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Effect of Water Harvesting Practices on Sustainable Maize Production among Smallholder Farmers in Water Scarce Areas of Ibanda District

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Abstract

This study was conducted to find out the effect of rainwater harvesting on sustainable maize production in Bisheshe and Nyamarebe Sub counties, Ibanda district. Specifically, the study was conducted to establish the water harvesting practices used by smallholder maize farmers, the relationship between water harvesting and maize yields, community perceptions on water harvesting and the challenges of the maize farmers in water harvesting. The study adopted a cross sectional survey design in which data was collected using questionnaires, interviews and observation; and analysed using descriptive and inferential statistics. The findings show that harvesting improved maize production in Nyamarebe and Bisheshe Sub Counties. This implied that water harvesting can support sustainable maize production in water scarce areas. The study recommends that farmers should be supported to harvest water for sustainable maize production.

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Introduction

Introduction

The study focuses on water harvesting practices as the independent variable and maize production as the dependent variable. This chapter presents the background of the study, statement of the problem, purpose of the study, study objectives, research questions, conceptual framework, significance of the study, scope of the study and definitions of the operational terms.

Background of the Study

Water harvesting (WH) can be defined as the process of concentrating rainfall as runoff from a large catchment area to be used in a smaller target area (Cooper et al., 2008) [1]. It consists of two components: the catchment area, where runoff is collected, and the cultivated area, where the runoff is concentrated (Alemu & Kidane, 2015) [2]. It may also be used for restoration of the productivity of land which suffers from insufficient precipitation, increasing productivity of rain-fed farming, minimizing risk of drought in areas prone to it and decreasing the threat of desertification through decreasing runoff and increasing infiltration.

Traditionally, water harvesting practices have been implemented and developed by local farmers in arid and semi-arid areas of the world in order to increase the amount of water available for crop production and tree growth (Biazin et al., 2011) [3]. It is applied in water scarce regions characterized by irregular and scarce precipitation, longer lasting dry periods between seasonal or irregular rainfall, ephemeral rivers and no shallow groundwater of appropriate quality. Where WH is applied the size of the productive land is enlarged because the water supply for human beings, cattle and small scale farming depends mainly or completely on WH (Biazin et al., 2012) [4].

In Africa, water scarcity is among the critical factors that pose threat to agricultural productivity and environmental sustainability. This is because agriculture, which is the main source of livelihood for the people, is largely rain-fed (FAO, 2011)[5]. Lack of sustainable alter for agriculture has resulted into low productivity in agricultural enterprises. Water is indeed an uncertain factor, in particular in Sub-Saharan Africa because of droughts and dry spells, and global environmental change is to exacerbate this uncertainty (IPCC, 2012). Hence, the core of sustainable agricultural intensification is embedded with sustainable water resources management. Water harvesting is suggested as a key option for a sustainable water management strategy to increase agricultural production while balancing the effect on the environment (Yosef & Asmamaw, 2015) [6].

In Sub-Saharan Africa, rain-fed agriculture covers 93% of the region's agricultural area (Alvarez & Steinback, 2009) [7]. It is characterized by low input–output features, suffers from extreme rainfall variability with few rainfall events, and high frequency of dry spells and droughts (Rockstrom et al., 2010) [8]. Furthermore, there is limited use of inputs such as fertilizer and pesticides (Neumann et al., 2010; Rockstrom et al., 2010; FAO, 2011) [8]5]. Thus, limited water and nutrient availability have been key factors for low agricultural production in Sub-Saharan Africa (Barron et al., 2003; Rockstrom et al., 2010)[8]. To close the gap, water harvesting has the potential of supplementing rainfall and thereby increasing crop yields through minimized risks of crop failure (Kool, 2011) [9].

In Uganda, the unstable distribution pattern of rainfall and moisture stress problem from year to year's results in uncertain and often uneconomic condition for agricultural production in arid and semi-arid parts of the country (Makurira et al., 2009)[10]. Each year, drought adversely affects agricultural production somewhere in the country. The country receives lower rainfall than maize crop water requirements. Moreover, the rains distribution is rarely in a pattern that satisfies crop needs. Efforts have been made to improve water availability in different communities.

Yield and water productivity can be substantially improved with the adoption of appropriate water harvesting practices in dry areas (MAAIF, 2014) [11]. They are used for crop and livestock production in arid areas like Masaka and Rakai (Zziwa, et al, 2018)[12]. WH has been pivotal in dry areas and use water resources available in the community. The commonly used WHTs are in-situ, micro-catchment and macro-catchment techniques, mainly based on the relative ratio of catchment to cropping area.

In Ibanda district, WH practices have been introduced and promoted in the semi-arid parts that receive low rains. These practices are aimed at boosting agricultural production in the area. Earlier attempts by the government have always focused on enacting various conservation laws, for instance, the construction of conservation structures such as contour ridges and storm drains (Mugisha & Fenner, 2014)[13].

However, such attempts were only successful in combating environmental degradation but have not significantly improved the livelihoods of the rural farmers especially maize producers. As a result smallholder farmers have remained vulnerable to variable weather patterns, particularly those in the drought prone parts of the district. Hence, despite the clearly expressed government's desire to increase maize productivity among smallholder farmers, the benefits are only felt by those in parts favored by rains (Mugerwa, 2007) [14]. The semi-arid parts of the district remain unable to produce enough food to avert hunger and depend on the high agricultural potential areas for food.

In Bisheshe and Nyamarebe Sub Counties, rainfall reliability is still a challenge in the two sub counties and even beyond. Rainfall patterns have changed and you find rain either coming early before the farmers have prepared fields or delaying and ending soon before the plants are ready for harvest. Unless the maize farmers in these sub counties adopt rainwater harvesting practices, maize yields will keep declining resulting into food insecurity and low incomes. Since not much has been investigated on extent on rainwater harvesting, farmers' perceptions and the challenges of the farmers in rainwater harvesting, this study is likely to fill this gap.

Research Problem

Maize cultivation continues to be a fundamental instrument for sustainable development, poverty reduction and enhanced food security in Ibanda District. Over 41.2% of the farmers in Ibanda are engaged in maize production while in Bisheshe and Nyamarebe sub counties, cultivation of maize remains the main source of livelihood for 73.0% of the small scale farmers (UBOS, 2014) [15].

Declining maize yields have been a cause for concern for the people of Nyamarebe and Bisheshe Sub County. This has been attributed to unreliable rainfall patterns and extended dry periods in the two sub counties (IDDP III, 2015). In order to improve maize yields, some farmers have adopted rainwater harvesting practices to supplement water from rain.

Sustainable maize production requires adequate moisture throughout the growing season. However, maize production in Bisheshe and Nyamarebe Sub County is mainly rain-fed. In the absence of rainwater harvesting interventions, maize yields are likely to remain low. Therefore, the study will contribute to what is known about water harvesting and maize yields as a foundation for interventions to improve sustainability of maize production in Ibanda district and beyond.

Study Objectives

General objective

The overall objective of the study was to assess the effect of water harvesting on maize production in rainfall deficient areas of Nyamarebe and Busheshe sub-counties in Ibanda district.

Specific objectives

• To establish the water harvesting practices being applied by smallholder farmers of Nyamarebe and Busheshe Sub-Counties.

• To establish the relationship between water harvesting practices and maize yield in Nyamarebe and Busheshe Sub-Counties.

• To determine the community level of knowledge and perceptions on water harvesting for maize production in Nyamarebe and Busheshe Sub-Counties.

• To document the challenges of water harvesting for crop production in Nyamarebe and Busheshe Sub-Counties

Research Questions

• What are the water harvesting practices used by smallholder farmers of Nyamarebe and Busheshe Sub-Counties?

• What is the relationship between water harvesting practices and maize yield in Nyamarebe and Busheshe Sub-Counties?

• What are the community level of knowledge and perceptions on water harvesting for maize production in Nyamarebe and Busheshe Sub-Counties?

• What are the challenges of water harvesting for crop production in Nyamarebe and Busheshe Sub-Counties?

Justification

Water harvesting techniques in semi-arid areas in Uganda are crucial for both economic and social activities that can improve living standards. The benefits of water harvesting include securing and increasing crop production in semi-arid regions where rainfall is insufficient, control of soil erosion and land degradation (Mugisha&Fenner, 2014) [13]. This is in addition to serving as an adaptation strategy to climate change.

Past experiences show that rainwater harvesting is an innovative approach for the integrated water resources management and sustainable development of semi-arid areas. Evaluation of appropriate water harvesting techniques is necessary to identify factors that impede farmers from using practices and give recommendations on their improvements (Mugerwa, 2007)[14]. Understanding the effects of climate change on water availability will assist in decision making regarding appropriate intervention of water harvesting techniques.

Water harvesting techniques in Ibanda district will eventually contribute to sustainable livelihood and poverty reduction. Farmers‟ awareness of climate change impact will effectively support and help more to evaluate as well as establish the impact of the climate change and variability on water resource utilization, coping, and adaptation strategies in Ibanda district.

Scope of the Study

Geographical Scope

The study was carried out in Nyamarebe and Busheshe sub-counties Ibanda district. The major economic activity across the two sub-counties is agriculture with emphasis on food crops like: sweet potatoes, beans, cassava, maize, bananas, groundnuts, onions and cabbage. The soils of the area are well drained, moderately deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storage capacity and low nutrient availability. In most places, they have topsoil of loamy sand to sandy loam.

The study areas have a semi-arid climate with mean annual temperature varying from 17ºC to 24ºC and experiences bimodal rainfall with relatives rains commencing end of March to May (about 400 mm) and short rains (SR) from end of October to December (500 mm).

The major sources of water are rain floods and seasonal rivers which appear during rainy seasons and dry up immediately after the rains. As a result of the little rains received, most villages in the two sub-counties are generally hot and dry leading to high rates of evaporation. Practicing agriculture in these rains fed conditions has remained a critical challenge for most smallholder farmers given that majority are small-scale mixed farmers with low investment for agricultural production and technologies.

Content scope

The study was limited to water harvesting practices as the independent variable and maize production among smallholder farmers as the dependent variable. It was specifically focus on water harvesting practices applied by smallholder farmers in the area, relationship between water harvesting practices and maize yield, community level of knowledge and perceptions on water harvesting for maize production and challenges of water harvesting for crop production in the area.

Significance of the study

Water harvesting can alleviate moisture stress problems and thereby improve agricultural productivity. Therefore, the study findings will be of benefit to policy makers, extension staff, NGOs supporting climate smart agriculture and other researcher.

The study findings will provide valuable information to policy makers. They can use the findings in the design of policies to address water scarcity in agriculture so that productivity can be improved. Hence, policy makers will use the findings when designing climate smart policies for water scarce areas.

Furthermore, the findings will be beneficial to extension workers. They will base on the challenges farmers are meeting in water harvesting to devise means of helping the farmers to cope with these challenges. For instance, they can teach farmers how to havest and retain water for a long time in the water collection ditches.

The NGOs supporting climate smart agriculture will also findings beneficial to their programs. They can base on the findings to identify the WH practices used by the farmers so that they inject in their support for the farmers. Hence, the findings will provide baseline data that can be used in interventions on climate smart agriculture.

The findings can provide baseline data for other studies on climate smart agriculture. They can use the findings to support their studies on water harvesting in other dry areas in Uganda and beyond.

Conceptual Framework

The study looked at rain water harvesting practices as the independent variable and maize production as the dependent variable. It is assumed from the study that water harvesting practices have an impact on small scale maize productivity in Bisheshe and Nyamarenbe. Water harvesting practices include; ridges/tied ridges/furrows, small pits (mategu), underground tanks, water dams, water pans, house tanks and large pits (Tumbukiza).

Proper application of water harvesting practices conserves the environment and improves soil conservation properties hence minimizing climate risk impacts on crop production. Rain water harvesting involves a variety of practices. The adoption of these practices is influenced by a set of social, economic, and institutional factors the variables. Household factors that have an influence on household's decision to utilize WH technology include Age of household head, sex of household head, and educational status of household head. Household's decision could also be influenced by economic factors such as off-farm/non-farm income, labor, land size and availability of inputs. Other key interventions include training on the technology and extending credit services.

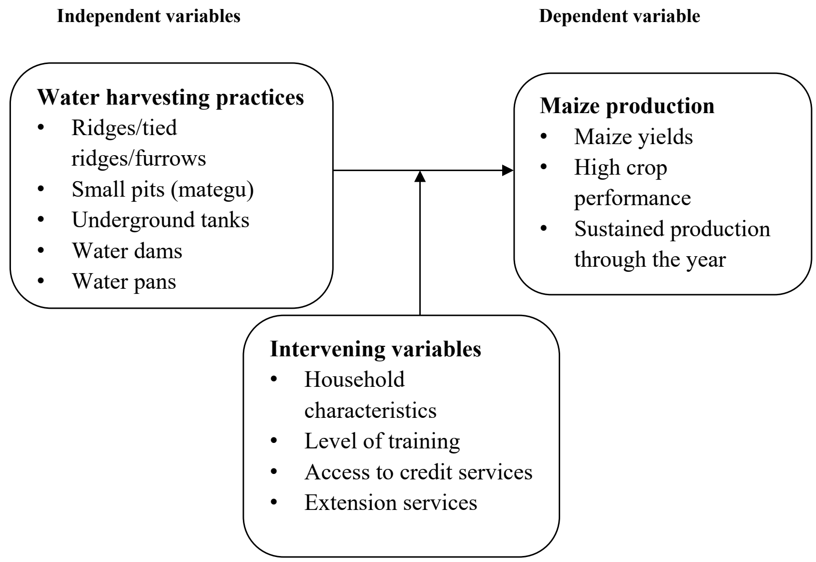

Figure 1: Conceptual Framework (Source: Researcher, 2019)

Chapter Three: Literature Review

Introduction

This chapter reviews what other scholars have written about water harvesting and crop yields.

Concept of Water Harvesting

According to Ramboll, (2010)[16], water harvesting, irrespective of the technology used, means harvesting and storing rainwater in days of abundance for use during the lean days. Storing of rainwater can be done in two ways: (i) in artificial storage and (ii) in the soil media as soil moisture. The term rain water harvesting (WH) is used in different ways and, thus, no universal classification has been adopted yet (Alvarez &Steinback, 2009) [7].

However, according to the African Development Bank-AfDB (2012) [17], water harvesting in its broadest sense is defined as the "collection of runoff water for its productive uses". Runoff may be harvested from roofs and ground surface, as well as from intermittent or ephemeral watercourses. It is a range of micro-catchments system, earthen bunds and other structures to capture and store run-off from elsewhere (Biazin et al., 2011) [3].

Water harvesting techniques can be applicable in all agro-climatic zones. However, it is more suitable in arid and semi-arid areas. These are areas of average annual rainfall of 200mm to 800mm (rarely exceeding 800mm); the average temperature is above 180c. The rainfall may 10 come in one or two seasons. In such environment, rain-fed crop production is usually difficult without some form of WH (Evans et al., 2012)[18].The same author generalized that the WH technologies can be applicable in the following circumstances: in the area where other permanent water resources like rivers, springs etc. are not available or uneconomical to develop and to use them; in dry environment, where low and poorly distributed rainfall, normally makes agricultural production impossible; in rain-fed areas where crops can be produced, but with low yield and with high risk of failure; and where water supply, for domestic, agriculture and animals is not sufficient.

Common Rain Water Harvesting Techniques Applied by Farmers

Different types of water harvesting management systems have been implemented throughout Sub-Saharan Africa as a strategy to secure water resources in rural areas (MesfinWelderufael, 2014) [19]. Water harvesting systems can be classified by the runoff generating process, the size of a catchment and the type of storage. Runoff generating processes are rivers, lakes and rainfall. The storage type could be storage within a soil profile, a tank or a reservoir and the size or scale of the system determines whether it is regarded a micro or macro scheme Mugisha&Fenner, (2014) [13]. There are three main categories of WH that have been devised and perfected over the years. Each category has its own methods and techniques that are employed to get the maximum amount of profit from each water source, be it floodwater, rainfall or groundwater. The three main forms of WH include Rainwater Harvesting (WH), Floodwater Harvesting (FWH) and Groundwater Harvesting (GWH).

In-situ WHTs enhance the collection of rainwater on the surface where it falls and store it in the soil (Biazin et al., 2011) [3]. The availability of water in the soil is improved through different agronomic measures such as modifying the soil structure, vegetation cover and density by enhancing infiltration while surface runoff and evaporation losses from the soil surface are reduced (Mihret & Tesfahun, 2014) [6]. This technology does not need a runoff generation area, instead it is a technique mainly used to efficiently utilize rainwater where it falls. It is one of the simplest and cheapest technologies that can be implemented in a wide variety of land use systems. The most widely used in-situ WHTs are tied ridges, mulching, conservation tillage and various furrow systems.

Micro-catchment WHTs collect surface runoff from the vicinity of an agricultural/cropping area mainly from sheet flow either to be applied within the field or externally in small reservoirs for later use. The catchment area is relatively small (less than 1000 m2) and so is the catchment to cropping area ratio (C:CA), with values in the range of 1:1 to 10:1 (Mugisha & Fenner, 2014) [13]. The catchments that provide runoff are normally farmlands, but nowadays rooftops of buildings, courtyards and rock catchments are also used. On-farm micro-catchment systems have been extensively used in different part of the world especially in arid and semi-arid regions. The main advantage of these systems is that the farmer has a control over the catchment and the cropping/storage area. The disadvantage of micro-catchment systems could be that part of the crop land need to be sacrificed to collect water. This depends on whether or not suitable areas for collecting water are available outside and nearby to the crop land. The fact that micro-catchment WHTs are constructed with low cost and the adoption of a simple design makes them easily adaptable and replicable to different environments (Munir & Ejaz, 2010) [20].

Macro-Catchments sometimes called medium sized catchments are characterized by large flood zones that are situated outside of the cropping area. Often farmers must use structures such as dams or bunds to divert, transfer, collect and store the runoff. Such systems are often difficult to differentiate from conventional irrigation systems and are considered FWH as long as the harvested water is available year round. Yohannes (2015) [21]. Examples of macro catchments include stone dams, large semi-circular hoops, trapezoidal bunds, hillside conduit systems, and cultivated reservoirs, all of which have a scale of between 0.1 ha to 200 ha (Yenesew-Sewnet, 2015) [22].

Large catchments water harvesting comprises systems with catchments many square kilometers in size, from which runoff water flows through a large streambed, necessitating more complex structures of dams and distribution networks. There are two major forms of large catchments i.e., floodwater harvesting within a streambed and floodwater diversion Yihunet al., (2013) [23].

Floodwater harvesting within a streambed involves blocking the water flow to flood the valley of an entire flood plain and force the water to infiltrate the ground and use the wetted area for crop production or pasture improvement Vohland & Barry, (2009) [24]. Floodwater diversion is a method in which water in a river; stream or creek bed is diverted from its natural course and used to flood nearby cropping areas as an irrigation method Shah et al., (2013) [25].

Earth dams are perhaps the most widespread method of water harvesting, especially from river valleys. A dam can be constructed to collect water from less than 20 km2 for a steep catchment and 70 km2 for a flat one. In Tanzania, low earth dams called „Malambo‟ have been built, especially in Dodoma, Munir & Ejaz, (2010) [20]. Some of these are medium-sized reservoirs for urban or irrigation water supply. Sometimes a regulating reservoir is designed to store flash floods from a single day's rainfall. The water is then slowly released so that it does not endanger bunds constructed on farmlands on lower land. The stored water drains away continuously until the reservoir is dry in a day or two, ready to receive the next flash floods. Due to the high costs of construction, earthen dams are usually built with support from donor-funded projects.

Cisterns are man-made caves or underground constructions to store water. Often the walls of these cisterns are plastered to prevent water loss, deep percolation and/or evaporation" Altieri & Koohafkan, (2008) [26]. The underground cistern (China Type), found in Ethiopia, is employed to supply water for domestic irrigation purposes to drought prone areas. There are two variants to this cistern, one being shaped like a bottle, the other in a circular formation. Both are constructed in a similar fashion with the ground excavated to form the shape of the cistern. The surface is covered with polyethylene or concrete plastering to avoid seepage loss. Both cisterns are expensive and difficult to build, often too complex for individual farmers to construct themselves. The capacity of each is 60,000L Araya, (2011) [27].

Ground water generally occupies in large areas under the earth's surface and will often supply other water sources such as streams, rivers, and springs. Often, aquifers are on the receiving end of water harvesting, in that regards, they are often used as a way to store harvested rainwater. Recently, awareness of depleting aquifers has spurred an increase in WH techniques that aim at directly recharging these rapidly depleting resources. Many forms of rainwater harvesting collect water and store it underground for future use. Not only does this recharge depleting groundwater sources, it also raises the declining water table and can help augment water supply Aziz &Tesfaye (2013) [28].

Moisture retention terraces and ditches are other techniques promoted through-out Eastern and Southern Africa. In Kenya the famous Fanya Juu terraces, which are made by digging a trench, normally along the contour, and throwing the soil upslope to form an embankment, has had a very significant effect on reducing soil erosion in semi-arid areas with relatively steep slopes (< 20 %). Cooper et al., (2008) [1] present evidence from Machakos district in Kenya suggesting that the adoption of Fanya Juu terraces played an important role in reducing land degradation over a period from the 1930s – 1990s when population increased more than fivefold. Similar widely spread techniques are the Fanya chini developed in the Arusha region, Tanzania (soil thrown down slope instead of upslope), stone bunds, and trash lines (successfully promoted through extension in dry areas of South-eastern Kenya). In Ethiopia annual mobilization campaigns are used to rehabilitate degraded lands by constructing retention ditches and stone terraces Binyam, et al., (2015) [2].

In-situ rainwater harvesting is essentially the prevention of net runoff from a given area by retaining rainwater and prolonging the time for infiltration Biraraet al., (2015)[29]. This practice employs a number of different techniques to catch the water where it falls FAO, (2010) [30]. The methods for this form of WH are diverse and are often a product of local ingenuity and varying cultural practices. Examples of water collection include deep tillage, dry seeding, mixed cropping, ridges, borders, trash lines, ponds, fog harvesting Itabari et al., (2011) [31]. For the most part, these practices are mainly used for irrigation.

Micro-catchment involves a distinct division of a runoff-generating catchment area, and a cultivated basin where runoff is concentrated and stored in the root zone and productively used by plants MAAIF, (2014)[11]. There are multiple advantages to this WH system than the others in that the design is simple and cheap, there is higher runoff efficiency than larger scale WH systems. They often prevent or reduce soil erosion and, finally, can be implemented on almost any slope and many level planes Foti, et al., (2008) [32]. Micro-catchments vary in size, method and technique from region to region. A micro catchment system in Ethiopia, for example, may be completely different in style and operation from a micro-catchment system found in Western Asia. Although there are little variations, there is a basic principle used within the micro-catchment category, they include; pitting, contour ridges, negarin, semi-circular hoops, meskat-type, vallerani type, contour bench terraces, and eye brow terraces or hill slope micro-catchments Biazin et al., (2012) [4].

Relationship between Rain Water Harvest and Maize yields in Rain Deficient Areas

In-situ WHTs have a great potential to improve the availability of water for agricultural use by enhancing infiltration of rainwater into the soil layer, where it is stored, but simultaneously reducing water losses through runoff and evaporation (Foti et al., 2008) [32]. Although in-situ WHTs are primarily implemented to improve the efficiency of water use in (semi-) arid areas, they can also contribute to minimizing soil loss from farmlands.

Several researchers report the benefit of in-situ WHTs such as tied ridges, mulching, conservation tillage, and furrow systems in improving on-site water availability for plant growth. There is evidence that in-situ WHTs such as tied ridges and furrow systems are efficient in reducing runoff from agricultural fields (Binyamet al., 2015) [2]. McHugh et al. (2007) reported a decrease of runoff by 75% using tied ridges compared to conventional tillage. Tied ridges can also improve soil-moisture content (SMC) in the soil layer due to increased infiltration of pond water from ridge depressions. Field investigations showed that conservation agriculture with crop residue with at least 30% left on the soil surface (Binyamet al., 2015) [2], tillage operation with sub-soiler and tie-ridger and combination of no tillage, furrows and retention of crop residue can substantially reduce runoff losses from farmlands.

In-situ WHTs such as mulching also decrease soil loss by absorbing the energy of raindrop in detaching soil particles from the soil surface (Antenehet al., 2014) [33]. Mulching also slows down surface flow velocity thereby delaying or disrupting the connectivity of runoff flow pathways (Kool, 2010)[9]. The effect of mulching on decreasing soil loss from farmlands is well documented (e.g. Mugisha & Fenner, 2014) [13]. Other techniques such as tied ridges and furrowing systems decrease the loss of runoff from agricultural fields, enabling the retention of detached soil particles in the depressions. There is ample evidence that shows the benefit of tied ridges and furrow systems in reducing soil loss from farmlands (e.g. Mugisha&Fenner, 2014) [13]. Some researchers also report the decrease of nutrient losses by the use of in-situ WHTs as a result of reduced soil loss from agricultural fields (Biraraet al., 2015) [29], emphasizing that any measure taken to control soil loss would also minimize nutrient depletion.

Micro-catchment practices have a high potential for combining water harvesting with soil conservation. Conservation of both moisture and soil has two major advantages that is; increased crop yields and rapid vegetation development that results into improved soil-moisture status as well as offering protection to the soil against erosion. Micro-catchment rain-water harvesting, provides a good means for changing from soil conservation based on just runoff control to a focus on land husbandry integrating conservation and production (Biazin et al., 2012) [4].

WH systems practiced in the catchment are useful for improving smallholder's livelihoods. Higher crop production is observed in 12 to 20 ha area near WH type micro dams. Use of micro dams and furrows for stream water abstractions allows year round cultivation that substantially contributes to household income and increasing food demand in the zone. Existence of suitable land use land cover and slopes in catchment areas of source stream of micro dam are significant in generation of optimal dry season potential (Antenehet al., 2014) [33]. Effectiveness of water distribution and use in micro dams/furrow commands is limited due to a low water conveyance factor, adequacy and equity. Dug out ponds are essential for livelihoods of lowland farmers. These systems with optimal storage size of 320 m3 per household are suitable for domestic uses and watering of livestock.

Subsurface runoff harvesting tanks have shown supplementary irrigation potential of 304 m2 per annum (Arbo, 2013) [34]. In water scarce mid and lowlands, this WH system has potential to increase household food security through cultivation of vegetables and securing maize crops against long dry spells. Crop water application using can irrigation is laborious, which sometimes forces farmers to skip the scheduled irrigation. Rooftop rainwater harvesting systems have relatively small irrigation potential ranging from 15 to 32 m2. These could supply water for small vegetable garden.

In-situ WH is sometimes called water conservation and is basically a prevention of net runoff from a given cropped area by holding rain water and prolonging the time for infiltration ((Araya, 2011) [27]. This system works better where the soil water holding capacity is large enough and the rainfall is equal or more than the crop water requirement, but moisture amount in the soil is restricted by the amount of infiltration and or deep percolation. The in-situ WH is achieved mainly by the following means

Tied ridges consist of ploughing and ridging at specific row spacing, followed by an operation to tie the ridges before planting. They were constructed using hand hoes or a single-donkey drawn ridge tie. They impede run-off thereby promoting infiltration. Tied ridges are basically in-situ WH technologies because they harvest rainwater where it falls. They are one of the conventional approaches to soil and water conservation, designed to enhance infiltration of rainwater into the soil. These have been found to be the most productive of the rainwater harvesting technologies in semi-arid areas. They can produce an average maize yield of about 3.6 tons per hectare in agro-ecological regions 4 and 5 (Mugisha & Fenner, 2014) [13].

Fanya Juus. This technique involves throwing of the soil excavated from the drainage channel to the upper side of the channel. Trees, bananas and at times maize plants are planted in some of the fanya juus. This helps crops utilize some of the excess water retained in the channel. Research results by Shah et al., (2013)[25] have shown that land under fanya juus treatment can yield an average of about 2.8 tons of maize per hectare in agro-ecological regions 4 and 5 in Zimbabwe.

Infiltration pits are pits dug along contour drainage channels to trap run off in order to provide water with an opportunity to infiltrate (Araya, 2011)[27]. They can be multi-functional as was observed in the study area. Some farmers filled the pits with grass and other organic material to form compost manure while others planted fruit trees and bananas in and around the pits. These pits trap rain and run off which later infiltrate to provide moisture for crops in the fields on the down-slope side of the pits. The dimensions and spacing of the pits varied from farmer to farmer and depended on other factors such as soil type, slope steepness and labour availability.

Community Perception on the Use of Rainwater Harvesting for Crop Production

According to Munir & Ejaz, (2010) [20], attitude and perception are a mental state of readiness, organized through experience, exerting an influence upon an individual's response to an object and the situations with which it is related. Formation and change of attitude are not two separate things, they are interwoven. People are always adopting, modifying and relinquishing attitudes to fit with the ever changing situation of the attitude object. Attitude cannot be changed by simple education.

If the technology is perceived by farmers as incompatible with the resource and other means available to them, then farmers tend to develop negative attitude towards the object, or at least show lack of enthusiasm to try the technology despite their knowledge about the importance of the technology (World Bank, 2015) [35]. This in turn minimizes the sharing among farmers leading to a very slower rate of diffusion and adoption of technology.

Water harvesting either through runoff collection from a catchment area upslope or through conservation of rainfall where it falls in the cropped area or pasture has received increasing attention in rain fed systems of the SSA (Biazin et al., 2012) [4]. Conservation farming with improved and non-invasive tillage systems (sub-soiling, ripping, etc.) has got increasing attention and perception (Ding & Widhalm, 2011) [36]. The perceived benefits of conservation tillage encompass improved infiltration, reduced soil erosion, and better carbon sequestration through the organic matter accumulated in the soil from the crop residues and cover crops (IFPRI, 2011) [37].

Supplemental irrigation of rain fed agriculture through water harvesting not only reduces the risk of total crop failure due to dry spells, but also believed substantially improves water and crop productivity (Itabari et al., 2011) [31]. Depending on the type of crop and the seasonal rainfall pattern, the application of WH techniques makes net profits more possible, compared to the meagre profit or net loss of existing systems. Implementation of rainwater harvesting may allow cereal-based smallholder farmers to shift to diversified crops, hence improving household food security, dietary status, and economic return.

According to (Munir & Ejaz, 2010) [20] most farmers perceive WH to directly boost yields and gives farmers 'water security'. This implies that WH users can be engaged in enhancing productivity inputs (Munamati & Nyagumbo, 2010) [38]. Also, according to agriculture sector review undertaken in Ethiopia to tackle the problem of food insecurity and rural livelihoods it is recommended that investment be made on rainwater harvesting to insure food availability water centered development is required (Mengistu & Desta, 2011) [39].

Adoption of hand-dug water harvesting technologies despite their technical benefits depend on knowledge of socio-economic and cultural dynamics. Socio-economic conditions of a region being considered for any water harvesting schemes are very important for planning, designing and implementing. Cultural beliefs and perceptions fundamentally describe the basic forms of behavioral attitudes evolved by a people, as they are taught to, and learned by each succeeding generations. The way society perceives and interacts with its environment is based on their culture, which determines their attitude towards it (Mesfin, 2014)[19]

Apart from bio-physical, institutional, technical and economic factors, farmers' attitude towards the technology is important requirement for technology dissemination and adoption. Attitude is a disposition to respond favorably or unfavorably to an object, person or institution or event. The characteristic attribute of attitude is its evaluation that must reflect a positive or genitive evaluation of the attribute object. Accordingly, there are three response categories that help us to infer about attitude. These are cognitive, affective, and conative responses (Mugisha & Fenner, 2014) [13].

Farmers believe water harvesting has an impact on cropping pattern, productivity, employment, and income of their incomes. Water harvesting practices, even though limited in terms of size and water capacity, perform very significant roles in various aspects according to their proper placement in the watershed context. The WH practices impact indicate not only increasing crop yields in both the rainy and the dry seasons, but also reduction of downstream sediment load (MAAIF, 2014)[11].

Farmers give many different reasons as to why they have or have not adopted a particular technology or practices. For instance a number of studies have pointed out the following reasons with respect to this issue. Many researchers and experts in the field of natural resources conservation and water harvesting forwarded their reasons about different factors that affect adoption decision of farmers to use water-harvesting works. Adoption of hand dug water harvest technology ultimately depends on the degree of acceptance by the farmers. The needs and aspirations of the farmers should be clearly understood and incorporated in the planning, designing and implementation process (Mihret & Tesfahun, 2014)[6].

Studies on rainwater harvesting systems for enhancing food security in Arid and Semi-Arid Lands have publicized deep optimism (Yenesew, 2015) [22]. This optimism is driven by the supposition that rainwater harvesting systems provides opportunities to stabilize agricultural setting in Arid and Semi-Arid Lands and makes them more productive and more resilient towards climate change. In reference to the adoption of agricultural technologies (including Soil and water conservation systems) which are affected by a number of factors such as farmers' perception about the technology and their attitude towards them (Yohannes, 2015) [21].

Water harvesting systems are also believed to help in reducing runoff velocity and soil erosion; contributing to groundwater recharge. However, poor design, poor management, and poor communication between designers, the government, and farmers can lead to the failure of a water harvesting system. The potential of a rainwater harvesting system to sustain agricultural production should be supported by other technologies, specifically Information Technology (IT). Soil and nutrient management, as well as a consideration of the farmers' social and economic condition during implementation, should be used to ascertain the success of the water harvesting system in improving local agricultural production (Kool, 2010)[9].

Availability of labour: the amount of labour input required for excavation of WH structures is one of the perceived constraints reported by number of literatures. By magnifying this issue (Makurira et al., 2009)[10], claim that WH is a labour intensive activity which requires profound expenditure of households‟ physical labour. The digging activity, even under the intensive package is the responsibility of the beneficent household. The beneficiaries undertake such arduous activity through collective labour called „Debbo‟. People participate in„ Debbo‟ provided that if there is a mutual benefit. Such practice has resulted contrary to the envisaged goal, i.e., the exclusion of the poor practice (Matarutse, 2010) [40].

Farm size: is often correlated with the wealth that may help ease the needed liquidity constraints. WH technology requires land, one of the scarcest resources, for runoff generation and storage construction. In his result study (Kool, 2010)[9] revealed the positive and significant impact of farm size on utilization of WH technology in Dejen district, Ethiopia. Similarly, IFPRI, (2011) [37] showed positive and significant association between farm size and farmers' utilization decisions on improved agricultural technologies.

Credit Service: The failure of some rainwater harvesting schemes in Sir Lanka due to financial constraints indicates the importance of credit service in promoting WH technology in smallholder farmers (Ding et al., 2011). The finding of (Binyam & Desale, 2015) [2] in Lanfuro District, Southern Ethiopia revealed that good access and use of credit was found positive and significantly related with the use of WH technology. All users of credit were found to be user of WH technology, while households with limited access for credit were non-users of the technology. The study conducted by (Biazin et al., 2012) [4] using binomial log it model undertaken Nepal revealed that the coefficient of availability of credit service was found significantly different between the two groups, those who have and do not have access for credit services, showing a positive impact of project intervention on disseminating and adopting technology at households level. The farmers who received credit were found to adopt improved technology 3.38 times higher than those by the non-receivers.

Another challenge is that the RHM systems, to some extent depend on rainfall distribution. During extreme drought years, very little can be done to bridge a dry spell occurring during the vegetative crop growth stage if no runoff producing events occur during early growth stages (Binyam & Desale, 2015) [2].

Loss of water due to evaporation: water in an agricultural production system can be lost due to evaporation from the soil surface, surface runoff (which simultaneously causes erosion) and through deep percolation / drainage, which sometimes can be later recovered for irrigation elsewhere (CTA, 2010) [41].

Gender issues: Women can benefit enormously from the WH-based systems. In practice however, female headed households hardly have the privilege to own WH ponds. In his recent case study, (Biazin et al., 2012) [4] witnessed that it is the strong male headed households that own WH ponds. Digging ponds demands a collective labor. This system is implemented through a "give and take" mechanism. As women are not as muscular as their male counterparts, almost all women- headed households are unknowingly barred from the benefits of WH. Women rarely participate in decision making with respect to WH works and utilization. The case study in Kobo, Ethiopia revealed that men are mainly involved as decision-makers, especially on rainwater utilization and management (Araya, 2011)[27].

Education level: There is a general argument is that education acts as a challenge in farmers utilization of Rain Water Harvesting (RWH). Educationist is believed to 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 (AfDB, 2012) [17].

Limited financial Resources; the implementation or improvement of a WH project must be affordable for all members of the group of users (Biazin et al., 2012) [4]. In developing countries the financial resources of farmers, especially of small farmers, are very limited. Even the tools needed for the construction and maintenance of WH installations are often not available. Construction material such as bricks, cement, pipes, plastics, containers, etc. cannot be afforded. In addition, plant seeds and tree slips are also needed especially at the beginning of a WH-fed cultivation of crops, vegetables or trees.

Un-availability of assets; in many cases marginally productive and subsistence farming practices in Botswana were linked to a lack of knowledge among individuals (Respondents B, C and N). This was attributed to the unavailability of adequate training and support at both an individual and group level within the farming sector. Similarly, poor performance of agriculture in other developing countries associated with the loss of traditional knowledge regarding optimal farming practice has led to a reduction in adoption and use of WH (Biazin et al.,2012) [4] due to the reluctance of farmers to invest in activities where returns are unreliable. A lack of resources, including finances, skills, labour and land, was acknowledged within the literature to be a key constraint to the adoption of WH by the poorest farmers MAAIF, (2014) [11] and although government schemes in Botswana were unsuccessful, the provision of grants and assistance from governments or NGOs has been shown to reduce the barriers to technology uptake Ambeet al., (2014) [42].

Conclusions and Gaps Identified

The literature reviewed shows that water harvesting has benefits in sustaibale farming in arid lands. However, the uptake of water harvesting technologies remains low. This is because the farmers have many challenges in harvesting water for agricultural production. However, most of the studies on water harvesting have been conducted outside Uganda. Furthermore, they have been conducted outside annual crops like maize. The study intends to address these gaps.

Research Methodology

Introduction

This chapter presents the methodology for data collection and analysis. It gives the research design, study area, study population, data collection methods and instruments, data quality control, data analysis techniques, ethical considerations and the study limitations.

Research design

A descriptive cross sectional research design using both quantitative and qualitative approaches for data collection was adopted to collect perceptual data from respondents in the area. The design has been chosen because it helped the researcher to generate basic knowledge, clarify relevant issues and break grounds on how rain water harvesting affects sustainable maize production and yields. This is ideal for the study since it enabled the collection of data across two sub-counties at one point in time. The qualitative methods was used to capture respondent's views, feelings, knowledge and opinions on the subject matter using interviews while quantitative methods involved the use of questionnaires to collect quantitative data.

Area of study

The study was carried out in Nyamarebe and Busheshe sub-counties Ibanda district. The District has a tropical type of climate, which is hot and wet with a bimodal rainfall averaging between 1000mm and 1200mm per annum. The two rain seasons are mid-August to December and Mid-March to Mid-May. Over the years however there have been gradual changes in the climate, which are intermittent. Such changes have aggravated to unexpected heavy rains and at times long droughts.

Figure 3.1: Map of Ibanda showing Nyamarebe and Bisheshe Sub County

The major economic activity across the two sub-counties is agriculture with emphasis on food crops like: sweet potatoes, beans, cassava, maize, bananas, groundnuts, onions and cabbage. The soils of the area are well drained, moderately deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storage capacity and low nutrient availability.

The major sources of water are rain floods and seasonal rivers which appear during rainy seasons and dry up immediately after the rains. As a result of the little rains received, most villages in the two sub-counties are generally hot and dry leading to high rates of evaporation. Practicing agriculture under these red fed conditions has remained a critical challenge for most smallholder farmers given that majority are small-scale mixed farmers with low investment for agricultural production and technologies. The choice of the areas is because it they are endowed with water sources yet there is continuous reduction in food crop production. Low levels knowledge and awareness on water harvesting practices remain critical issues for sustainable crop production in the area.

Study Population

The study population comprised of smallholder farmers, agricultural advisors and local leaders. Farmers were targeted for their involvement in farming activities and hence might have relevant information about the subject under investigation. On the other hand agricultural advisors and local leaders were considered because they implement policies as well as provide advisory services on agricultural programs in the area.

Sample Determination

The sample size for the current study was determined by Kirkwood (1998:192)'s formula, at 95% level of confidence, with 5% as the tolerable error. In this case the sample was determined as follows:

$$\mathbf{n = \frac{p \times q \times (Z_{\&/2})^2}{e}} \textbf{ or}$$

$$\mathbf{n = Z^2_{\&/2} \times \frac{(p) \times (1\text{-}p)}{e^2}}$$

Where:

n = Sample size

p = Number of farmers estimated to be applying small scale WT practices = 25% = 0.25

q = Number of farmers not applying WT practices= 75% = 0.75

e = standard error = 5% = 0.05

$Z_{\&/2}$= Z value of 95% confidence = 1.96 from the Z-table

Substituting the values into the formula: $n = 0.25 \times 0.75 \times \frac{(1.96)^2}{0.0025} = 288$ respondents

Sampling Process Technique

The study adopted simple random and purposive sampling techniques to select the study participants Simple random sampling was used in the selection of farmers for the study. The list of maize-farming households in Nyamarebe and Bisheshe were got from the extension staff in the two sub counties. The households were assigned numbers and the numbers written on pieces of paper. These papers were mixed up in a paper bag and 288 pieces of pare randomly picked from the paper-bag. The numbers on the pieces of paper were selected to represent the households to participate in the study.

For the extension staff and local leaders, purposive sampling was used. This method was used because they were key informants with the required information on water harvesting for sustainable maize production.

Data Collection Methods

Farmers in the area were the main source of primary data for the study. In addition, local leaders, agricultural service providers and weather experts provided additional primary data as key informants.

Questionnaire administration

Questionnaire administration was used to collect data from the farmers. This involved approaching the households and identifying the household head. After explaining the purpose of the study and its possible benefits, the household head was asked to respond to the questions in the questionnaire. The language of data collection was Runyankole and Rufumbira since the two are the languages spoken in the area. Since the researcher had an assistant who was fluent in Rufumbira, he was the one who collected data from the Bafumbira while the researcher collected data from the Banyankole and Bakiga. After the data collection, the respondents were thanked for co-operation and assured that all data collected was confidential and would be used for academic purposes only.

In-depth Interview for key informants

To capture in-depth information on the topic, interviews were conducted to enable the researcher get information from the key informants like agricultural officers, extension workers and local leaders using interview guide. The information gathered through key informants' was used to harmonize and supplement the data collected from farmers through structured questionnaire.

Field observation

During interview sessions, the researcher observed critically the biophysical and major terrain features such as topography, soils, erosion status, and water harvesting practices. Additionally, farms were visited to ascertain the level at which farmers apply rain water to manage maize production in dry seasons. This helped the researcher to capture actual data through assessment. Observation method further helped the researcher to identify the challenges faced by farmers in harvesting rain water.

Data Collection Instruments

Questionnaires

A semi-structured questionnaire that has both closed ended and open ended questions was designed and used to generate data from the respondents. The questionnaire was translated into Runyankole to make the questions more simple, clear and understandable to the farmers/respondents. The household head was the appropriate respondent for the questionnaire designed for this study. The study questions covered a wide range of information including household characteristics such as (age of household head, sex, education status, family size, source of income and livelihood); rain water harvesting techniques applied; effect of rain water harvesting on maize yields; perceptions using rainwater for maize production and the challenges encountered during rain water harvesting.

Interview guides

These were used to collect data from the key informants. These guides had open questions to guide the discussion with the extension staff and local leaders. They were used because they keep the discussion focused on the objectives of the study.

Field observation guides

These were used to observe the water harvesting practices of the maize farmers and the condition of their maize crops. To keep evidence of the observation, photos were taken in order to have visual picture of the practices and maize condition in the study area.

Data Quality Control

Content validity

Validity refers to the degree to which results to be obtained from analysis-of the data actually represents the phenomenon under study (Westercamp, 2013) [43]. To establish content validity of instruments, the researcher consulted experienced and skilled researchers including the university supervisor. This was done by administering two (2) respondents within the study population but outside the sample. Results from the field will help to identify gaps and make modifications to the instruments, where necessary.

Reliability of instruments

Reliability refers to the degree at which the instrument consistently measures what it is measuring (Westercamp, 2013) [43]. To ensure quality of this study, the researcher took a number of measures during the field work, analysis and conclusion process. Before real collection of data, data instruments pre-tested on 2 respondents from each group to determine their reliability and these respondents will not be among the interviewers. Reliability of the questionnaires in relation to the consistency of the respondents' answers were computed using the Cronback's Alpha Coefficient and found to be 0.74. This implied that the instruments were reliable for the study.

Data Analysis and Presentation

Data Processing

Data from the field was carefully classified, edited basing on clarity, completeness, accuracy and consistence to ensure dependability. This was done to remove errors and to ensure that a better quality work was produced.

Data Management

The data collected was entered into Microsoft Excel version 2010 to ease management and removal errors. It was later exported to SPSS version 21 for further data Analysis. The chi-squared test was used to check the significance variables at $P \leq 0.05$.

Methods of Data Analysis

Data analysis involved the processing raw data and this was done at two levels using SPSS. The two levels include; descriptive and inferential analysis. Descriptive analysis was used to determine Univariate statistics for both nominal and scale data. Techniques for summarizing continuous data included mean, variance and standard deviation while frequencies and percentages were used for categorical variables.

Inferential statistics involved using both associations and multivariate analysis to make general inferences about the study phenomenon. Chi-square tests (X2) was used to test for any possible associations between categorical variables. A linear regression model was adopted to test for a significant association between maize yields water harvesting practices.

Multivariate analysis using logistic regression was performed to assess the significant challenges that are closely affect the use of water harvesting practices than the others. The model was defined and presented as follows.

$$\log\left(\frac{p}{1-p}\right) = \alpha \cancel{+ b_1x_1 +} b_2x_2 + b_3x_3 + \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots + b_nx_n + e$$

Data from interviews was analyzed by thematic content analysis. The data was categorized and common themes were identified. Analysis of the knowledge, perceptions and challenges regarding water harvesting was also done.

Ethical considerations

The researcher upheld ethical considerations expected of him in the design, conduct, analysis and dissemination phases of the study. Ethical approval for the study was obtained from the Research and Ethics Committee of Bishop Stuart University.

Permission was obtained from the sub-county leaders to proceed to the respective parishes and villages to proceed with data collection.

The researcher informed all the study's participants of the main purpose of the study and seek their consent prior to their participation in the study. The identity and respect of the participants was upheld.

The rights of the participants' were respected, including those who decline to participate in the study, since participation in the study was voluntary. The data collected was used solely for purposes of this evaluation study.

Accuracy standards were followed in the collection, analysis, and interpretation and reporting of the study findings. Ethics pertaining to academic writing and publishing was followed by the researcher throughout the study.

Study Limitations

One of the limitations of the study was that it was cross sectional in nature. The data was collected at a particular point in time without need for follow up. However, the effect of water harvesting on maize yields is not instant.

Secondary, the study was conducted in only two sub counties yet climate smart agriculture is required in all areas engaged in farming. This indicates that the results might not necessarily be generalisable to other areas producing different crops.

Results

Introduction

This chapter presents the results from the fieldwork and analysis of the findings.

Response Rate

All the questionnaires were returned duly filled. Therefore, the response rate was 100% of whom 93 were engaged in rain Water harvesting while 195 were not engaged in the practice.

Socio-Demographic Characteristics of the Respondents

According to Figure 4.1, the majority of the majority of the maize farmers who practiced water harvesting were male (68.8%) and married (61.1%) while for the non-participants, 66.7% were male while 94% were married. This indicated that more males than females were engaged in maize production; just as the married were more active than those who were not married.

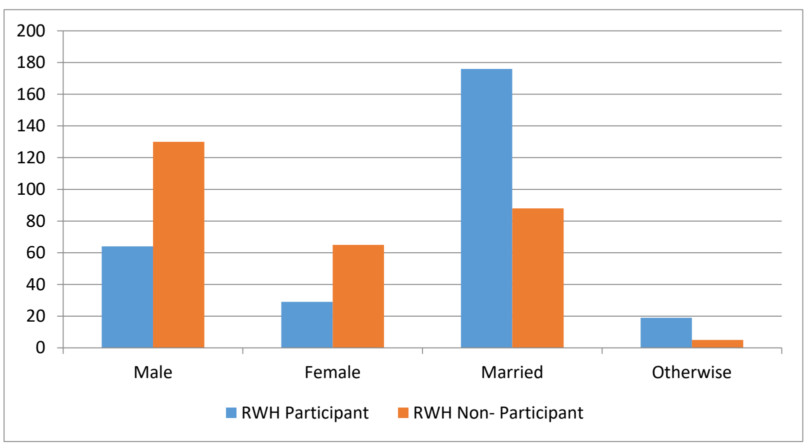

Figure 4.1: Maize farmers by participation, gender, and marital status

The results also revealed that the majority of the maize farmers who participated in rain water harvesting were middle aged, had low levels of education, average family sizes, small farm sizes and small pieces of land under maize. For those who did not participate in RWH, the majority were middle aged, had low levels of education, average family sizes, small farm sizes, and small pieces of land under maize (Table 4.1). The results of the t-test analysis show significant differences between the participating and non-participating maize farmers in terms of age and number of years of schooling.

Table 4.1: Respondents age, schooling, family size and farming experience					
	Water harvesting status	N	Mean	Std. Deviation	t(p-value)
Age of Respondent	Yes	93	41.88	11.879	-2.136(0.034)
	No	195	45.22	12.617	
Number of Years of Schooling	Yes	93	8.81	2.837	2.805(0.005)
	No	195	7.85	2.657	
Family Size	Yes	93	5.91	2.435	.686(0.493)
	No	195	5.74	1.807	
Farming Experience	Yes	93	12.52	9.120	-.744(0.457)
	No	195	13.33	8.429	

Water harvesting practices in maize farming in Nyamarebe and Bisheshe sub-counties

The first task of this study was to find out the water harvesting practices of the maize farmers in Nyamarebe and Bisheshe sub counties. The farmers were asked to list the water harvesting practices they have ever heard of and they responded as shown in Figure 4.2 below showing that they majority knew about Fanya Juus(38%) followed by Fanya Chini(30%), soak away pits(19%) and side road drains. This indicated that the most known modes of water harvesting were Fanya Juu and Fanya Chini.

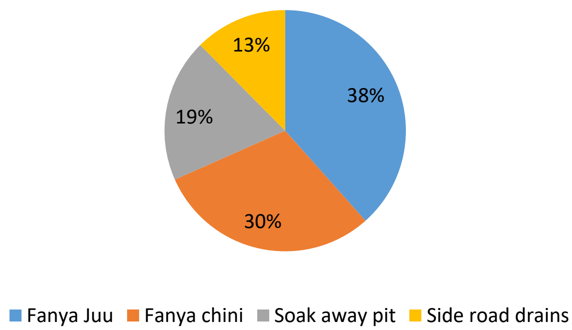

Figure 4.2: Water harvesting practices known to the farmers

The farmers were also asked to give out their sources of information about water harvesting practices. According to Figure 4.3, the majority of the maize farmers received information about water harvesting from radio(49%), followed by fellow farmers(26%), newspapers914%) and extension farmers (11%).

This was supported by the extension staff members in the interviews. For instance one extension worker said, *"Farmers only use trenches to conserve water because those are the ones they have ever heard about"*

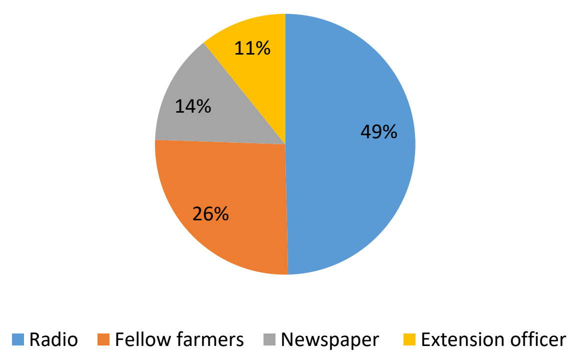

Figure 4.3: Farmers source of information about water harvesting

The maize farmers who practiced water harvesting were asked the practices they used in water harvesting. As shown in Figure 4.4, the participating farmers were asked the water harvesting practices they used in maize cultivation. The majority of the farmers were using Fanya Juu trenches(50.0%) followed by Fanya Chini(24.7%), Side Road Drains(16.2%) while soak away pits(8.6%) were the least used.

The responses from the local leaders and extension staff were in line with the findings. One local leader said that, "Farmers only use trenches to trap moving water in their maize gardens. More especially, they do so in order to avoid water washing away their crops"

Similarly, the extension officer said, "Farmers use of water harvesting in maize production is low compared to perennial crops. However, some use Fanya Juus in order to retain water in their fields"

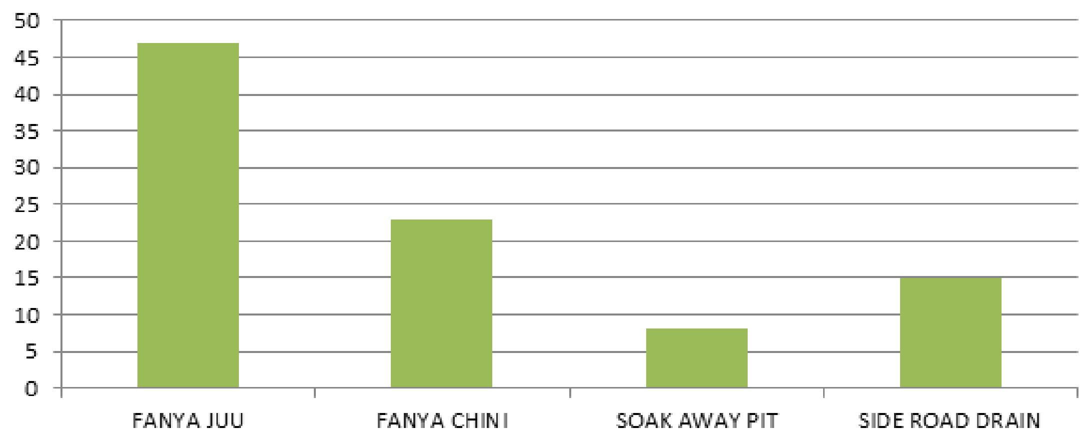

Figure 4.4: The WH practices commonly used by the farmers

The farmers were also asked the other water conservation practices used in maize production. According to Table 4.2, the majority of the maize farmers was using conservation tillage as a water conservation strategy followed by mulching and manure addition while ridging was the least used conservation strategy.

Table 4.2: Other water conservation strategies

	Source	Frequency	Percentage	Valid Percent	Cumulative percent
Valid	Ridging	17	18.3	18.3	18.3
	Mulching	23	24.7	24.7	43
	Conservation tillage	31	33.3	33.3	76.3
	Manure addition	22	23.7	23.7	100.0
	Total	93	100.0	100.0	

Relationship between Water Harvesting Practices and Maize Yield Sustainability

A two-step model was used to assess the relationship between rainwater harvesting and sustainability of maize production in Bisheshe and Nyamarebe (Table 4.3). At 0.05 significance level, there was a statistically significant association between use of water harvesting in maize production and farmers' access to credit ($p=0.001$), access to training($p=0.030$) and educational background(0.011). This indicated that the farmers' age, access to credit, access to training and educational background are factors in the farmers' decision to use rain water harvesting from maize production.

Table 4.3: Determinants of maize farmer participation in water harvesting						
ever use of RWH in maize growing		B	Std. Error	Wald	df	Sig.
	Intercept	1.636	1.015	2.600	1	.107
	Age	.029	.016	3.127	1	.077
	Family size	-.008	.078	.012	1	.913
	Farming experience	-.007	.020	.146	1	.703
	Land size	.012	.053	.055	1	.814
No	Aum	-.102	.121	.715	1	.398
	Access to extension	-.158	.156	1.027	1	.311
	Access to credit	-1.084	.322	11.319	1	.001
	Access to information	-.143	.333	.185	1	.667
	Access to training	.933	.430	4.721	1	.030
	Sex	-.132	.307	.184	1	.668
	Education	-.128	.051	6.394	1	.011
	Marital status	-.373	.647	.332	1	.564

The variability of maize production with water harvesting status was also measured. The findings as shown in Table 4.4, the mean yields per acre was higher among the farmers who used water harvesting practices(648 kgs) compared to the non-users of water harvesting practices(245 kgs).Variability among those not practicing water harvesting(CoV= 122%) was about four times when compared to those with RWH (CoV= 41%). This indicated that the use of RWH assisted in improvement of maize yields in Bisheshe and Nyamarebe.

These findings are in line with responses from the extension staff during the interviews. According to one extension officer, “Harvesting water has improved crop yield. However, depleted soils also affect maize yields”

However, one local leaders asserted that, “Framers are getting better yields but I cannot say whether this ie because of harvesting water because it is still done on low scale”

Table 4.4: Variability of maize yields among farmers according to water harvesting status					
Participation Status	Mean	Minimum Kg/acre	Maximum Kg/acre	Std. Dev Kg/acre	CoV
With WH technologies	648	338	1575	106	41%
Without WH technologies	245	254	635	22	122%

As can be seen from the Plate 4.1 below, a farmer who had used furrows to conserve water in his maize field got a bumper harvest.

Plate 4.1: Health plants and a bumper harvest after water harvesting adoption

However, farmers who did not adopt water harvesting practices had challenges with drought. Their crops were destroyed by the prolonged dry conditions and the farmers never harvested anything from their maize fields. As can be seen from Plate 4.2, the drought affected the farmers so much that they did not get any returns from the effort they put in this maize farming enterprises.

Plate 4.2: Miserable maize plants after water stress for non-water harvesting adopters

The farmers were also asked to give their opinions on how rain water harvesting impacts maize yields in Bisheshe and Nyamarebe (Table 4.5). The findings show that the majority of the farmers agreed that water harvesting improves food security (70%), improves plant height(66%), increases number of cobs per plant (69%) and produces stronger stems (66%). However, a minority agreed that it facilitates more planting times per year (36%) and improves household incomes (31%). These results indicate that the farmers appreciate the value of water harvesting despite the fact that not all of them practice it in maize production.

Table 4.5: Farmers opinions on the impact of water harvesting on maize productivity

Opinion	SA		AG		NS		DA		SDA	
	F	%	F	%	F	%	F	%	F	%
WH improves food security	89	31	112	39	38	13	30	10	19	6.6
WH improves plant height	80	28	110	38	45	16	30	10	23	8
WH increases more cobs per plant	77	27	120	42	59	20	21	7.3	11	3.8
WH produces stronger stems	75	26	115	40	54	19	24	8.3	20	6.9
WH facilitates more planting times	41	14	64	22	100	35	43	15	40	14
WH improves household incomes	35	12	55	19	78	27	73	25	47	16

Community perceptions towards water harvesting for maize production

Another objective of the study was to find out community perceptions on water harvesting for maize production. The famers' perceptions towards water harvesting were analysed and as shown in Table 4.6, the majority of the maize farmers in Bisheshe and Nyamarebe had negative attitudes towards use of water harvesting in maize production. The table shows that 73% agreed that they are expensive to construct and maintain, 61% agreed that they require a lot of labour, 60% were of the opinion for the well-off families, 65% agreed that they cannot hold water for long and 52% said they require a lot of technical expertise. Furthermore, a minority of the farmers agreed with the view that they sustain production throughout the year(34%) and that they apply to small holder farming (18.7%). These results indicated that the farmers have negative perceptions towards water harvesting for maize production.

The findings supported the local leaders who said that farmers generally do not see it as necessary to harvest water in maize production."Farmers are not used to harvesting water in annual crops like maize", said one local leader. This was supported by one extension officer who said, "Farmers see water harvesting as expensive and not worth the profits from maize cultivation"

Table 4.6: Farmers' perceptions of water harvesting for maize production										
Opinion	**SA**		**AG**		**NS**		**DA**		**SDA**	
	F	%	F	%	F	%	F	%	F	%
They are expensive to construct and maintain	90	31	121	42	15	5.2	33	11	29	10
They are labour intensive	70	24	107	37	59	20	31	11	21	7.3
They are adopted by well-off households	71	25	101	35	45	16	43	15	28	9.7
Cannot hold water for a long period	89	31	99	34	33	11	40	14	27	9.4
They require technical expertise	60	21	88	31	66	23	32	11	42	15
They sustain production through the year	31	11	65	23	140	49	30	10	22	7.6
They apply to smallholder farming	25	8.7	33	11	54	19	80	28	96	33

Farmers challenges in Rain water harvesting for maize production

Another objective of the study was to find out the challenges farmers meet in adopting water harvesting practices in maize production. Their responses are summarized in Table 10.

Table 4.7 shows that of all the farmers engaged in maize production in Nyamarebe and Bisheshe, 77.8% had challenges with lack of training, 73.3% had challenges with unreliable extension services, 68.8% had problems with lack funds, 63.25 had a challenge of unreliable rainfall, 52.8% had problems with evaporation and water seepage losses while the minority (34.7%) had problems with the topography.

The responses from the interviews also supported the farmers. To one local leader, "Farmers do not have enough money to hire labour to dig the water retention trenches. Moreover, they lack adequate training"

To the extension staff, "*Unreliable rainfall and the topography makes rainwater harvesting difficult"*

Table 4.7: Farmers' challenges in adopting water harvesting for maize production		
Challenge	**Frequency(N=288)**	**Percentage**
Lack of training	224	77.8
Unreliable extension	211	73.3
Lack of funds	198	68.8
Unreliable rainfall	182	63.2
Evaporation and seepage losses	152	52.8
Topography	100	34.7

The farmers were asked to suggest ways that could help enhance water harvesting for maize production in Bisheshe and Nyamarebe sub counties (Table 4.8). Of all the farmers engaged in maize production in Nyamarebe and Bisheshe, 76.7% said that formation of farmers groups can help address the challenges of adoption of water harvesting in maize production, 69.1% cited financial support from the government, 68.8% suggested frequent extension visits, 68.4% said more training on water harvesting can help while 65.3% said provision of inputs can address the challenges.

The suggestions rhymed with those from the interviews. According to one local leader, *"Financial support from the government can improve water harvesting for sustainable production"*

According to one extension officer, *"Formation of farmers groups can facilitate the training of farmers in water harvesting for maize production"*

Table 4.8: Farmers' suggestions on how to address the challenges in adopting water harvesting for maize production		
Solution	Frequency(N=288)	Percentage
Farmers group formation	221	76.7
Financial support from the government	199	69.1
Regular extension visits	198	68.8
More training on water harvesting	197	68.4
Provision of inputs to farmers	188	65.3

Chapter Five: Discussion, Conclusions and Recommendations

Introduction

This chapter contains a discussion of the study findings, makes conclusions and makes recommendations. The discussion, conclusion and recommendations were done basing on the study findings which were to identify the water harvesting practices being applied by smallholder farmers of Nyamarebe and Busheshe sub-counties, the relationship between water harvesting practices and maize yield, community level of knowledge and perceptions on water harvesting for maize production and the challenges of water harvesting for crop production.

Socio-Demographic Characteristics of the Maize Farmers in Bisheshe and Nyamarebe

The study found that the majority of the maize farmers were male and married. Male farmers are stronger and more able to do the hard labour of rainwater harvesting. At the same time, married farmers are more stable and have many family members that can help in constructing rainwater harvesting technology. These findings agree with ADB (2012) [44] who found that marital status and gender influence a farmers' probability of adopting rainwater harvesting.

The majority were middle aged, had average education, family sizes and ample farming experience. However, significant differences were found between participating and non-participating maize farmers in terms of age and educational background [45]. The participating farmers were younger and more educated than the non-participating farmers. This could be because better educated people are open to innovations. More still, family size provides labour while farming experience has exposed farmers to losses and hence the desire to reduce them [46].

Rain Water Harvesting Practices

The study found that the majority knew about Fanya Juus and Fanya Chini modes of water harvesting. These are rainwater harvesting technologies that involve ditches that collect surface running water. In the maize fields, these can be applied because they involve using gravity to direct water to parts of the maize farm. This finding is in line with Biazin, et al (2012) [4] who argued that use of gravity facilitates rainwater harvesting in field crops.

The study found that farmers received information about water harvesting from a variety of sources. However, the main source of information for the farmers' were radios and fellow farmers. Few farmers were found to be getting information from newspapers and extension officers. A possible explanation for this could be inadequate extension converge in maize production. This corroborated previous studies that revealed that extension services are poor and hence not a main source of rain water harvesting in Nyamarebe and Bisheshe [47].

The study also found that the main practices for rainwater harvesting were use of Fanya Juuand Fanya Chini. To a lesser extent, farmers were also suing side road drains and soak away pits. This could be because these are the modes of water harvesting that are known to them. The farmers were using the rainwater harvesting technologies that they had heard of over the radio. In the absence of more sources of information on rainwater harvesting, farmers will not use technologies they are not used to. This is in line with Mugisha and Fenner, (2014) [13] who did a similar study and came out with similar findings.

The maize farmers were also using other methods of water conservation for maize cultivation. The findings show that the majority were using conservation tillage, manure addition and mulching to conserve water in their maize fields. A small majority were also using ridging to conserve water in their maize fields. This is in line with Mihret and Tesfahun(2014) [6] who found that farmers used a variety of methods to conserve water in cultivation of annual crops.

Rainwater Harvesting and Maize Yields

The study was also interested in finding out the effect of rain water harvesting on maize yields. The study found that maize yields varied with adoption of rainwater harvesting. Higher yields were found to be realized with rain water harvesting technologies compared to yields from non-participating farmers. This finding agreed with past studies (Binyamet al., 2015; Antenehet al., 2014) [2] [33] which reported variability of maize yields with adoption of rainwater harvesting technologies.

The farmers' opinions were also in support of rainwater harvesting. The majority of the farmers agreed that rainwater harvesting improved food security through higher yields, improved plant height, increased cobs per plant and stronger stems. This implied that according to the farmers, rainwater harvesting had benefits in sustainable maize production. This finding agrees with Biazin et al (2012) [4] who found that rainwater harvesting improved plant health and this improved yields [48].

Some of the farmers also agreed that rainwater harvesting facilitated more planting times and improved household incomes [49]. This indicated that rainwater harvesting supports sustainable maize production in Bisheshe and Nyamarebe. Because it allows farmers to have adequate moisture in the soils, they can plant maize at more times than when there is no moisture in the soil. This indicated that rainwater harvesting supports sustainable maize production in Nyamarebe and Bisheshe.

Community Perceptions on Rainwater Harvesting in Maize Production

The study found that community perceptions about rainwater harvesting were negative. A majority agreed that they are labour-intensive, expensive and for the well off. This was an indication that the small scale farmers felt that rainwater harvesting was beyond their means [50]. Any technology that is considered expensive by farmers is likely not to be taken up well because of resource constraints. According to the World Bank (2015) [35], lack of enthusiasm to try the technology despite their knowledge about the importance of the technology often arises from the perceived expense involved in its adoption [51].

The farmers were also of the view that the rainwater harvesting technologies available cannot hold water for long because of resource constraints and lack of training [52]. When the farmers lack enough expertise about a technology, they might be hesitant in trying it out (Ding & Widhalm, 2011) [36].

However, some of the farmers agreed that they sustain production and are relevant in small scale agriculture [53]. They help in water conservation and this opens up the maize growing season. At the same time, the healthy plants produce more cobs and hence better yields for the farmers. This indicated that rainwater harvesting supports sustainable maize production in moisture scanty areas (Itabari et al., 2011) [31].

Challenges of Rainwater Harvesting

The study found that rainwater harvesting was challenging for the maize farmers in Nyamarebe and Bisheshe. First, unreliable extension means the farmers do not receive adequate training in rainwater harvesting. Because of this, water may not be well conserved in the soils for the maize plants. This implies that the maize farmers are not well conversant with rainwater harvesting technologies. This concurs with what Makurira et al (2009)[10] found out from a similar study [54].

Another challenge that was cited by the farmers was financial constraints. Constructing rainwater harvesting technologies requires enough labour and money for workers. However, the farmers lack enough funds and this means they might not afford to construct water harvesting technologies without financial support. This confirms what IFPRI, (2011) [37] found out from a study in Ethiopia.

Another challenge was unreliable rainfall in the study area. The high evaporation rates lead to seepage and the water ends up escaping and not being used by the maize plants. This means that the farmers will not gain from their efforts. This is in line with Biazin et al (2012) [4] who conducted a similar study and came out with similar findings.

However, the study found that the farmers had some ways of coping with the challenges of rainwater harvesting. According to the farmers, formation of farmers groups, financial support from the government, frequent extension visits, and provision of inputs can address the challenges. According to Antenehet al., (2014) [33], training, extension and financial support to maize farmers may improve adoption of rainwater harvesting for maize production in Nyamarebe and Bisheshe

Conclusion

Basing on the study findings, the following conclusions were drawn:

Farmers' age, educational background and marital status were factors affecting adoption of rainwater harvesting in Nyamarebe and Bisheshe. Hence, interventions should target these groups because they are more open to new technologies.

Rainwater harvesting improved maize yields in Nyamarebe and Bisheshe. However, there was limited knowledge about the different water harvesting technologies. This study concluded that low adoption of water harvesting was due to low extension coverage.

Rainwater harvesting was still a challenge in Nyamarebe and Bisheshe. Farmers needed support and training in order to improve uptake. This study concluded that training and government support are key factors in the uptake of water harvesting for maize production.

Recommendations

Basing on the findings and conclusions, the following recommendations are made:

Farmers need to be sensitized on the benefits and technologies of rainwater harvesting. This can be done through up-scaling of extension services so that farmers are given the knowledge and skills of rainwater harvesting.

There is a need to form farmers groups so that extension services in rainwater harvesting can be enhanced to farmers as groups. This would reduce the costs and time that would be spent looking up individual farmers to train them.

Financial support should be provided to the farmers so that they use it in rainwater harvesting. This can be done by formation of groups through which assistance can be channeled.

Other scholars can explore how extension work can be enhanced in rainwater harvesting.

Figures

The Fanya Juu Method of Rain Water Harvesting on A Contour Line

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