farmers in Kyannamukaaka Sub-County, Uganda. The paper employs a cross-sectional survey design, targeting 130 people from whom 98 respondents were selected. Data was collected through questionnaires, interviews and observations, and analyzed using SPSS. Results indicate tarpaulin (94.9%), contours (99%), mulching (96.9%) and in-field water harvesting (92.9%) as run-off harvesting techniques. Provision of water for irrigation (96.9%) and domestic animals (99%), increased food production (100%) and animal productivity (91.8%), and incomes (87.9%) are the benefits of run-offs. Finally, inadequate incomes (94.9%) and experts in sewing (94.9%), increased costs of input/material (90.8%), and inadequate government support (99%) were the limitations to run-off harvesting. The paper concludes that, farmers must harvest run-offs for sustainable agricultural production. The paper recommends that Kyannamukaaka Sub County should create awareness, sensitization and build capacity of farmers in runoff water harvesting and sewing polythene-line technology, and government should support the farmers through subsidies on run-off water materials.*

Keywords: *Climate change, Drought, Livelihoods, Run-offs, Subsidies*

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1. Introduction

Rural communities all over the world have been harvesting rainwater when it falls (United Nations [UN], n.d). However, water scarcity lowers the agricultural yields and prohibits farmers to succeed in their agricultural ventures (Practical Action, n.d, p.1; Nijhof *et al.*, 2010). This affects their wellbeing and food security of people both in rural and urban areas, and further slows down the development and economic growth on national and regional level (Aroka, 2010; Ibraimo & Munguambe, 2007). East African region is one of the most severely hit region on the African continent by the changing weather patterns, and farmers in the region have resorted using various practices to harvest and store the run-off water to sustainably manage the changing climates (FAO, 2016; Ngumbi & Dindi, 2018).

FAO (2016) indicates that, Uganda is endowed with two rainfall seasons in a year. Unfortunately, the surface run-offs water from such rains has not been tapped for efficient use by farmers in rural areas to enhance agricultural production (Ibid.). This means that, prolonged droughts and dry spells coupled with inadequate knowledge in run-off water harvesting and storage continue to menace agricultural production in rural areas, causing food insecurity, poverty, malnutrition, death and underdevelopment (Ngumbi & Dindi, 2018; Njarui *et al.*, n.d).
The prolonged dry periods extend their adverse impacts to various districts Njarui *et al.*, n.d; Ngumbi & Dindi,

(2018) such as Masaka where Kyannamukaaka Sub County in located. The water sources are very limited in this area, and where they exist, they cannot supply enough water to support the economic activities of the locals (Kato, 2018; URN, 2012). Due to insufficient water supplies, women and children have to move longer distances to fetch water, whereas those involved in farming have resorted to cultivating in wetlands during the prolonged dry seasons and growing crops on the mainland only in the rainy season (Ibid). As Han (2006) argues, as rains become more infrequent and unpredictable, new measures in the management of rainwater are essential. Run-off water harvesting provides one such adaptation technique. Efficient run-off water harvesting during the rainy seasons ensures available water for the farming activities during the prolonged dry spells. This paper assesses the techniques smallholder farmers use in harvesting run-off water and in reusing it in food production as their primary measure to ensure food security in Kyannamukaaka Sub County, Masaka region.

2. Literature Review

There is a considerable amount of previous research related to run-off water harvesting. These studies focus mainly on different harvesting techniques, effects of run-off water harvesting on small-holder farmers, and limitations to harvesting and use of run-off water.

2.1 Techniques farmers use to harvest run-off water

The previous studies identify multiple run-off water harvesting techniques. These include a simple banana planting pit, road water harvesting banana plantation pits, storage/diversion measures, contour farming, planting cover crops or green manures, use of mulch, and in-field rainwater harvesting (International Development Program [IDP], n.d; Ibraimo & Munguambe, 2007).

Water harvesting for banana plantations is an in-situ water harvesting technique, which was implemented through the Farmers Field Schools (FFS) approach in the Mbarara District to improve soil moisture retention and soil fertility (Ibraimo & Munguambe, 2007; Malesu, 2018). Two types of techniques are used: (1) a simple banana planting pit; and (2) road water harvesting banana plantation pits.

The first technique, simple banana planting pits, these are free standing water harvesting structure are constructed to tap and collect the run-off water (IDP, n.d). With such techniques, small pits are dug measuring 10-30cm in diameter and 5-15 cm deep with a distance of 1 meter apart. The techniques commonly in areas with low rainfall (350-750mm) but with deep soil (Ibid). The pits catch run-off and concentrate soil moisture around the roots. Further stated that, the techniques are suitable in gently sloping lands.

The second technique, road water harvesting banana plantation pits, implies that rainwater is harvested from the road surface, whereby the road drainage is used to convey the water for storage or recharge. During heavy rains, the nature of many roads becomes apparent: they intercept surface run-off and generate streams on their relatively compact surfaces (Salman et al., 2016). The location of the road in relation to contour lines, the height of the embankment, the longitudinal and lateral slope of the road, the surface material and the under drainage are all important factors in determining how much run-off is generated from a road and hence how water can be retained (van Steenbergen and Tuinhof, 2010).

Storage/diversion measures, such as small water ponds, valley tanks and water harvesting from roads emerged as the strongest technologies (GoU, 2017). These measures have great scope in providing supplementary water for agricultural production in Uganda during the dry seasons, as well as during the common dry spells in the wet season (Ibraimo & Munguambe, 2007). Water harvesting ponds can be designed in various shapes, materials and dimensions such as, circular, square and rectangular ponds (Knoop *et al.,* 2012; Malesu, 2018, GoU, 2017). Water is collected in the pond by channeling it from surrounding fields, ephemeral streams, paved surfaces (paths, roads), channels (cut-off drains) or naturally sloping surfaces. They are usually constructed near homesteads for easy access.

Contour farming, in turn, involves aligning plants in rows and tillage lines at right angles for normal flow of run-off. It creates detention storage in the soil surface horizon and slows down the run-off, thus, giving water time to infiltrate into the soil (Ibraimo & Munguambe, 2007). Contour ridge is a micro-catchment technique which consists of making ridges following the contour at a spacing of 1.5 to 2 meters. This means that a ratio between catchment and cultivated area ranges from 2:1 to 3:1 respectively (Haile & Merga, 2002; Malesu, 2018). Run-off is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges, and crops are planted on both sides of the furrow. Contour bunds are small structures that control erosion, improve infiltration and improve crop yields (Knoop *et al.*, 2012). The bunds are usually built on hillsides along contours. Contour bunds reduce the speed of run-off, which allows the water to infiltrate, thus improving the soil moisture (Ngumbi & Dindi, 2018). Contour bunds come in various designs, including stone bunds, soil bunds, tied ridges and stone face bunds.

Planting cover crops or green manures such as *Mucuna pruriens utilis, Pueraria phaseoloides, Centrosema pubescens, Setaria spp., Stylosanthes spp* and *Glicine spp* provide another technique of achieving in-situ mulch (Ibraimo & Munguambe, 2007; Malesu, 2018). For example, Alley cropping is a similar technique used in agroforestry system. It integrates trees and shrubs, which are pruned during the cropping season to provide in-situ green manure and to prevent shading of crops. The beneficial effects of the system in reducing erosion, surface run-off and soil moisture loss depend on the proper choice of the protective species. Promising results of maize production with *Gliricidia* and *Leucaena* have been obtained (Ibid).

Mulch, in turn, can be applied to the soil as a protective layer to manage the microclimate (Ibraimo & Munguambe, 2007; p.29). Mulch can be organic material (wood, hay, leaves, needles, shells) or artificial (plastic, geotextile). Different mulch types serve different purposes in different locations. In general, mulch is used to reduce water loss through evapotranspiration, suffocate weed growth, protect against heat and cold, and to add soil nutrients. Organic mulch in particular creates ideal conditions for beneficial microbes and insects (e.g. earth worms) that improve soil quality, while discouraging other insects such as slugs.

Finally, in-field rainwater harvesting technique is a micro catchment technique, Lesikar & Alexander (2017) which combines the advantages of water harvesting, no-till and basin tillage to stop run-off completely on clay soils (Hensley et al. as cited in Ibraimo & Munguambe, 2007). The technique consists of a catchment area which promotes in-field run-off and a cropped basin which allows the stoppage of ex-field run-off completely, maximizes infiltration and stores the collected water in the soil layers beneath the evaporation sensitive zone. Ridges are immediately done after each cropped basin to allow a better conservation of water in the soil profile. Mulch is placed in the cropped basin to minimize evaporation losses. The ratio between the catchment area and the cropped area, according to the field experiences with crops in the semi-arid areas, is about 2:1 (Rensburg van *et al.*, as cited in Ibraimo & Munguambe, 2007).

2.2 Effects of harvested run-off water to smallholder farmers

Ibraimo & Munguambe (2007) clarify that run-off rainwater helps to mitigate the effects of temporal shortages of rain to cover both household and productive use. Run-off water harvesting improves access to water for agricultural production thus increasing food security. Salman *et al.* (2016) state that, run-off water is required for the sustainable development of agricultural production by small-scale farmers and it ensures that crop yields improve the basic food needs for the population into the future. In areas where mulches are used, its beneficial effects include protection of the soil against raindrop impact, decrease in flow velocity by imparting roughness, and improved infiltration capacity (Ibraimo & Munguambe, 2007). Molden as cited in Salman *et al.* (2016) informs that managing the scarce rains through collecting run-off water is crucial for improving food security and livelihoods. In fact, the greatest potential increases in yield are in rain-fed areas where run-off water is harvested. Run-off water does not only prevent flooding but also reduces the effect of drought with rainwater being conserved for immediate or future use (Contreras, Sandoval & Tejada, 2013).

GoU report (2017) indicates that, soil and water conservation practices increased water infiltration in the soil hence favourable crop growth. This ensured better production and improved livelihoods for the households. Additionally, stored run-off in the valley tanks when put into effective use, enhances increased productivity of the soils, thus creating sustainable increased incomes from the sale of the agricultural products. Such systems have been demonstrated in Kinoni and Nansimbi, Kiganda Sub-County, Mubende District (GoU, 2017). Njarui et al. (n.d) assert that, water harvesting from surface-run off ensured year-round increased supply of vegetable yields and household income by up to 500%. They add that, this water source is used for human use, livestock and crop production. Researchers add that, *to make it useful for animals like cows and pigs, it should be purified through the use of Moringa powder, ash, and charcoal dust.*

2.3 Limitations to harvesting and use of run-off water

The main limitations to harvesting and use of run-off water derive from lack of knowledge and appropriate technologies, high costs of run-off water harvesting, and lack of government support and supportive policies. Malesu (2018) reports that farmers do not have the technical knowledge to place and build run-off rainwater harvesting structures, thus limiting their capacity to harvest and use the run-off water. Contreas, et al. (2013) provide a similar example from Bangladesh, where rainwater from the roofs and other sealed surfaces during heavy rains has led to accumulated flooding in urban areas, when the drainage system was not properly designed. Malesu (2018) further reports that, financing is also a challenge, since farmers often cannot afford to invest in rainwater harvesting. In cases where a farmer is to use modern technologies to harvest the run-off, accessing materials such as lined-polythene, and sewing and installation, imply high costs. For example, in Kenya, a 250 cubic metre system and providing irrigation for three months on a one-acre piece of land costs USD $3,000 (Ibid.).

Inadequate policies and lack of government support are barriers to smallholder farmers who would wish to harvest run-off for future use (Malesu, 2018). Stronger support is needed from national and local governments for both rooftop and run-off water harvesting techniques (Ibid.). Malesu (2018) claims that rainwater harvesting, and roof water harvesting in particular, were prohibited in Nairobi, Kenya, since it was seen as competing with the Nairobi water company earning income from selling water.

3. Methodology

3.1 Research design

The study employed a cross-sectional survey design to assess effect of run-off water harvesting to food production in Kyannamukaaka Sub County. The design was used to assess the adjustments to the smallholder farmers and community members to yields a large amount of data at one point in time from a sizeable population in an economic way. Thus, this enables the researchers to generalize results for entire population.

3.2 Study population and Sample size

The study population included 130 smallholder farmers using various techniques for run-off water harvesting. The researchers used Sloven's formula to calculate a sample of 98 respondents who participated in the study as shown below:

$$n = \frac{N}{1+N(\alpha)^2}$$

Where; n = sample size; N = target population; $\alpha = 0.05$ level of significance.

N = 130

α =0.05 level of significance

$$n = \frac{130}{1+130(0.05)^2}$$

n = 130÷1+ (130*0.05^2)

n= 130÷1+ (130*0.0025)

n=130÷1+0.325

n=98.11

A sample of 98 respondents participated in the study

Purposive and simple random sampling techniques were employed to select the participants. Purposive sampling technique was used to select participants with the specific information the researcher wanted, whereas simple random sampling technique gave a chance of each member to be selected and participate in the study

3.3 Data collection

Data was collected through questionnaire, interview and observation. Data was collected on the techniques, effect of harvested run-off water and limited to the use and storage of harvested run-off water by smallholder farmers in Kyannamukaaka Sub County, Uganda. Interviews were used to collect a wide range of data from specific respondents. On the other hand, activities undertaken by smallholder farmers using run-off water for e.g., food crops, fodders and trees, were observed in Kyannamukaaka Sub County. A questionnaire was administered to those who could read and write to collect data in the shortest time possible.

3.4 Reliability and validity

Content validity index was used to test for validity of the questionnaire (CVI > 0.50 for both experts) and Cronbach alpha coefficient was used to test for reliability (Cronbach alpha >0.60 for all variables).

3.5 Data analysis

Qualitative data was transcribed and edited to attached meanings. Data was later coded and entered into the computer and analyzed using MS Excel to generate frequency tables from which presentation, interpretation and analysis was made. This is supported by Komp & Tromp (2006) who explain that, content analysis examines the intensity with which certain words used. This implies that the total responses from instruments were classified and recorded into pragmatic content matrix to aid the analysis.

3.6 Ethical considerations

Cohen *et al.* (2007) emphasize that research deals with human beings, and researchers have a responsibility to recognize and protect the rights and will of the participants. The authors ensured not to cause any harm to the participants, and they were guaranteed with anonymity, confidentiality and disclosure. Authors ensured voluntary participation and both the authors and participants had to sign a consent before they participated in the study. This further ensured that knowledge and truth was employed to errors in the study.

4. Results and Discussion

The purpose of this study was to examine the techniques commonly used by farmers in Kyannamukaaka Sub County, Masaka to harvest run-off water and the results are represented in the next sections.

4.1 Techniques for run-off water harvesting

The paper examined the techniques commonly used by farmers to harvest run-off water as indicated in Table 1:

Table 1: Techniques commonly used by farmers to harvest run-off water

Techniques	Frequency (n=98)	Percent
Tarpaulin/Tundubaali	93	94.9
Mulching	95	96.9
Roadside trapping	57	58.2
In-fed rainwater harvesting	91	92.9
Planting cover crops	79	80.6
Contours	97	99.0
Tree planting	80	81.6

Source: Primary Data, 2019

Results in Table 1 indicate that, majority of the respondents (99.0%) reported contours as the major approach farmers use to harvest water run-off in the study area. This was followed by mulching (96.9%), tarpaulin (94.9%), and in-fed rainwater harvesting (92.9%). Additionally, respondents indicated tree planting (81.6%) as an approach for water harvesting, which was followed by planting cover crops (80.6%) and roadside trapping (58.2%). This implies that, the respondents had knowledge and were using a number of techniques to harvest and store run-off water in their farmlands.

Contours were the major approach for harvesting run-off water by the farmers in Kyannamukaaka Sub County. The contours not only trap and store water for crop intake, but a technique for soil erosion control. The respondents asserted that, they plant grass species and crops on the sides of the contours to control the gravitational flow of the water and soil. The common plants grown include; Rhodes grass, Lemon grass, *Callindra calothyrsus*, *Tithonia diversififolia*, Cocoyam (obukopa), elephant grass, *Sesbania sesban*, and *Mucuna pruriens*. Knoop *et al.* (2012) agree with the results and affirm that, the grass on the contours helps to filter sediments, mitigate excess run-off, and reduce flooding. It was revealed that, these plants grown on the contours provide fodder for animals, birds; spices for tea and food for the households. They are also used as mulches which control and protect moisture and water loss from the soil due to prolonged dry spells which commonly occur in the area. This is supported by Knoop *et al.* (2012) who state that, grass strips slow run-off by increasing surface roughness and improving water infiltration into the soil, whilst also gathering fertile soil sediments.
One of the respondents reported that,

> *…I use contours to harvest water for my bananas and coffee, and this water is used slowly by the plant, that is why you can see my coffee and bananas are looking good. I also planted elephant grass, Callindra calothyrsus, and Russian comfrey which help me to get more milk and eggs from cows and birds respectively.*

Additionally, respondents also indicated that, they were practicing mulching as a strategy for run-off water harvesting in Kyannamukaaka Sub County. Mulching prays a key role in soil and water conservation in the soil. Ibraimo & Munguambe (2007; p.29) clarified that, mulches are applied to the soil as a protective layer to manage the microclimate. This implies that, a well mulched gardens have flourishing crops, and, and the farmer benefits from high yields, hence, more incomes. In reference to contours, the farmer who practices both technologies achieves more. Therefore, when the mulches rot, they add humus and hence improve soil fertility and increase land suitability and productivity. Ibraimo & Munguambe (2007) further stipulate that, organic mulches in particular create ideal conditions for beneficial microbes and insects, e.g., earth worms which improve soil quality, while discouraging other insects such as slugs. One of the respondents noted,

> *…when mulches are used, the soil is able to store water for a long time and release it slowly enhancing plant growth especially during dry periods. Farmers reported that, they use elephant grass, maize stalks (waste), dry banana leaves and Kikuyu grass as mulches.*

More so, respondents used tarpaulin as an approach for run-off water harvesting. This approach was used by farmers who had passion fruits, coffee and bananas gardens especially during the dry period. These water harvesting ponds can be designed in various shapes, materials and dimensions such as, circular, square and rectangular ponds (Knoop *et al.*, 2012; Malesu, 2018, GoU, 2017). When asked how the approach works, the respondents asserted that a pit measuring 8*4*6ft is dug, smeared with cow dung mixed with silt soils, and later a tarpaulin is placed. It was also revealed that, a small channel (route) is created to allow run-off water reach into the tank. Four square small boxes measuring 2*2ft are dug for every after 4ft to allow easy control of silt from reaching the tarpaulin (tank). Water collected into the tank is used for mixing herbicides and pesticides to be applied for weeds and pest-diseases control. It was also revealed that run-off water was given to animals, like cows, goats and pigs, though the main purpose was for irrigation of coffee and bananas during dry period. It was further reported that to minimize risk of accidents and malaria outbreak, the tanks are covered by strong poles, a polythene and black soil, which was then used for growing simple rooted crops.

Furthermore, the respondents had in-fed rainwater harvesting technique collecting run-off into their garden instead of being lost the swamp/bush. This technique was easy to use, since it requires only creating small channels to direct water into the gardens to support the plants. This is in agreement with Malesu (2018) who clarifies that, the system is useful in agricultural production where micro-catchments are used. The approach is suitable for bananas and coffee, and works best when integrated with the contour approach. This is an efficient approach as it carries water with all its constituents to the plants.

Planted tree and cover-crops were techniques commonly used by the farmers to harvest and store run-off water on their farmlands. Trees help to bind the soils together, thus minimizing soil erosion. Importantly, the planted trees should have the ability to add nitrogen into the soils for supporting plant growth. Malesu (2018) further explains, that promising maize yields were obtained as a result of intercropping maize with *Gricidia* and *Leucena leucocephala*. The respondents further reported, that they plant nitrogen fixing tree species, which grow faster and are multipurpose. In this case, the trees also provide firewood, stakes, fix nitrogen into the soil, act as wind breaks, and provide fodder for animals, and their canopy reduces moisture loss and soil drying-up. Further, the trees planted help in Eva-transpiration which is important for rainfall formation, thus contributing to the hydrological cycle. When cover-crops are integrated with trees or crops, they play a vital role in sustaining and maintaining the collected and stored water into the soils. The findings are in line with those of Ibraimo & Munguambe (2007) and Malesu (2018), who inform that planting cover crops or green manures such as *Mucuna pruriens utilis, Pueraria phaseoloides, Centrosema pubescens, Setaria spp, Stylosanthes spp* and *Glicine spp* provide another technique for achieving in-situ mulch. The cover crops provide suitable conditions in the soil, since where they exist, soil erosion, nutrient loss and moisture loss will be minimized. Farmers indicated the common cover crops planted were lablab, pumpkins, and jack beans. These were common in coffee plantations, but pumpkins were discouraged in bananas because they are hosts for pests to them.

Respondents reported even roadside trapping as a method used for harvesting run-off water into the gardens. It was revealed that, divergence channels were made to direct and allow water into the gardens. This also refers to storage/diversion measures such as, small water ponds, valley tanks and water harvesting from roads emerged as the strongest technologies (GoU, 2017). The respondents further noted that on the channels, grass is planted to hold the soil together to ease the conservation works. Van Steenbergen and Tuinhof (2010) further explains that, the location of the roadside approach in relation to contour lines, the height of the embankment, the longitudinal and lateral slope of the road, the surface material and the under drainage are all important factors in determining how much run-off is generated from a road and hence how water can be retained. One of the respondents noted that:

> *…the method was useful for me to have sustainable food production for the households. I achieved this through creating a big depression for sustainable water holding and later, water filtrates into the soil and used by the plants. On top of the divergence channels, I planted sweet potatoes, Irish potatoes and cocoyam, which provide food for the family especially during dry period.*

4.2 Effect of harvested run-off water to the farmers

The respondents were required to respond on the values of run-off water to the farmers as indicated in Table 2:

Table 2: Effect of harvested run-off to farmers

Benefits	Frequency (n=98)	Percent
Provision of water for irrigation	95	96.9
Provision of water domestic animals	97	99.0
Increased food production/yields	98	100.0
Increased incomes	86	87.8
Employment opportunities	59	60.2
Conservation of soil moisture	49	50.0
Increased animal productivity	90	91.8

Source: Primary Data, 2019

As shown in Table 2, the results indicate that all of the respondents (100%) reported increased production on their farmlands as a result of run-off water harvesting. This was followed by provision of water for domestic animals (99.0%) such as cows and pigs which were commonly kept at the households. Harvested run-off water was also used for irrigation of crops especially during dry periods (96.9%). Additionally, there was increased animal productivity (91.8%) from both animals and crops. Eventually the farmers received higher incomes (87.8%). Results also show that 60.2% of the respondents reported harvested run-off water to have offered them employment opportunities through increased vegetable growing and fruits, which provided throughout the years using the collected water. The harvested run-off water ensures conservation of soil moisture (50.0%) which enhances sustainable production by the farmers on their lands.

Harvested run-off water increases food production for the households. This is a result of the practice of water application to plants throughout the dry period. This implies that, farmers apply or water their crops/plants, food production and harvests will be high. In doing so, the household will be ensured with enough food and vegetables, thus improving their food security. GoU report (2017) further asserts that run-off water, when applied to crops, ensures better production and improved livelihoods in the households. The respondents reported that, they were able to harvest enough food due to increased use of the corrected run-off water. However, to ensure food production, run-off water application should be integrated with mulch and tree planting to ensure that applied water is not lost through evaporation but infiltrated and sustained into the soil. This is supported by GoU report (2017) which indicates that, soil and water conservation practices increase water infiltration in the soil hence favoring crop growing.

Findings show that, harvested run-off water was useful to providing water for irrigation of crops. The respondents noted that, the run-off water was applied to vegetables, maize and bananas. Those who irrigated their gardens harvested vegetables throughout the year by using the collected run-off water. It was observed that, households had tomatoes, sukuma wiki, egg plants, bitter berries, and onions, which supplied regular vegetables for home and sale to earn incomes. The results are supported by Njarui *et al*. (n.d) who assert that, water harvesting from surface run-off ensures year-round supply of vegetables and increased vegetable yield and household income by up to 500%. One of the respondents revealed that, he always harvested and sold vegetables to the community, and in case of surplus, the remaining vegetables were taken to Bukunda trading center, where he earned extra profits. He further asserted that, his family always had maize throughout the year because of using run-off water from tarpaulin. The results are in line with the findings of Molden as cited in Salman et al. (2016) according to which managing the scarce rains through collecting run-off water is crucial for improving food security and livelihoods.

Harvested run-off water was also useful for the provision of water to domestic animals such as cows, goats and pigs which were commonly kept at the households. The run-off water was used to clean animals' pens, kraals and litter to ensure better sanitation, hence minimizing disease outbreak. The harvested water was also used for drinking by the cows, which supported increased milk production. One of the respondents noted that the more the water an animal takes, the more the milk it produces. However, this should be coupled with good feeding of the animals. The results are in support by Njarui et al. (n.d) who add that, run-off water is used for livestock and crop production. We add that, to make it useful for animals like cows and pigs, it should purified through the use of *Moringa* powder, ash, and charcoal dust.

Captivatingly, it was revealed that, the incomes come from the sale of harvests from the land grown with support from run-off water. It was found out that, the respondents had run-off water ponds from which water was drawn and applied to crops to flourish and provided enough yields form the gardens. One of the respondents noted that,

> *...I have gained a lot form the growing vegetables, maize and fruits with support from the harvested run-off water. When I harvest the yields, I supply them to my clients who pay promptly, which money I invest in local poultry keeping. For example, as I talk now, I have managed to buy 200 local chicken using incomes from the sale of farm produce grown with support of run-off water. This implies that, I will be able to have eggs for my family and the surplus can be sold for income which eventually enhance household incomes and sustainable living, and livelihoods.*

Farmers used harvested run-off to the animals especially during the prolonged dry spell in order to get high yield of milk. In addition, the farmers also used the run-off to irrigate fodder such as grasses. One of the observed fodder garden was flourishing farmers could not even image that it was a dry period. Further, those who harvested run-off water had appropriate run-off technologies integrated into fodders and grasses which supplement the water given to the animals. Grass species such as elephant and Rhodes grass are planted contours to provide fodder for animals. Fodder trees for example *Callindra calothyrsus*, *Sesbania sesban*, *Mucuna pruriens*, *Lablab purpureus*, and *Tithonia diversififoli* are also planted to provide fodder to animals too. A farmer noted that, the fodder was good enough to increase milk from the cows, and when sold, it ensured increased incomes.

Results also indicated that, run-off water was very important for conserving soil moisture which supports plant growth. Moist soils are vital for the health and growth of crops, implying that, it ensures sustainable food production. In areas where run-off water harvesting was undertaken, soil moisture was enhanced through water application to plants and crops. Farmers further asserted that, by applying the run-offs on mulched gardens, the moisture is conserved into the soils, hence useful to the crops grown. This means that, crops and plants grown survived through all the harsh conditions. Additionally, moist soils ensure decomposition of dry matter, which later improves the organic contents of the soils and their micro bioactivities.

A respondent found practicing run-off harvesting reported that, run-off is very useful and I have been using it for watering my bananas, climbing beans and vegetables. She added that, last season using run-off in my water pond she grew tomatoes and received over 500,000/- Uganda shillings. She further explained that, this was as a result of the moist soils due water application to the vegetables for better growth.

Results also reveal that, the harvested run-off water promotes employment opportunities among the households in Kyannamukaaka Sub County. Some of the employment opportunities reported were nursery bed operation, vegetable growing, brick laying and animal rearing. This implies that, harvested run-off water was crucial for economic growth and empowerment. Therefore, farmers were able to start nursery beds, vegetable and other food crop growing as opportunities for household income improvements. One of the respondents noted that,

> *...it was through a nursery bed which I have operated for over five years and I have been using the harvested run-off water. Actually, I like this job very much as it has given me a lot of opportunities, including meeting the Ministry of Agriculture and the British Broad Corporation (BBC) Climate Change Team. As per now the nursery was chosen to be the center for supply of seedlings of various species to the farmers.*

4.3 Limitations to harvesting and use of run-off water

When the respondents asked the limitations to run-off water harvesting and storage, the following limitations were recorded as indicated in Table 3:

Table 3: Limitations to harvesting and use of run-off water

Limitations	Frequency (n=98)	Percent
Low levels of incomes	93	94.9
Inadequate knowledge	80	81.6
Increased costs of inputs for runoff harvesting technologies	89	90.8
Inadequate government support to the farmers	97	99.0
Lack of experts to sew lined-polythene	93	94.9
Lack of agricultural extension workers	86	87.8

Source: Primary Data, 2019

The results, as shown in table 3, indicate that, inadequate government support (99.0%) was the major limitation to run-off water harvesting in Kyannamukaaka Sub County. This was followed by low incomes (94.9%) and lack of experts to sew lined-polythene (94.9%). Further, high costs inputs for run-off harvesting technologies (90.8%), lack of agricultural extension workers to help farmers design and adapt run-off water harvesting techniques (87.8%), and inadequate knowledge (81.6%) in run-off water harvesting were reported as hinders.

Regrettably, findings revealed that, inadequate knowledge was one of the limitations to run-off harvesting and storage. Some of the respondents noted that, they were unable to harvest run-off water on the farmlands due to the limited knowledge they had over water harvesting. Results content with Oweis & Taimeh (2001) who claimed that low awareness on run-off water harvesting technologies hinders its harvesting, storage and usability by the farmers. One of the respondents noted that,

> *…though it rains two seasons a year, harvesting run-off remains a challenge to me because I am ignorant about the techniques suitable for sustainable water harvesting and storage. I wish we had extension workers in our village, I should not have been limited in harvesting run-off water for my crops and animals.*

Inadequate capacity and technical know-how to construct and set-up of run-off rainwater harvesting structures continues to challenge the farmers in Kyannamukaaka Sub County. Contreras, Sandoval & Tejada (2013) and Girma *et al. (*2014) clarify that, when lined-polythene is poorly sewn and installed, its efficiency for harvesting and storage of volume of rainwater run-off may not be observed. The results are supported by Malesu (2018) who informs that inadequate capacity of the farmers limits harvesting and use of run-off water. Therefore, this poses a threat to the farmers, and eventually they were faced with issues of food insecurity, low incomes and unemployment, which affects their livelihoods.

Furthermore, findings show that, lack of agricultural extension workers was a setback to run-off water harvesting and storage and it affected the farmers most in Kyannamukaaka sub County. It was reported that, the Sub County lacks Agricultural extension workers, so farmers need someone to guide them through both harvesting and storage techniques. One of the respondents stated that,

> *…the knowledge I have, it was gained through agricultural talk shows/radio programs on Bukedde but no any agricultural officer I have ever observed in the area. This implies that, if the extension officers were in place, and helped farmers through together with the knowledge from the radio, farmers would then be with abundant knowledge in run-off rainwater harvesting.*

Additionally, results showed that lack of experts to sew lined-polythene for underground tanks for collecting run-off water was a limitation which hinged seriously the farmers. This meant that, those farmers who wished to harvest and store run-off water for long time use could not do so. A farmer at Kaluuma village hired labourers who came and dug the pit for the tank, based on the knowledge acquired from the radio program, bought the 1000 gauge polythene (kiveera) but he failed to get someone to sew it, the way it should be done, up to now it is just kept in the house.

More to that, the findings indicated that, high costs inputs for run-off harvesting technologies were a limitation to harvesting run-off water including its storage. The respondents noted that they would wish to harvest and store water but the inputs like tarpaulin, 1000 gauge polythene, expertise and labour for installation are high. The results are in line with Malesu's (2018) findings, which show that purchasing materials, such as lined-polythene, sewing and installation, required for appropriate run-off water harvesting is costly. This implies that, the cost for inputs to construct reliable run-off harvesting and storage systems need to be subsidized to support the farmers to enhance their potential.

Results revealed that, lack of government support limited run-off water harvesting and storage on their farmlands. Respondents further noted that government had played no role in promoting run-off water harvesting and storage. The results are supported by Malesu (2018) who informs that, inadequate policy and lack of government support has hinged the smallholder farmers who would wish to harvest run-off for future use. Therefore, stronger support is needed from national and local governments for both rooftop and run-off water harvesting techniques (Malesu, 2018; Oweis & Taimeh, 2001). This is because some inputs to run-off water harvesting and storage are costly. This calls for subsidization of the costs and ensuring that extension workers are recruited and sent to the communities to sensitize and create awareness among the farmers. This would aid the farmers to gain knowledge and skills in

water harvesting and storage, hence enhancing sustainable food security and livelihoods. It was revealed that ability to harvest and store run-off water using long term techniques is influenced by available financing. The findings are supported by Oweis & Taimeh (2001) who state that, financial and technical support coupled with limited recognition within government bodies affected run-off water harvesting and storage. Without financial capacity, a farmer cannot purchase the inputs like lined-polythene, tarpaulin, labour and pay for technical expertise to design and install the tank. This is further supported by Oweis & Taimeh (2001) who claim that poor design becomes an obstacle to run-off rainwater harvesting and storage as well as its utilization.
One of the respondents further revealed that,

> *…I wanted to design and dig a tank, but I was limited by inadequate capital for the labourer, and in addition, low capital halted the purchasing and sewing, a lined-polythene to be installation in the pit (tank).*

This implies that the farmers were unable to harvest and store water for future use for their crops. The respondents noted that, they rather use the other techniques to harvest, store and releasing slowly into the soil than the modern techniques. Another respondent noted that,

> *…I use mulch, cover crops (Lablab purpureus), plant trees (which fix nitrogen into the soil, i.e., Callindra calothyrsus and Sesbania sesban), and construct contour which I also plant with elephant grass. These helped me to ensure that the soil is moist, and conserve into the soil, and control nutrient loss which are paramount factors for enhancing flourishing crop growth, hence food security.*

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5. Conclusion and Recommendations

5.1 Conclusion

The purpose of the study was to examine the techniques commonly used by farmers to harvest run-off water in Kyannamukaaka Sub County, Masaka. The study employed descriptive cross survey design and mixed methods. Results indicated contours, mulching, use of tarpaulin and in-fed rainwater harvesting as the techniques for run-off water harvesting; Harvested run-off waters increase production on farmlands, used for domestic animals and used for irrigation of crops and pasture especially during dry periods. This has improved animal health and productivity that is, production of more milk which the farmers sell to earn more incomes. For limitations, the main findings were inadequate government support, low incomes and lack of experts to sew lined-polythene and high costs inputs for run-off harvesting technologies in Kyannamukaaka Sub County.

5.2 Recommendations

The study recommends that, awareness, sensitization and capacity building should be provided to the farmers, increased government support to the farmers through subsidies on the inputs for run-off water material, and expertise in sewing should be enhanced.

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