GLOBAL RESILIENCE PARTNERSHIP

Socio-economic Effects and Impacts of Road Run-off Harvesting in Arid and Semi-Arid Lands: Case of Mbitini Ward, Kitui County, Kenya.

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Roads for Water

Abstract

In Mbitini agriculture is mainly for subsistence and rain fed with crop production not fully meeting household consumption needs. This area is one of the regions seriously affected by the current drought being experienced in Kenya, whereby the mainstay of agricultural activities has come under pressure. The situation demands innovative solutions to help farmers adapt to the unfavorable drought conditions in their environment.

The main question in this research is whether road runoff harvesting can bring impactful solutions and a positive change to the people of Mbitini. The potential for road water harvesting in Mbitini is high, regarding the improvement and increase of crop production with increased water availability.

This research furthermore focused on finding the impact of road water harvesting on the food security situation in Mbitini ward in Kitui County. Fieldwork methodology included household surveys of adopters and non-adopters of road runoff harvesting, and an additional cost-benefit analysis to determine return on investment of road runoff harvesting structures and crop yield. Results indicate that households that carry out road run off harvesting (RRH) are more food secure compared to their counterparts who don't utilize road water. This is because of increased crop yields and higher variety of crops grown. This benefit is expected to shoot up, if Mbitini farmers adopt more advanced RRH systems as compared to the simple structures consisting of diversion channels to their farms. Options include channeling water from culverts into check-dams or lined ponds, cementing the canals and trenches that channel road runoff to their farms and reservoirs, covering the storage structures to reduce evaporation and for road development bodies to put to priority designs that ensure proper road alignment for road runoff harvesting.

Keywords: Road runoff harvesting, Food Security, Water harvesting, Cost-benefit analysis,

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Acronyms

AGORA - Access to Global Online Research in Agriculture

ASALs - Arid and Semi-Arid Lands

HH - Household

KeRRA - Kenya Rural Roads Authority

KFSSG – Kenya food security steering group

Masl – Meters above sea level

SPSS - Statistical Package for Social Sciences

RRH - Road Runoff Harvesting

RWH - Road Water Harvesting

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CHAPTER ONE: INTRODUCTION

Water is a vital resource to man, animals and plants. No known living thing can function without water and there is life wherever there is water on earth (Rothschild and Mancinelli, 2001). One of the greatest challenges of today is climate change, the case in which climatic conditions shift over a longer period of time. On a local scale in Kenya this has resulted in erratic and unreliable rains for the last 5-10 years. In the last 100 years, Kenya has faced 28 droughts three of them being experienced in the last decade (Huho and Mugalavai, 2010). The frequency and severity of droughts in Kenya, seem to be increasing over time. Huho and Mugalavai, 2010, observed that climate change results to total crop failure, livestock deaths and severe food shortages especially in Arid and Semi-Arid Lands. Agriculture being the largest sector in the Kenyan economy contributing to about 30% of GDP is highly dependent on climate and soil resources (Mariara and Karanja, 2006) Agriculture sector is also the largest contributor to employment and accounts for 70% of export earnings (Mariara and Karanja, 2006).

In Mbitini, agriculture is responsible for food security and standards of living as it is the main livelihood source in the area. Generally, climate change, lack of soil and water conservation measures, and reduced tree cover; have all contributed to low productivity of the agriculture sector in Mbitini ward. As a result, inhabitants of this areas face challenges in sustaining their livelihoods. In many cases there is hunger, diseases and conflicts. Women and children are most affected by water shortage, for they are left with the task to fetch water at long walking distances.

1.1 Road development

Besides these challenges, road construction is an important development in the area to allow access to markets, education and healthcare facilities. Furthermore, the all-weather roads of Mbitini serve as a major intervention in the hydrology of the area acting as catchments where rainfall concentrates into rills and directs and accelerates the flow of water downhill. Without interventions, this runoff causes erosion and sedimentation, taking soils away from roads and roadsides. The drainage systems of roads are catered to get the water away from the road, thereby it is often channeled into adjacent farms, for example through culverts. In this way, the

runoff concentrates and forms a new stream. The outfall channels destroy farms by causing gullying which keeps on expanding each rain season.

Majority of farms that border roads have gulley's that have advanced to a level beyond being corrected by the normal tillage operations. This points out the challenge and potential the area has for Road Runoff Harvesting (RRH). This water can be utilized to recharge underground water reserves and moisture in soils, as well play a role in soil conservation and controlling of gullying. Road runoff can be harvested and be put into various uses including irrigation, domestic uses, watering livestock and other economic activities like making of bricks and clay pots. It can also be used to water tree nurseries, trees and fences around the homestead which can boost income from sale of extra seedlings, timber and firewood (Wachiuri, 2016).

1.2 Road water harvesting potential

Farmers in Mbitini are agro-pastoralists who rely on rainfall for crop and livestock production. The area (Mbitini ward) has bi-modal rainfall pattern with two crop growing seasons in one year. Rainfall patterns in Mbitini are every so often erratic and insufficient for agriculture. The long rains of 2016 which are greatly relied on by farmers failed leading to crop failure and food insecurity in most parts of the country of Kenya, Mbitini included. The government of Kenya declared a national drought emergency on 10th February 2017, with twenty three out of forty seven counties being affected and the number of food insecure people doubling from 1.3 million to 2.7 million Kenyans (Relief web, accessed on 12/5/2017). Kitui County is one of the twenty three counties critically affected by droughts (http://www.nation.co.ke.). As a result, food prices in Mbitini have increased significantly. Maize prices have doubled up threatening food security of this ward whose staple food is maize. (Relief web, accessed on 12/5/2017)

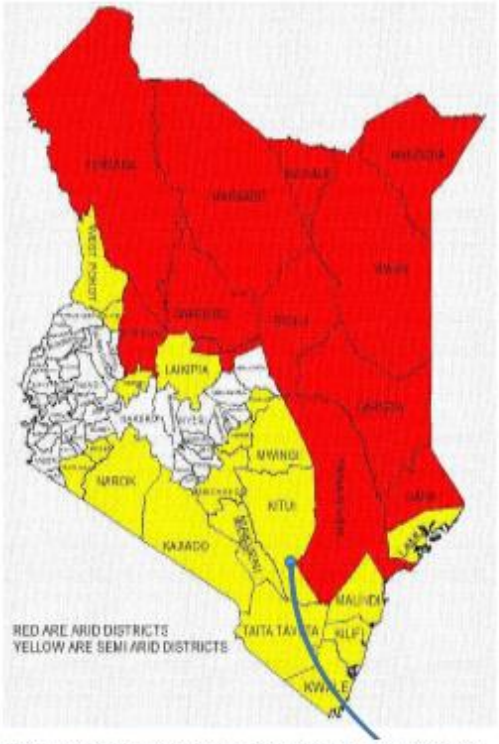
Regardless of the challenges, there is an opportunity of harnessing the road water harvesting potential of this area to improve on productivity and extend the crop growing season. Road water harvesting has the potential of improving water access for domestic, economic and agricultural use if implemented properly and correctly. The "Roads for Water" concept is a new technique to the farmers of Mbitini, it deals with creating multi-functional roads which can also manage water for increased resilience for roads and roadside communities. This involves road water harvesting for the benefit of safeguarding roads, preserving landscapes and making water available for agricultural production (www.roadsforwater.org).

This research comes in to explore and expose the road runoff harvesting potential that could benefit Mbitini farmers to ensure maximum benefit on crop production and food security. The research tries to understand if road run-off harvesting (RRH) has a significant positive impact on agriculture sector (crop production and livestock keeping) in Mbitini. A positive impact of RRH on agricultural productivity means that the technology can be used as a tool to minimize effects of droughts and improve the capability of farmers to thrive in dealing with shocks and stresses.

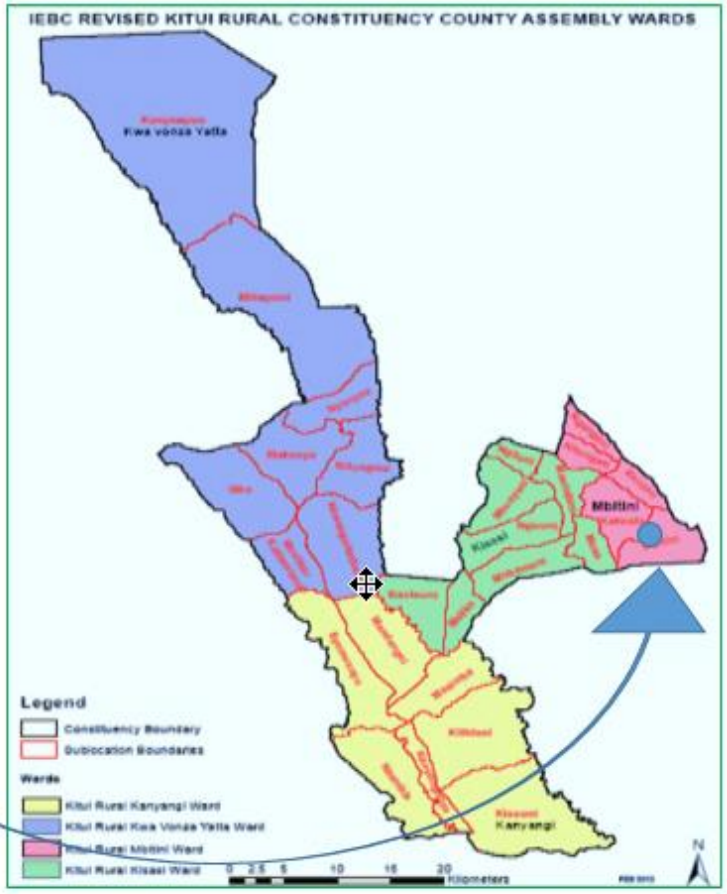
CHAPTER TWO: BACKGROUND

This chapter discusses in general background information of the study area describing geographical positioning of the study area, physical and climatic conditions and administrative boundaries. This chapter also reviews literature from existing sources concerning road water harvesting in Kenya and Sub-Saharan Africa.

2.1 Geographic Location and Description



Pic 1: Map showing where Kitui County is located in Kenya. (Source: WFP/VAM Kenya)



Pic 2: Map showing where Mbitini ward is located. (Source: http://softkenya.com/constituency/kitui-rural-constituency/)

Figure 1: Location of Mbitini in Kenya

Key: Mbitini ward

In pic 1, the red color represents the arid counties of Kenya while Yellow color shows the semi-arid counties of Kenya. The white color shows the wet areas of Kenya. In pic 3, the different colors represent different wards.

Mbitini ward is located in Kitui County which is located in southern part of Kenya. Kitui boarders Tharaka and Meru Counties to the north, Embu County to the northwest, Machakos and Makueni Counties to the west, Tana River County to the east and Taita Taveta County to the south. The altitude of the County ranges between 400 meters and 1800 meters above sea level. According to the 2009 census, Kitui County covers a total area of 24,385.1Km^2 and has a population of 1,012,709. The geology of the County is composed of basement metamorphic rocks with gneisses being found in few hills of the County (Source: www.kitui,go.ke).

In Kitui County, Mbitini ward is located in Kitui Rural sub-county. It covers an area of 131.10 Km^2 and has a population of 24,858 (KNBS, 2009). Sub-locations in Mbitini ward include Mbitini,Katwala, Kitungati, Ngangani and Kanzau sub-locations.

Figure 2: Google earth image of Mbitini town

Figure 2 shows a satellite image of Mbitini market center. The main roads that connect the town to other areas can be seen clearly.

2.2 Climate

The Climate of Kitui is hot and dry and falls under arid and semi-arid zone with most of the County being classified as arid (https://www.slideshare.net/simbagoma/kitui-county-integrated-

development-plan-july-20141). Rainfall patterns are very unpredictable and unreliable. The annual rainfall average for the County ranges between 500 -1050 mm with 40 percent reliability (Khisa *et al*, 2014). The County experiences high temperatures through ought the year which range from 16^0C to 34^0C and the area is not well endowed with natural surface water resources as they are scarce with those that exist; most of them drying up immediately after the rains (GOK, 2009b).

Khisa et al, (2014) observes that Kitui County has been experiencing a reduction in food production because of its vulnerability to changing and erratic rainfall pattern which has adversely affected food production. Rainfall patterns of the region are characterized by short periods of high intensity rains followed by long dry spells with months of March, April, May, October, November, December and January recording some rainfall with the remaining months of the year recording no (zero) rainfall. In her report, Khisa et al, (2014) records that the average rainfall received in most of the years in Kitui County was below 250mm. (Khisa et al, 2014)

The information from Khisa's report concurs with rainfall weather data from world weather online site as shown in figure 3 below. From year 2010, it is evident that the average rainfall amounts for Kitui County have been decreasing drastically. The year 2014, 2015 and 2016 have had average rainfall amounts of less than 300mm and the consistent failing rainfall has led to food insecurity due to the combined effect of crop failure or little harvest from the three years.

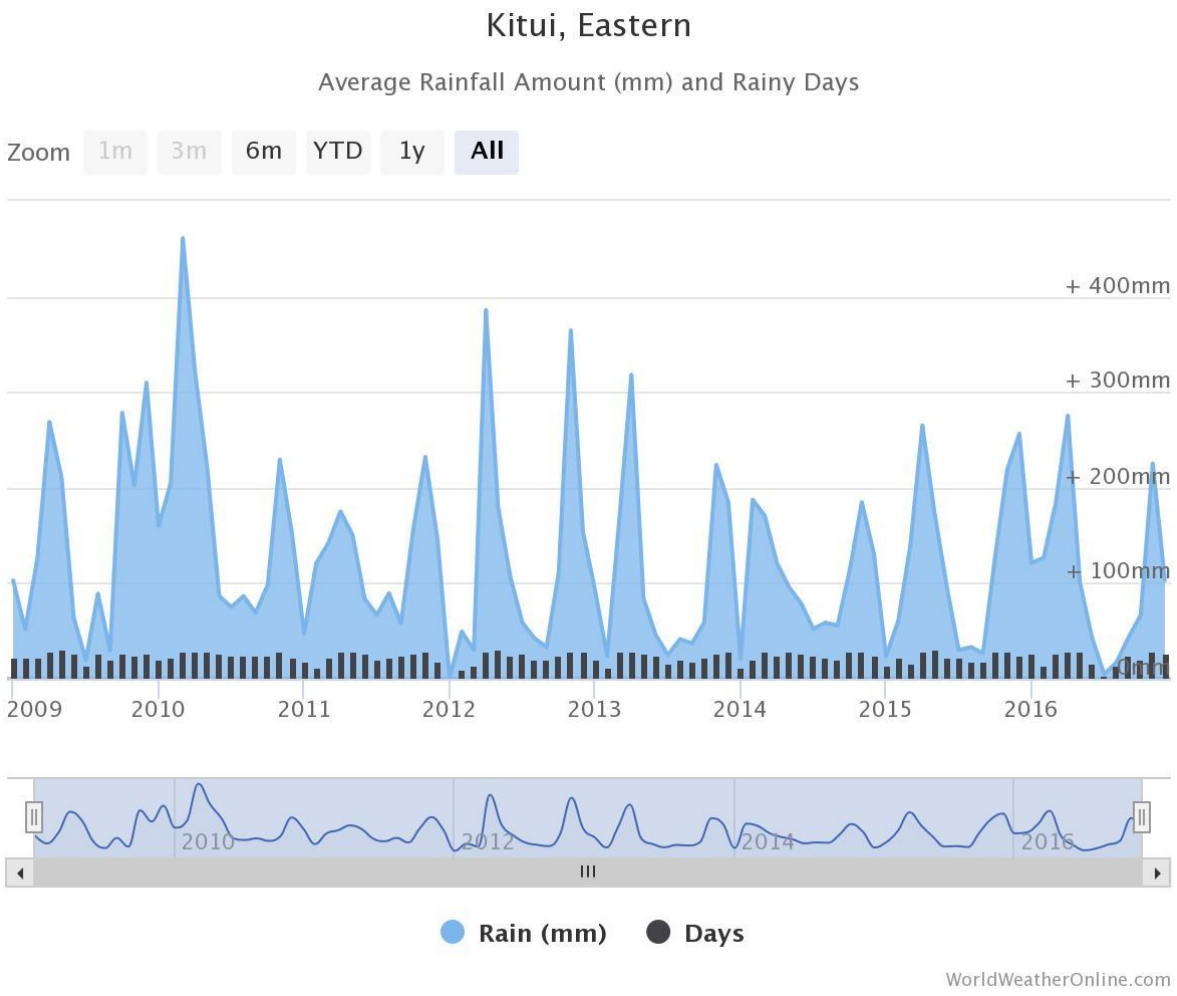


Figure 3: Rainfall distribution from 2009 - 2016 for Kitui County

(Source: https://www.worldweatheronline.com/kitui-weather-averages/eastern/ke.aspx)

The coldest months in the County are between July and August with the hottest months between September and October to January and February. July is the coldest month with temperatures falling to a low of 14°C while the month of September is normally the hottest with temperature rising to a high of 34°C. Due to the high temperatures experienced in the county throughout the year, the rate of evaporation is high with a mean annual evaporation ranging between1800 to 2200mm. Kitui experiences two rain seasons with long rains being experienced as from March to May while short rains are experienced from October to December. The short rains are more reliable than the long rains (Source: https://www.slideshare.net/simbagoma/kitui-county-integrated-development-plan-july-20141).

2.3 Farming and ways of livelihoods

Kitui County is characterized by a fast growing population, water scarcity, falling food production and low resilience to climate change. Agriculture is the main economic activity practiced by dwellers of Kitui County. Livestock rearing and subsistence farming are the main forms of agriculture practiced. The staple food for Kitui residents is maize and beans. Main crops cultivated include maize, beans, cowpeas, pigeon peas, cassava, millet, sorghum, sweet potatoes and green grams. The main types of animals reared include chicken, goats, sheep, donkeys and cattle. The joint impacts of climate change and rapid population growth are increasing food insecurity, environmental degradation, and poverty levels in the County (https://pai.org/wp-content/uploads/2014/07/PAI_Kitui.pdf).

Over 85% of the County's population lives in rural areas and the average population density is sparse with 44 persons/km^2 whilethe average land holding size is 12 ha per person. Majority of Kitui inhabitants (87.3%) derive their livelihoods from agriculture and rely on family labor in the agricultural production. Dairy farming, beef rearing, poultry rearing, bee keeping, rabbit farming and pig farming are the main animal production activities. (https://www.slideshare.net/simbagoma/kitui-county-integrated-development-plan-july-20141) The geology of the County is composed mainly of basement metamorphic rocks. More specifically to the study area, Mbitini's geology area is dominated by metamorphic rocks of gneiss and schist type. All major soil types of clay, loam and sand are found in the study area (http://awsboard.go.ke/wp-content/uploads/2016/07/EIA-KATWALA-MBITINI-WATER-PROJECT.pdf)

2.4 Scientific background on Road Water Harvesting

Road water harvesting involves designing and organizing components, systems and structures to harness and divert run-off from roads and road sides into structures that avail the water for agricultural, domestic, commercial or industrial use. Roads and roadsides refer to all types of transportation ways, from motorways through to rural roads to footpaths and livestock trails (Kubbinga, 2012). In road water harvesting, roads and road sides act as catchments and the water is directed into a reservoir or directly to the farm. Roads are external catchments as they are catchments that lie outside the farm land and are generally longer than 30meters (Kubbinga,

2012). In his thesis, Kubbinga 2012 defines road runoff harvesting as the collection of runoff from roads and roadsides for productive purposes. Productive purposes include crop production for subsistence, for cash crops, for fodder production, for livestock to drink and provided it is clean enough, also for domestic use.

2.4.1 Potential of road water harvesting

Road water harvesting has the potential to transform ASALs to be more productive. If water from roads is not handled properly, the result is erosion, flooding, and siltation/sedimentation; due to the disturbance of natural drainage systems (Woldearegay et. al, 2014). However, the negative character can be turned around with road water harvesting to generate substantial positive impact especially where water is getting scarcer (Woldearegay et. al, 2014). Road water harvesting is a relatively new concept in Kenya, as it has not been carried out in a systemic manner. However, many farmers have taken initiative at their own farms to harvest water and prolong their soil moisture and water availability. The practice has been adopted in various areas such as Makueni, Machakos, Kitui, Nakuru and Laikipia Counties (Ngigi, 2003a). Road runoff harvesting for irrigation has been done as individual effort without any guiding structures. Individual farmers have taken the initiative to collect road runoff on a small scale and direct it to their farms for irrigation (Mutunga & Critchley, 2001).

A report published by Metameta Research in collaboration with Mekelle University of a study carried out in Tigray, Ethiopia in 2014 shows that road runoff harvesting, (RRH) improves in situ moisture distribution in soils and enhances availability of water for crop production. The difference in soil moisture was caused by improved recharge process of underground water which was facilitated by road runoff harvesting structures.

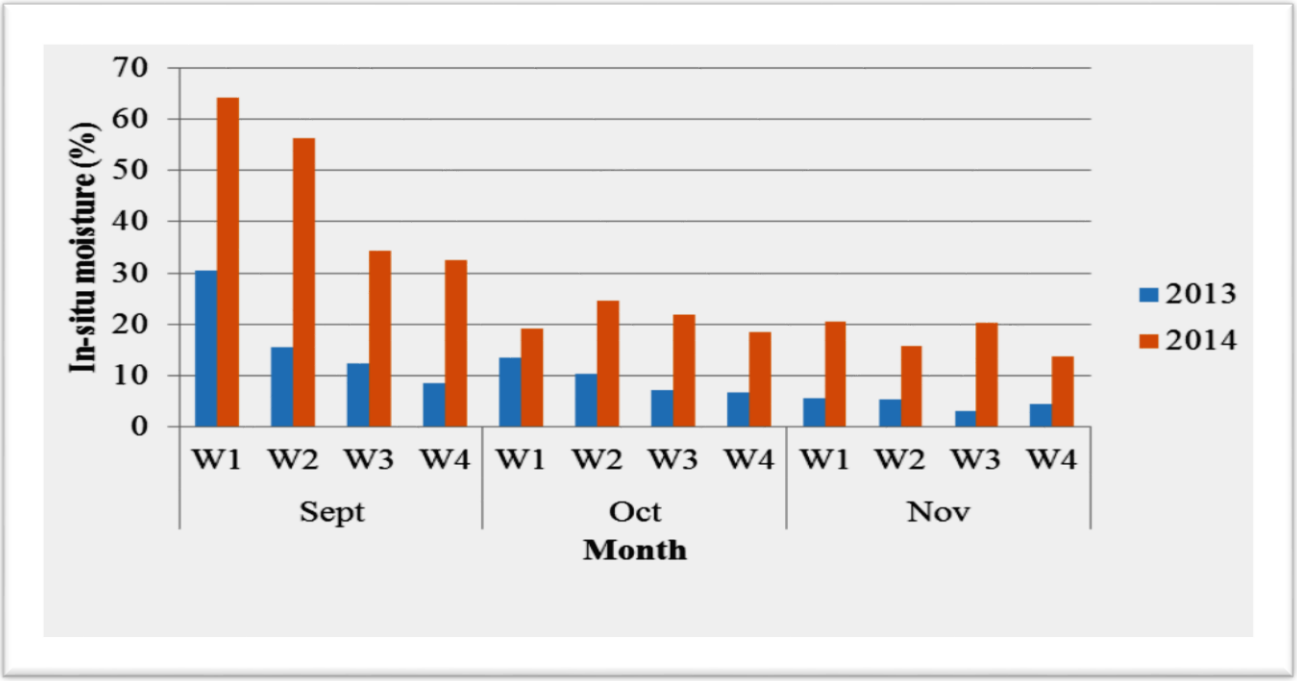


Figure 4: Impact of RRH on in situ moisture content in soils *(Source: Woldearagay, 2014)*

The data proves that there was improved soil moisture by over 100% hence this soil has the potential of supporting crop growth. Consequently, RRH can play a key role in ensuring food security in ASALs. To achieve this, farmers need to first adopt the technology and this can only be arrived at if the benefits of carrying out RRH outweigh the costs of implementing RRH structures in their farms. This study will also look into the profits of practicing RRH in Mbitini by carrying out cost-benefit analysis of costs incurred in constructing RRH structures and benefits accrued from carrying out RRH.

2.4.2 Methods of Road Water Harvesting

Kubbinga, 2012 in his report, highlights two major categories of road runoff harvesting:

1) Runoff harvesting with roadside drain where rainwater is collected primarily from the surface of the road. And 2) Runoff harvesting with culvert where rainwater is collected in the uphill area adjacent to the (rail) road.

Road runoff harvested can further be classified into 3 broad categories depending on the purpose of use of the harvested road water (www.roadsforwater.org). The three categories comprise of:

- Storage structures where harvested road water is stored in ponds, earth dams or cisterns either for the domestic, commercial or for livestock production use.
- Spread over land where road water is spread over bunds, terraces, pits, micro-basins, trenches and borrow pits and used mainly for crop production.
- Shallow aquifer recharge where road water is held in trenches, recharge structures, tube recharge or borrow pits to allow for water to infiltrate to replenish soil moisture content and recharge shallow underground aquifers.

All the three categories listed above can be integrated to provide an effective system that yields maximum benefit to the farmer. For example a farmer can construct canals that directs water from the roads or culverts to terraces in the farm and finally into on-farm pond. This allows to achieve stored water for brick making and other uses, water for agriculture spread over the farmland and aquifer recharge from the on-farm pond. With road runoff harvesting (RRH) there are no restrictions of "specific methodologies" to observe in order to come up with a good RRH system. It just requires farmer's innovation in designing a system that benefits them maximally. Training on road water harvesting should only serve as basic education for farmers to use that knowledge to design and construct systems that work for them. **Error! Reference source not found.** shows some of the innovative ways Kitui farmers can use to utilize road water for maximum benefit. It is key to note that most farmers in Kitui have not been exposed to proper road run-off harvesting technologies such as the ones shown in **Error! Reference source not found.** below.

Figure 6: Road water management solutions

Figure 5: Some of the road runoff solutions that can be utilized by Kitui farmers (Source: www.roadsforwater.org)

In Mbitini there is a high potential for implementation of road runoff harvesting systems. A good road/rain water harvesting system should be designed in a way that it provides communities with access to an on-site water supply, if possible at home, or near their homesteads, or at locality that is easy to access. Similarly, good road/rain water harvesting techniques should ideally involve basic construction techniques, be inexpensive to maintain, have a long functional life span and provide a safe source of water at a relatively low cost when compared to the conventional methods such as river diversion or ground water pumping. A multi-sectoral approach is necessary for successful introduction of road water harvesting to the people of Mbitini (http://www.jkuat.ac.ke/departments/warrec/?p=1873)

Woldearegay et al, (2014) discusses that for water harvesting from roads to be implemented effectively there should be cooperation and strong linkage between multiple stakeholders with clear tasks and responsibilities for each stakeholder. Road side communities, state bodies relevant to road construction and water harvesting and donors should all be involved right from the planning stages to making the designs to implementation of the projects.

2.4.3 Importance of Road Water Harvesting

So, why the emphasis on road water harvesting? To begin with, road water harvesting reduces road maintenance costs by reducing water related damages. Puertas et al, (2015) reports that water-related damages constitutes a major cost factor in road maintenance. If this is checked it means that roads which attract high investments from African governments will become more durable and resilient. Woldearegay et al, (2014) underscores that investment in roads in many countries exceeds that of any other programmes. This is true for Sub Saharan Africa which is a fast growing economic region. With the growth, it's expected that more roads will be constructed.

With road water harvesting, the negative character of flooding, water logging along roads and water related damages on roads is minimized. Secondly, more concentrated run-off from culverts and drains can be directed to reservoirs or directly to the farm land where the water can be used for crop production and livestock keeping, domestic use, brick making, industrial and commercial use.

Nissen-Petersen (2006) lists other benefits that could arise from road runoff harvesting: income from the cultivation of crops and fruit trees, selling water to neighbors, raising ducks, geese, fish and bees in or near open water reservoirs and recharge of wells or dams. Although road runoff can be harnessed for productive purposes (Nissen-Petersen, 2006), the practice remains primarily at individual farmer level despite its apparent ease of application (Wachiuri, 2016). There is neither technical guidance (Critchley & Mutunga, 2003, p152) nor policy direction (Eriksson & Kidanu, 2010, p4) for this kind of rain water harvesting in Kenya (Wachiuri, 2016). One of the gaps to policy formulation is the lack of enough information to guide and inform policy makers. In his report, Kubbinga, 2012 admits that concept of road runoff harvesting is relatively new to researchers and development agents. This research comes in to focus on impact of road water harvesting on food security in Mbitini and contribute to advising policy.

CHAPTER THREE: RESEARCH DESIGN & METHODOLOGY

This chapter covers the research problem, outlines the justification that necessitated the study and highlights objectives for the study, research questions, importance of the study and the methodology in which the study was conducted

3.1 Problem Statement

Mbitini Ward has been plagued by several socio-economic concerns that have continued to undermine efforts geared towards achievements of sustainable development. These include: high poverty levels, poor development and infrastructure, loss of tree cover and land degradation. Underlying factors are amongst others: high dependency on wood fuel and charcoal production, while land degradation emanates from soil erosion mainly due to road runoff and overgrazing induced denudation. Provision of water can play a big role in achieving food security at the household level and enable improvement of the erratic water supply issues, failing harvest and attract investors. RRH is an area that has not been tapped into in its full potential and hence there is a need of maximising on road runoff potential as opposed to leaving the runoff to flow downstream unutilized. This study therefore aims to investigate the impact of RRH in Mbitini. As no research has been done on RRH in Mbitini coupled by the fact that the technology is minimally practised in Kitui County, there is a knowledge gap, which this study seeks to fill. The focus is to gain more understanding how RRH can impact food security dynamics of farmers in ASALs.

3.2 Research Objectives

The overall objective of the study is to examine the linkage between road run-off harvesting and socio-economic parameters at the household level with a key focus on its impact on livelihoods and nutrition standards, in Mbitini Ward, Kitui County, Kenya.

3.2.1 Specific objectives

- To compare and contrast the nutritional situation between households practicing RRH and those not practicing RRH in Mbitini.
- To capture and report on main challenges that may limit successful implementation of run-off harvesting technologies in Mbitini.
- To document best practices of RRH, analyse what techniques are used and what benefits they render.

- To quantify the impact that road run-off harvesting is having on household's food production and access to water in Mbitini.
- To examine socio-economic factors that influence on adoption or non-adoption of RRH technologies in Mbtitini by means of a cost-benefit analysis.

3.3 Research Questions

The main research question of this study is;

In what ways does road runoff harvesting impact the water and food security conditions of agro-pastoralist farmers in ASALs, for the case of Mbitini Ward, Kitui County, Kenya?

To address this, the study seeks to answer the following sub-questions:

1. What is the current condition of household's livelihoods in terms of water and food security? (socio-economic)
2. What interventions of road runoff harvesting are taken?
3. How do these interventions of road runoff harvesting impact water and food security of the livelihoods?
4. What are the similarities and differences in regards to availability of food and water in the home between those practicing RRH and those not practicing?

3.4 Justification and significance of the Study

Mbitini ward, part of Kitui County is categorized as an ASAL which has a challenge of water scarcity and food security. In ASALs, shortage of water during dry seasons is a major challenge and water harvesting remains as one of the most important considerations for enhancing agricultural productivity. There is a knowledge gap as to whether RRH can be used as a tool to counter the effect of droughts and promote crop growth for food security in Mbitini. Findings of this research will as well be applicable to other arid and semi-arid lands of Kenya who face similar conditions as Mbitini. Findings of this research will most importantly be useful to the County government of Kitui to guide in its plans for road development in Mbitini by integrating RRH into its development agendas, farmers to aid them in improving their farming and the academia world as more knowledge concerning linkage of RRH to improved food security will be generated. The study will further serve as a guide and a baseline to sharpening strategies

being used by Roads for Water Consortium as it will investigate techniques to implement RRH and its impact on the socio-economic situation of households.

3.5 Research Methodology

To achieve the study objectives, the research was carried out by comparing socio-economic factors between households currently practicing road run-off harvesting technologies and those not practicing. Key socio-economic parameters of interest to this research include; food security, water access, level of income for households, health and lifestyles and livelihood options. This was achieved by investigating the following indicators.

- If the household produces enough food that caters for the entire household consumption needs.
- If the household produces more than enough (excess) for its consumption and if the excess is sold.
- If the household has enough food throughout the year.
- Some of the coping mechanisms of the household to food shortages.
- If the household practices run-off harvesting technologies.
- If the household has improved access to water.
- If the household has adequate means of accessing water for domestic consumption throughout the year.
- Some of Households coping strategies to water shortages.
- If road water harvesting improves food security and access to water at the household level.
- If the household practices irrigation and the overall impact of this to households food situation (Impact of RRH to yields)

The research was carried out in two phases; before the onset of short rains in November and after the short rain season in February. This helped build a clear distinction of the contribution of run-off harvesting to household's food security and access to water.

The study employed use of structured questionnaires which comprised both closed and open ended questions. This allowed for both quantitative and qualitative data to be received from the

fieldwork exercises allowing for the research to tap into the numbers and as well as reasoning behind the choices farmers are making, insight in their strategies and more.

3.5.1 Methods of data collection

The study was carried out in Mbitini ward which covered Mbitini, Katwala, Kitungati, Ngangani and Kanzau sub-locations. Villages that were covered during the study include Kwa Kasau, Makangani, Kisio, Kamunyuni, Kya Musivi, Muluti, Kimelwa, Syonzunu, Yangalyu and Kanzakame. Each of these villages had respondents who practice RRH and those who do not being interviewed. The study was mainly targeting Mbitini farmers especially those who practice RRH with those who don't being interviewed to establish the contribution and impact of RRH in Mbitini.

Table 1: Villages and their population

Village		Frequency
Valid	Kwa Kasau	14
	Makangani	5
	Kisio	9
	Kamunyuni	6
	Kya Musivi	6
	Muluti	16
	Kimelwa	7
	Syonzunu	5
	Yangalyu	4
	Kanzakame	2
	Total	74

The study was based on the following forms of data; the primary data and the secondary data. Primary data was generated from Household interviews. Secondary data was generated mainly through review of literature of relevance to this study. Collection of primary data involved different methods as listed:

1. field observation

This involved observation of various features and behaviors of significance to the study. Observation was also used to verify the answers given by respondents through the interviews. Photographs were also be taken to provide visual evidence of the various components that will be discussed in the final report.

2. personal interviews

The questionnaire tool used enabled a systematic process of capturing information from respondents concerning various aspects of importance to the study. To eliminate bias the respondents were randomly selected across the sub-locations of Mbitini Ward. The questionnaire comprised both closed and open ended questions. Open ended questions aimed at collecting specific information, attitudes, perceptions and the reasons behind how things work out. Closed ended questions allowed for quantification and comparisons between various variables of importance to the research.

3. Secondary data

Secondary data involved review of literature from existing sources of records from relevant government institutions and other relevant research reports.

3.5.2 Calculating Sample size

Sample size to be used in the study was found through the use of formula shown: (john, 2003)

- $N= Z^2P (100-P) / E^2$
- Where,
- N= the minimum desired sample size
- Z = is the appropriate value from the normal distribution for the desired confidence

When level of confidence is 95%;

- Z = 1.96
- E = margin of error 10%
- P = (Prevalence rate) 20% was the proportion of target population estimated to be carrying out RRH in Mbitini.

$$\frac{1.962 \times 20\ (100 - 20)}{100} = 61.4656 \text{ (Approximated to 62 persons)}$$

62 persons were interviewed during the household questionnaire exercise in November, 2016 before the rains began. An extra dozen (12) people were interviewed on February, 2017 after the short rains. This strategy aimed at capturing impacts of both long rains and short rains to road runoff harvesting in Mbitini.

3.5.3 Data Analysis

Data collected from the field was cross checked and then entered in SPSS version 22, cleaned, validated, bench checked and analyzed using SPSS version 22 and MS EXCEL. The data is presented in this report through graphs, tabulations and narrations.

CHAPTER FOUR: SOCIO-ECONOMIC SITUATION

This chapter discusses results and findings of the study and interprets the meaning and significance of the findings. The chapter focusses on socio-economic data describing characteristics of households like demographics, sources of income and education. This provides a starting point for the analysis on impact of RRH on socio-economics.

4.1 Demographics

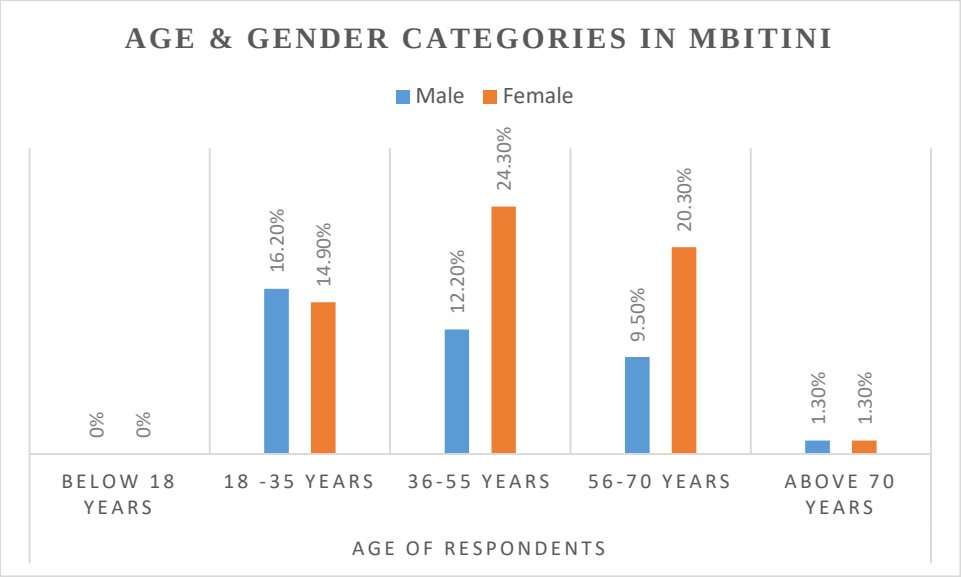


Figure 6: Gender and age of respondents in Mbitini

The average age of respondents was 45 years with most respondents having more than 35 years. This indicates that majority of youths in Mbitini do not practice farming but are engaged in other forms of earning their livelihoods like self-employment (businessmen/women), petty trading, informal and formal employment. The people above the age of 35 years rely mainly on farming as their main source of livelihood. 31.1% of respondents interviewed fall under youth category, 36.5% fall under middle life category with 32.4% of respondents falling under the old age category. Minors were not interviewed as the study targeted grown-ups above the age of 18 years. Farming which is the main source of livelihoods for inhabitants of Mbitini is mainly practiced by those who are between the ages of thirty six to seventy years. Majority of youths do casual work as their main source of livelihood, while most of those employed are between thirty-six to fifty five years. Majority of business and self-employed people are between thirty six to seventy years.

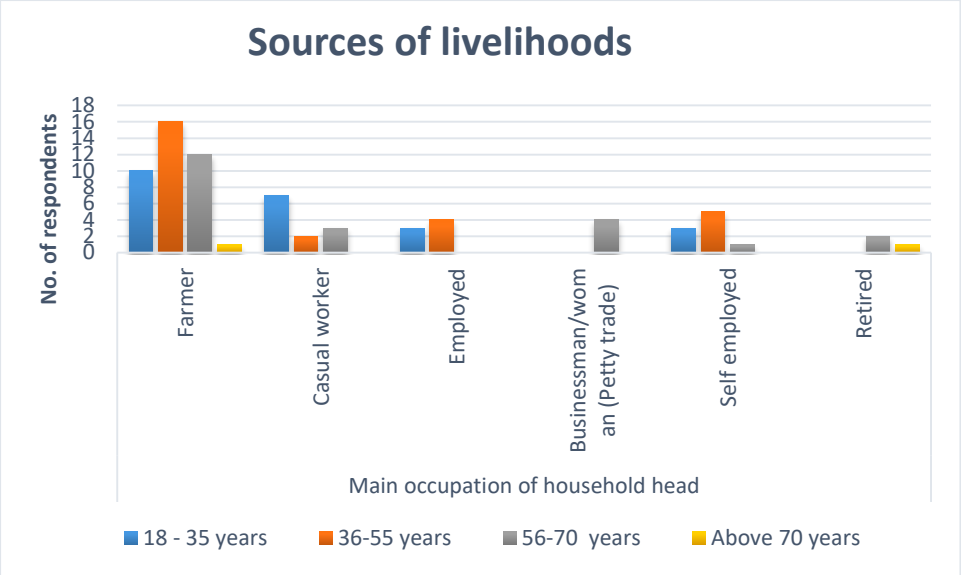


Figure 7: Sources of livelihoods for different age groups in Mbitini

Out of the 74 respondents interviewed, 60.8% were female with 39.2% being male as shown in figure 6.

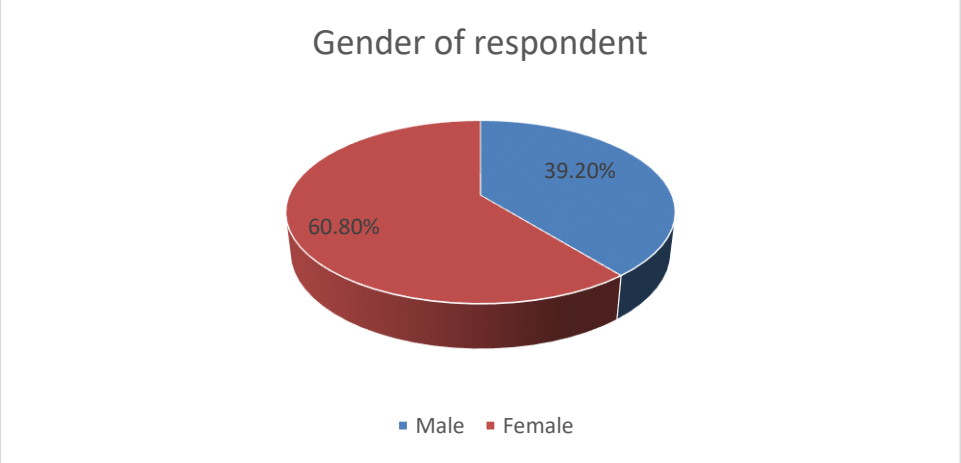


Figure 8: Gender categories among respondents from HH interviews of Mbitini Ward

As shown in figure 6 above, women are more involved in farming than their male counterparts in Mbitini. Traditionally the role of men was hunting, herding cattle, carving and other manual activities. Still, men are the bread winners for the home who mostly carry out activities like brick making, herding cattle/livestock rearing and other casual labor jobs to earn their daily income. For women, from traditional times to date; their role involves farming, domestic work and raising their children. This division of labor explains why the study found out that more women

are involved in farming. Out of all respondents interviewed, 79.03% were married, 14.52% were widows or widowers and only 6.45% were single.

4.2 Household dynamics

The average household size in Mbitini was found to be 6 people per household. From the household interviews, the largest household size had fifteen members with the smallest household size having only one person. The standard deviation for the total number of household members' is 2.86 which infers that the range of household size in Mbitini is 6 ± 2.86. This illustrates that the household heads have a lot of dependents. The large household sizes also means that there is more demand for water and food in Mbitini. Table 2 shows descriptive statistics of average household sizes in Mbitini.

Majority of the households had a male figure who was the head of household. Households that had females as the head, were single parented families or families where the male household head figure had passed away.

4.2.1 Main occupation of household head

Main occupation of household heads in Mbitini; 54.8% were farmers, 16.1% were casual workers, 9.7% were employed, 6.5% were business men and women involved in petty trading, another 9.7% were self-employed and 3.2% were retired. **Error! Reference source not found.** shows this.

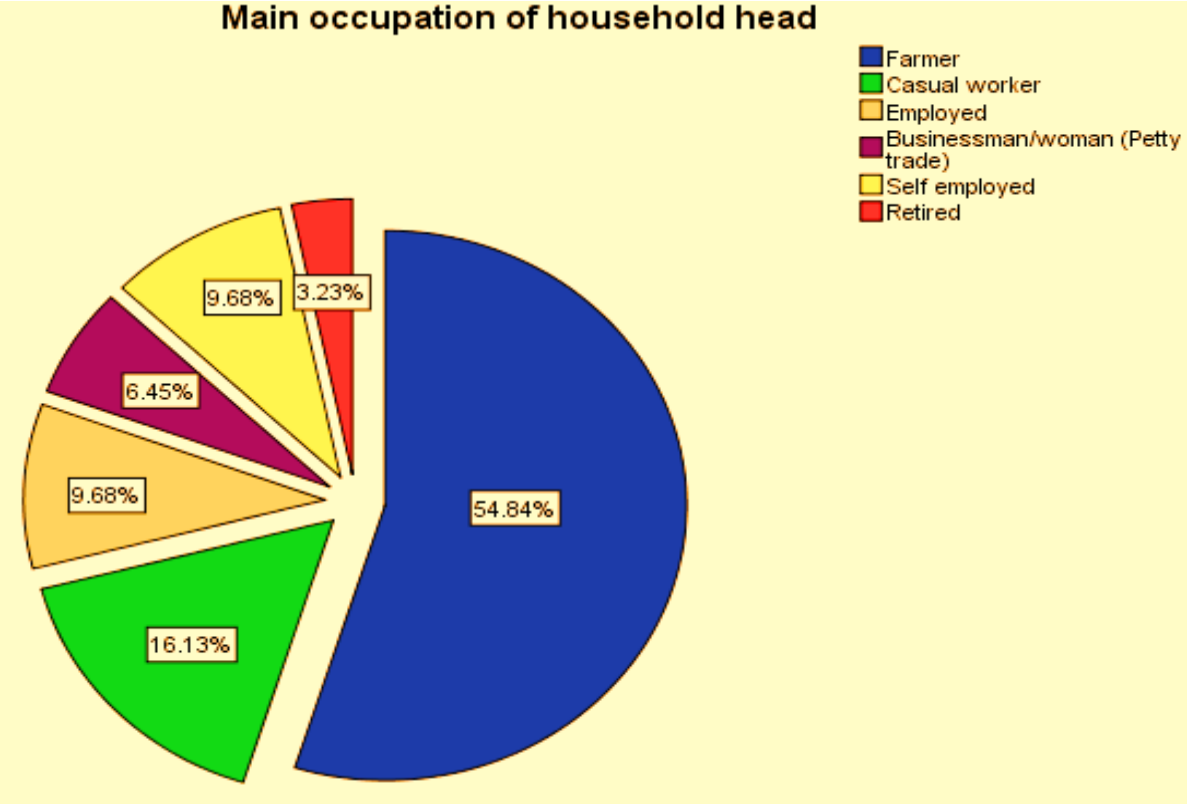


Figure 9: Main occupations of Household heads in Mbitini

As the study found out, main occupation of household head in Mbitini depends on their level of education. On performing chi-square test of independence, a p-value of 0.25 was obtained which infers that there is a significant statistical difference on main occupation of household head and level of education of household head. This infers that those who are better educated hold better occupations like employment, self-employment or enjoy benefits of retirees as compared to those who are lesser educated who mostly occupy positions of casual workers and farmers. **Error! Reference source not found.** shows this point clearly. Those who are illiterate or only attained basic education up to primary school level are mostly farmers. This can be connected to majority of respondents interviewed being elderly people above the age of 35 years. Also, it relates with the fact that traditionally; formal education was not much of a priority. Mbitini being in a rural setting much of the traditional practices are still alive today. Majority of Mbitini residents above the age of forty have little education as they either dropped out after attaining primary education or used not to attend school at all during their school going years. Those who have attained up to college level education are mostly business men/women or self-employed. Most people in Mbitini have multiple sources of income as a means of adapting to situations of crop failure.

Agriculture is practiced by all households of Mbitini. Agriculture therefore serves as a basic livelihood activity, however due to unreliability of the sector in Mbitini, other occupations like petty trading, casual labor, private businesses and employment are given first priority when available. These other occupations depend on availability of resources, markets and labor, willingness to take risks, experience and level of education.

4.2.2 Household Source of Income

The main source of income for households in Mbitini is crop cultivation with over half of the population of Mbitini (61.3%) relying on this activity. This is followed by employment (14.5%) whereby breadwinners (those employed) are not only relied on for provision by their nuclear families but the extended families as well. Other major sources of income in Mbitini include private businesses (12.9%) and casual labor (11.3%). Livestock keeping is an alternative source of livelihood especially during droughts or when there is total crop failure. Chicken, goats and cattle are sold to provide money for school fees, buy food, pay loans and other household expenditures.

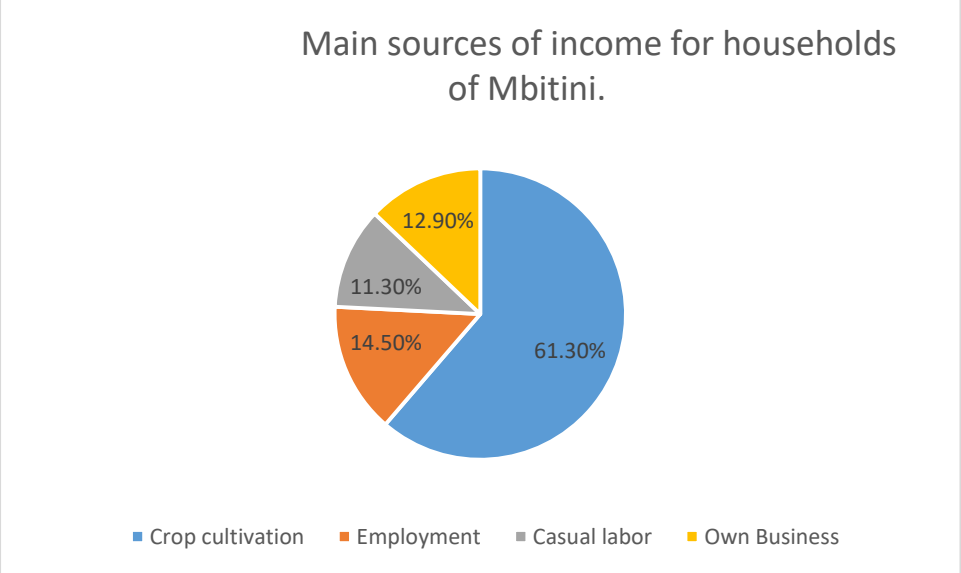


Figure 10: Main sources of income for households of Mbitini

Main crops cultivated for sale include green grams, pumpkins, pigeon peas and fruits (e.g. Mangoes, Pawpaws' Avocadoes). These crops fetch high prices in the market hence they are preferred for sale. Maize, beans, cowpeas, millet, sorghum and cassava are mostly cultivated for household consumption.

4.2.3 Education level

17 out of the 74 respondents were illiterate and had no formal education. 30 out of 74 respondents who are the majority group had only attained a basic education of up to primary school level. 17 out of 74 respondents interviewed had attained secondary school education. 4 out of 74 respondents had attained education up to polytechnic level with other 6 more respondents who had schooled up to college level.

Male HH heads were more educated as compared to their female counterparts. This is partly due to the fact that time immemorial Mbitini has been a patriarchal society where the male child is given more preference especially towards education and leadership positions. However, with modernization; this bias has been eliminated and nowadays both male and female child get equal opportunity of attending school. Figure 10 below shows this.

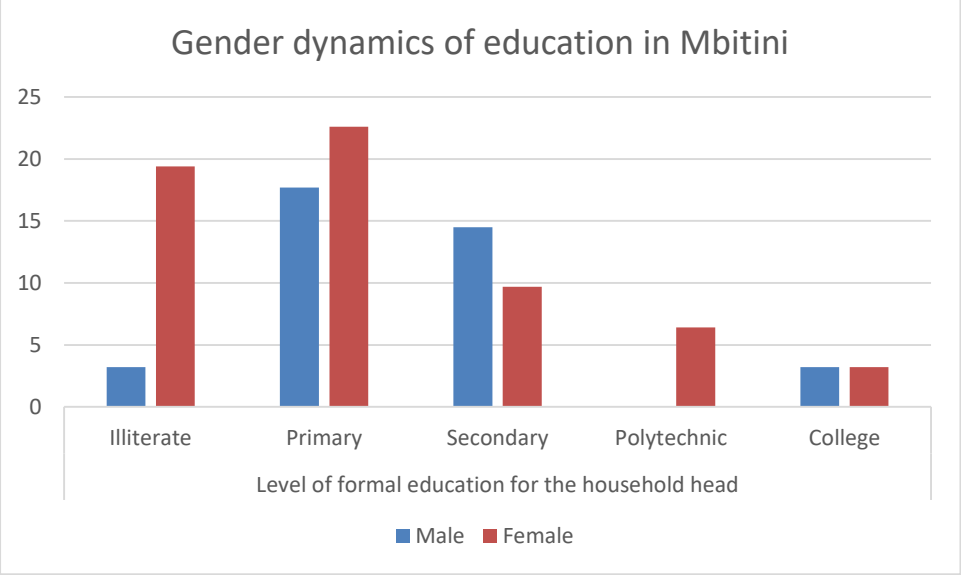


Figure 11: Gender dynamics of education in Mbitini

Conclusion:

From the discussions throughout the chapter, it can be distinguished that households in Mbitini have a high demand for food and water due to large number of people per household (Average household size in Mbitini is six people). Two thirds (71%) of the population of Mbitini relies on farming and casual labor as their main sources of livelihoods. Most of the casual labor jobs revolve around crop farming including preparing land for cultivation, planting, cultivation and harvesting of produce. These people are not guaranteed of a secure income at the end of a certain

period (e.g. like in employment) and therefore they are at a risk of food insecurity when the rains fail and the jobs are not available.

Therefore, it is important to provide solutions that improve crop production and water availability in the home as a measure of countering droughts experienced in Mbitini. As discussed in chapter one and two of this study, road runoff harvesting has the potential to improve on productivity, extend the crop growing season and improve on water access. However in order to attract farmers to adopt RRH, it is necessary to educate them of the benefits they are likely to get from RRH.

As discussed in this chapter, majority of respondents were farmers above the age of 35 years and therefore training and other interventions connected to RRH should target this group. Also, due to high illiteracy levels especially among women above 35 years of age; more women should be targeted for training and intervention and the trainings should be done in the local language, involving easily comprehensible concepts and use photographs and video slides to enable the farmers to easily grasp the concepts. The next chapter discusses on agriculture and water situation in an effort to understand more on the current conditions of households of Mbitini.

CHAPTER 5: AGRICULTURE AND WATER SITUATION

This chapter sets the scene for analysis on RRH impact on water and food security. Results of data analysis starting with the land characteristics, farming characteristics, food security and water resources characteristics are discussed in-depth in this chapter.

5.1 Agricultural production

Aspects of agricultural production discussed here include land ownership, land sub-division, crop production and its challenges and livestock production together with its challenges.

5.1.1 Land Ownership

All respondents said that they own land. Majority of respondents (58%) own three to six acres of land, followed by those who own less than three acres of land (21%). Average land size is 4.174 acres of land. Those who stay close to Mbitini town own relatively smaller land sizes (About two acres of land) as compared to those who stay in the rural parts of Mbitini (Majority own above three acres of land). Out of all respondents interviewed, 75.8% have title deeds with only 24.2% having no tittle deeds. Land adjudication and issuance of title deeds has reduced cases of land conflicts in the area. Some of the reasons given by those who had no title deeds is that they were yet to pick them up from land registry office. Majority of respondents (61.3%) acquired their land by inheritance, 32.3% acquired their land through purchase and the other 6.5% live on rental land.

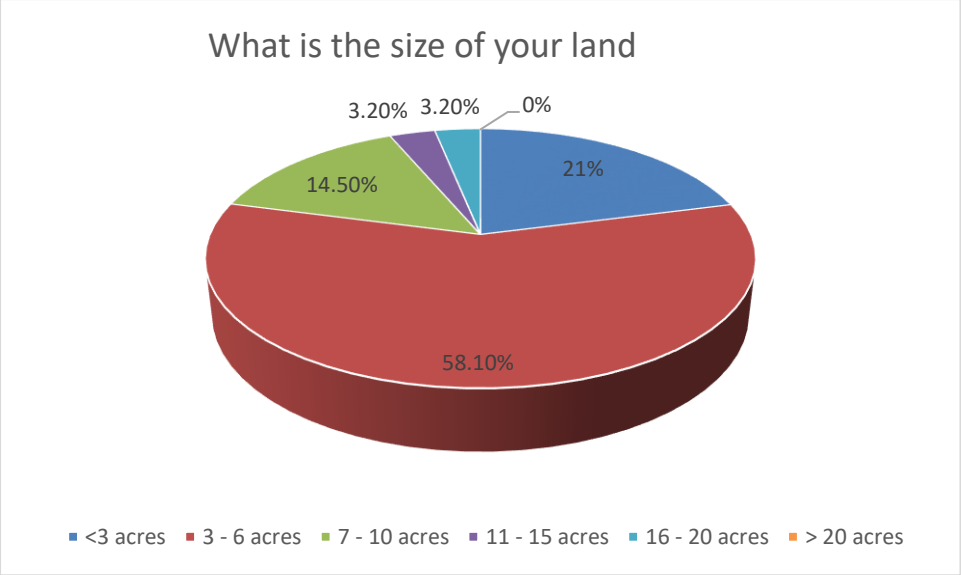


Figure 12: Land ownership in Mbitini

Division of land in Mbitini favors crop production, which is always allocated the biggest sub-division of land, followed after by land allocated for pasture. Mean farm size allocated for crop production is 3.5 acres with pasture taking 1.6 acres of land. Average land size allocated for homestead is 0.125 acres. Other uses include brick making which is allocated an insignificant portion of land. There is no land that is left fallow.

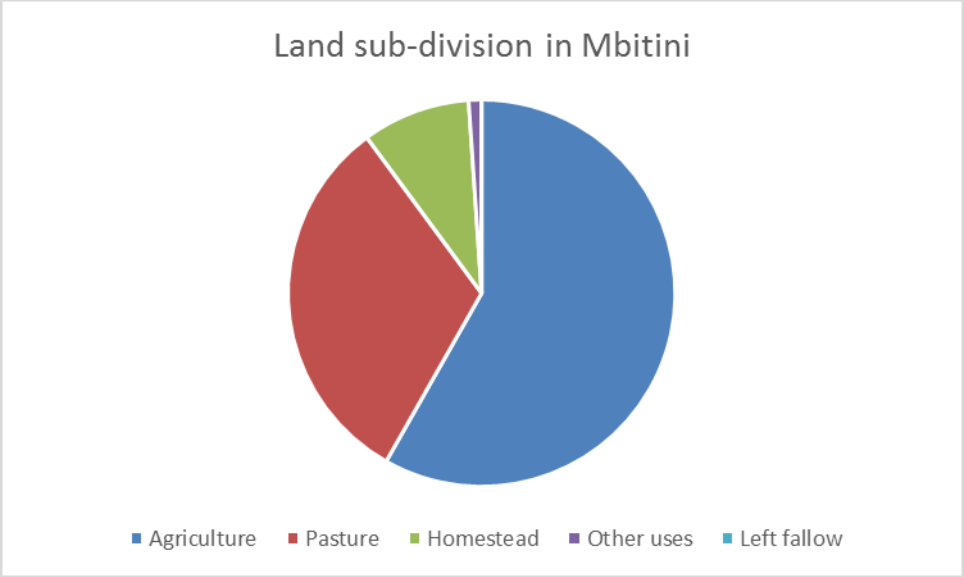


Figure 13: Land subdivision in Mbititni

5.1.2 Main crops cultivated

Main crops cultivated for domestic consumption by interviewed farmers of Mbitini included maize, and beans. Main crops cultivated for commercial purposes include maize, beans, green grams, cow peas and pigeon peas. Other crops they grow for domestic consumption green grams, cow peas, pigeon peas, cassava, sweet potatoes, amaranthus, custard apple, pumpkin, dolichos, mangoes, pawpaws, sorghum, millet, passion, tomatoes, bananas, sugarcane, Kales, spinach, tomatoes, onions and capsicum. Other crops grown for sale include kales, spinach, tomatoes, cassava, onions, bananas and mangoes.

The respondents gave estimates in Kgs of the crops they harvested, total value of production and income earned from sale of harvest from the previous season. Average household production was 294 kilograms of mainly cereals and pulses. The total value of production was 13,105 Ksh per season which means that one household in Mbitini saved spending 13,105 Ksh to buy food had they experienced total crop failure. The average income per household was 4,366 Ksh from sale

of harvest. The findings indicate that despite the erratic rains, crop production is still a profitable venture in Mbitini. There is still room for improved yields with proper water and soil conservation techniques in place. Cereals are mainly used for household consumption as well as pulses. However pulses get sold for money to pay school fees, buy food, clothes and household assets. The reason why pulses are preferred over cereals when it comes to selling is because they fetch higher prices in the market. Normally, a kilo of green grams or pigeons goes for 80 ksh as compared to that of Maize which goes for 25 Ksh. Maize and beans are only sold after farmers have stored enough for their households to last them until the next harvest season. The crops are sold to local retailers.

5.1.3 Challenges faced in crop production

The number one ranked challenge that farmers in Mbitini face regarding crop production is pests and parasites. The second ranked challenge is unreliable rainfall, with third ranked challenge being high cost of inputs. Fourth, fifth and sixth ranked challenges are lack of labor-force (cannot afford costs of hiring people to cultivate), lack of good markets (Produce fetches low prices) and crop diseases respectively. Other challenges mentioned include Human diseases, lack of water for irrigation, poor infrastructure and insufficient knowledge and skills of best farming practices.

5.1.4 Livestock farming

Livestock keeping is a very important part of farming and life to the inhabitants of Mbitini, because they depend on it for income and food security. Being agro-pastoralists, Kamba people of Mbitini value livestock keeping not only as a source of livelihood but also as part of their lifestyle and culture. Types of animals kept include chicken, cattle, goats, sheep and donkeys. These animals are kept for domestic consumption, manure, for breeding, to provide draught power and for sale as shown in table 2 below. Cattle and donkeys are a source of power for purposes like pulling of ploughs, fetching water through carrying water jerry cans, ferrying farm produce, charcoal and firewood to the homesteads and the markets.

Table 2: Types of animals kept in Mbitini

Type of animals Kept	***Animals kept for domestic consumption (Products e.g. eggs, milk & Meat)***	***Animals kept for sale (sale of animals or their products e.g. eggs, milk, skin)***	***Animals kept to provide manure***	***Animals kept for livestock breeding***	***Animals kept for their transportation services (draught power)***
Chicken	Yes	Yes	Yes	No	No
Goats	Yes	Yes	Yes	Yes	No
Sheep	Yes	Yes	No	No	No
Donkeys	No	Yes	Yes	No	Yes
Cows (local breed)	Yes	Yes	Yes	Yes	No
Hybrid cows	Yes	Yes	Yes	Yes	No
Bulls	Yes	Yes	Yes	Yes	Yes

People of Mbitini keep relatively small herds of animals due to their small farm sizes. Constraints to livestock farming in this area includes animal diseases, pest and parasites, distant water points for livestock which take long hours to access, lack of pasture, and theft. These challenges limit thriving of the livestock sector. Most households keep two bulls (which are used in farming), one donkey, a couple of goats (less than 10) and several chicken. However, it is important to note that most farmers keep animal numbers that their land size can sustain. In case the animals give birth and multiply, the farmers sell some of their livestock to ensure they keep a manageable number. Cattle mainly feed on grass while goats feed on shrubs and herbs which grow in plenty in Mbitini. However, during dry spells, farmers are forced to buy feeds to sustain their animals until the onset of rain seasons.

5.2 Food security

The research focused mainly on the status of household food production to determine if what is produced is enough for the household consumption needs. To establish this, the focus is on household family sizes, sizes of farmlands, types of crops cultivated and animals kept, amount of harvests, and experience of respondents with droughts.

The animals kept in the home promote food security as they can be eaten or sold to get money for buying food. This agrees with Sansoucy (1995) who argued that livestock are not only a source of high quality food but equally important, are a source of income for small scale farmers in developing countries. Aside from direct food production, livestock also provide skins, fibre, fertilizer and fuel. They are also important for the socio-cultural sector of Mbitini as they are used as dowry for the bride. Livestock are also used as security when taking loans and they as well represent liquid assets that can be redeemed at any time which increases economic stability of the household. On the other hand, Animals use crops residues as feeds and their wastes is used as fertilizer for crops.

All these promote households food security in Mbitini either directly or indirectly. More frequently, crop production in Mbitini is never enough to fully meet household consumption needs. When respondents were asked whether they buy food, 80.6% replied an affirmative yes with only 19.4 % who don't buy food because they produce enough food for their families from crop farming. Reasons given as to why respondents buy food are as follows:

- After the food we had stored gets finished
- Because I own a small portion of land for farming which does not produce enough food that can sustain us till next harvesting season
- Did not harvest anything from last season (I planted but the crops failed)
- Did not harvest anything from last season (Livestock ate/destroyed all my crops)
- Food I had stored was destroyed by weevils
- To change diet

64.5% of the respondents gave reasons that are connected to failing harvest as to why they buy food. They either harvest nothing or very little that cannot sustain their households until the next

harvesting season. This failing harvest is as a result of lack of rainfall. The other 35.5% buy food because of pests and diseases destroying stored harvest, livestock destroying crops or for the sake of changing diet.

Responses from field interviews show that residents of Mbitini ward do not have enough food for themselves and their families throughout the year, only 27.4% indicated they have enough, the other 72.6% resolve to strategies shown in figure 9 to cope with lack of enough food throughout the year.

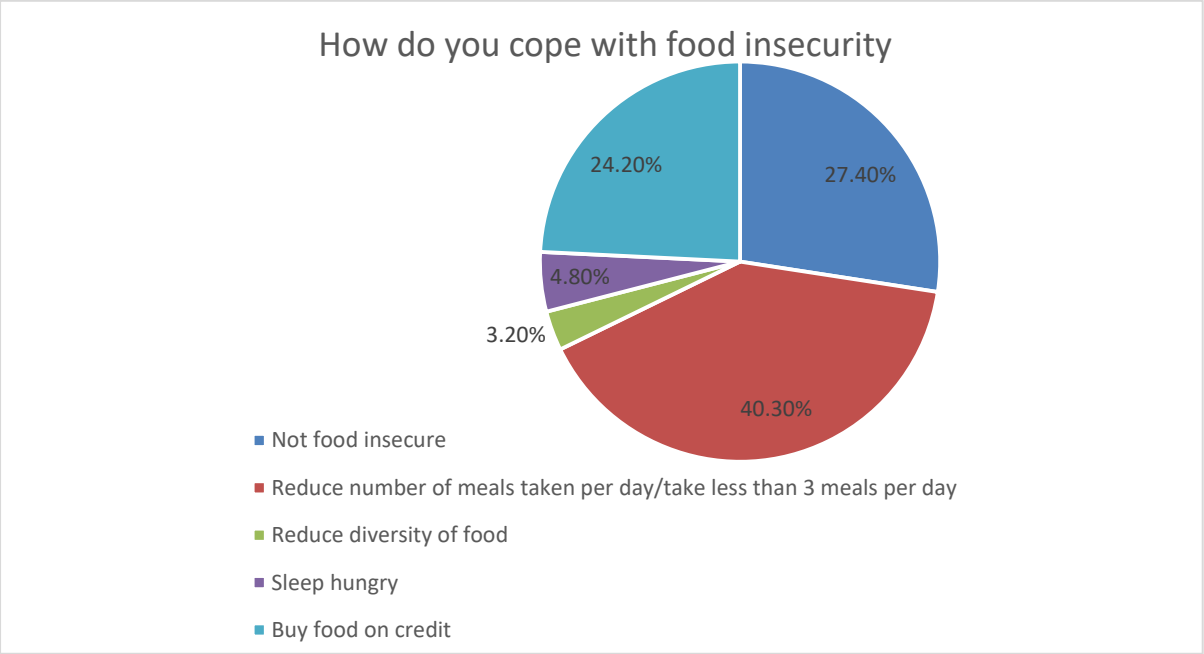


Figure 14: Strategies on how households in Mbitini cope with food insecurity

Crop production from most farmers who practice RRH was higher compared to those who don't practice RRH. From the category of households that practice RRH, majority of respondents (16.13%) said that they have enough food for themselves and their families throughout the year as compared to 11.29% of respondents who do not practice RRH who said that they have enough food throughout the year. More (38.71%) respondents who do not practice RRH said that they don't have enough food throughout the year as compared to 33.87% of respondents who practice RRH and don't have enough food throughout the year.

Also, more (33 respondents) who practice RRH agreed that their food security situation has been improving for the last five years as compared to those (28 respondents) who do not practice

RRH. There was however a general agreement from respondents of Mbitini that food security situation has been improving in the area within the last five years. This is attributed to diverse sources of livelihoods (Employment, casual jobs, private businesses) in the area as compared to the traditional way where almost everyone dependent on farming as the sole source of their livelihoods.

Of the farmers, 16.1% said that they had extra (excess) farm produce for sale, while the others have not. Some of the crops like green grams and pigeon peas are grown purposely for sale (can sell all the harvest from these crops) while crops like maize and beans are grown mainly for household consumption. Average walking distance to the market where farmers sell their produce was found to be 3.2 Kilometers.

5.3 Water resources

Mbitini is naturally endowed with very few seasonal rivers that are dry for the most part of the year. The rivers only flow within a day or two after a rain event. As a result, rivers and sand scooped wells are the main water sources upon which the people rely. Water from flowing rivers is not used by residents as it is usually dirty, contaminated and full of disease causing organisms. Respondents said that they wait until the rivers dry up (the rivers dry up very fast after a rain event) and it's only until then when they make scoop holes from where they fetch. Water from the scoop holes is regarded as good quality water and some households use it for drinking without boiling or treating the water.

During rainy season most households harvest rain water using buckets and jerry cans. This water however does not last them for long (Lasts for about 3-4 days). From field responses, locals use water from scoop holes, rooftops, boreholes and wells for domestic use as it's regarded as clean water. Domestic uses that consume a lot of water include cooking, drinking, washing, cleaning and bathing. Boreholes, scoop holes and wells are perennial water sources. They give forth good quality water which is not salty nor does it either have a bad taste or foul smell. Ponds are seasonal water sources used mainly for watering livestock and making bricks.

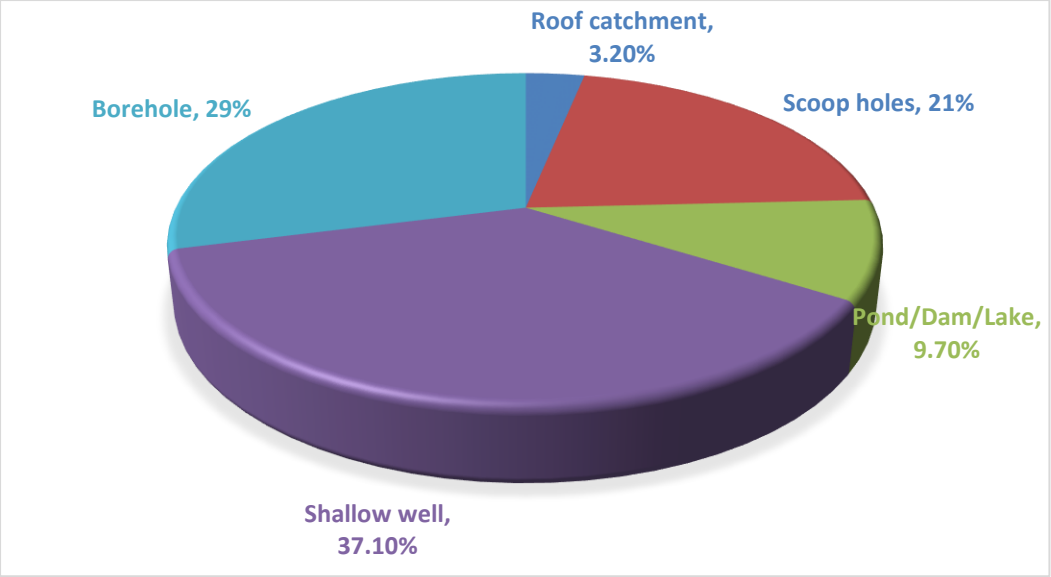


Figure 15: Household's main sources of water in Mbitini

5.3.1 Water Access

The average distance to household's main source of water was found to be 3 kilometers with the average time taken to household's main source of water being 30 minutes. Also, majority of households have their own private wells, while those who don't, buy water from their neighbors. The maximum distance covered to a household's main source of water was eight kilometers with the minimum distance being one kilometer. Likewise, the maximum walking time covered to walk to households main source of water was found to be one hour and twenty minutes with the minimum time covered being only 10 minutes.

5.3.2 Water quality

In regards to nature of household's main source of water, majority (62.9%) said that they rely on perennial sources of water while 37.1% said that they rely on seasonal sources of water. Concerning, the status of household's main source of water, 56.2% said that their main sources of water were protected with 43.5% saying that their main sources of water were unprotected. Most people used lids to cover their wells or fenced their water resources to bar animals from contaminating it.

When asked about the type of treatment method used on their drinking water, 37.1% did not treat their water before drinking it, 8.1% boiled their water with the remaining 54.8% treating their

water with chlorine before drinking it. This helped reduce cases of water related diseases with 46.8% responding that they had no cases of water related diseases in their families within the past one year. However, 37.1%of respondents had typhoid, 4.8% had amoeba and 11.3% of respondents had bilharzia within the past one year. When asked how they regard quality of water drawn, 12.9% of respondents said that the water was of poor quality, 24.2% of respondents being of opinion that the water quality was fair (average), while majority (62.9%) said that they accessed good quality water.

5.3.3 Water economics

62.9% of respondents said that they buy water, with 37.1% replying that they don't buy water. Those that don't buy water own their well or draw water from communally owned water resources that do not require one to pay.

A couple of residents have formed groups whereby they collectively construct a well or a borehole, whereby the members are not required to pay for the water. However outsiders to the group are required to pay. Maintenance costs are paid for using the money collected from those who buy water (Outsiders to the group).

On an average basis, one household in Mbitini uses 4 jerry cans of water per day and spend 64 Ksh per day on water. This translates a total monthly expenditure of 1,923 Ksh on water per household. Water is one of the main areas of household expenditure in Mbitini. The maximum amount of money spend by households in Mbitini in buying water is 150 Ksh/HH/day while the minimum amount spend on water is 10 Ksh/HH/day. Reasons the respondents gave as to why they buy water are shown in figure 16 below.

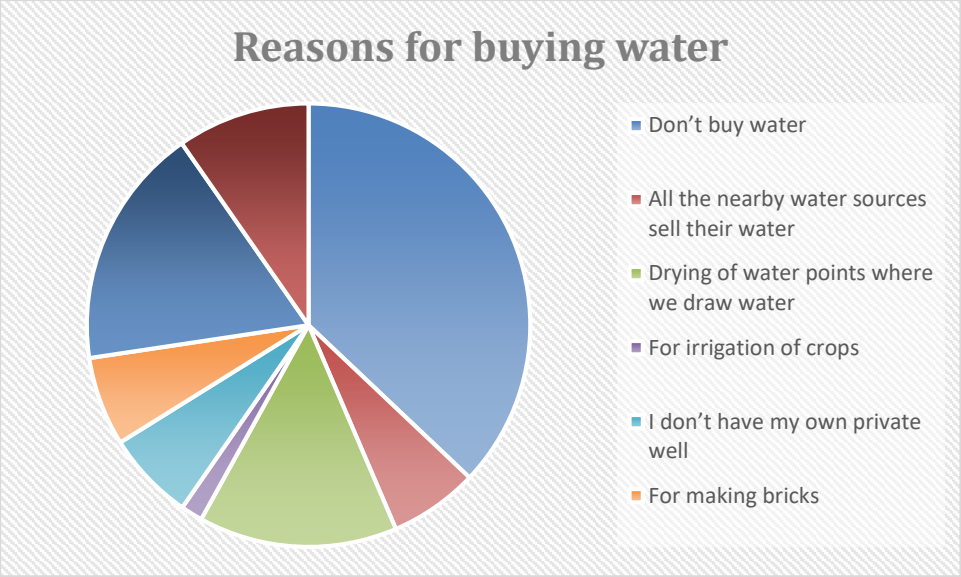


Figure 16: Reasons why Mbitini residents buy water

Main challenges faced in accessing water in Mbitini revolve mainly around water scarcity, droughts, long dry spells, unsafe water points, water related diseases and affordability of buying water. Other challenges mentioned include high costs of constructing and maintaining wells, poverty, long walking distances to water points and harsh terrain.

Adaptation strategies to water access challenges include; constructing their own private wells to ensure a guaranteed supply of water and walking to far distant water points when the usual water points dry out. Adaptation strategies to water quality problems include; boiling water, buying fresh water from water kiosks, treating water using chlorine agents to avoid water related diseases,

Conclusion:

The findings indicate that despite the erratic rains, crop production is still a profitable venture especially when it rains well. Majority of respondents do not have enough food for themselves and their families throughout the year and they counter this deficit by buying food. Most of the respondents gave reasons connected to failing harvest as to why they buy food. They either harvest nothing or very little that cannot sustain their households until the next harvesting season. This failing harvest is as a result of lack of rainfall and proper water and soil conservation measures. RRH comes in as a complimentary technology to add onto the soil and

water conservation measures that farmers are currently practicing. The next chapter looks at the impact of RRH on water availability and agricultural production.

CHAPTER SIX: ROAD RUN-OFF HARVESTING

As discussed in previous chapters, water is lost along roads due to runoff, causing negative impacts of erosion and sedimentation. However, the negative can be turned around into a positive. To harness this potential, run-off harvesting technologies are key. Barron and Okwach (2004), demonstrated that simple rainwater harvesting technologies combined with soil fertility measures can improve agricultural production. In this chapter the methods of road runoff harvesting in Mbitini are discussed and how this is organized by farmers.

6.1 Methods of Road Water Harvesting

There are many different techniques that can be used to harvest runoff flowing from and along roads. The following photographs (**Error! Reference source not found. Error! Reference source not found.Error! Reference source not found.**) give a visual impression of how road runoff is captured by culverts and channeled to neighboring farms in Mbitini. The concentrated runoff from the culverts causes erosion and gulley-formation. Many culverts constructed in the area are designed to drain water away from the roads into the neighboring farms. This has a lot of negative impact to the farmers of which they have been complaining of the huge gulley's in their farms and their fertile top soil being washed away downstream. Farmers lose their fertile top soil and the crops that they had planted too as the increased concentrated flow from the culverts flows downstream. These small streams eventually dry out some distance further downstream. The water does not get enough time to settle down and infiltrate to the soil, therefore recharge of soil moisture and groundwater does not take place. This negative character is not only caused by culverts, but the roads also act as catchments and release water to the neighboring farms. This destruction is a negativity that can be turned around with proper road water harvesting measures in place.

Figure 17: Road catchment in Mbitini

The all weather road acts as a catchment with the culvert concentrating and channeling the road run-off to neighboring farms. The red arrow shows direction of flow of road run-off.

Figure 18: The outfall runoff

The outfall runoff from the culvert flows towards neighboring farms eroding and creating gulleys. Local efforts of planting trees to buffer against the road water runoff are overwhelmed with the runoff concentrating and building up in the culvert to route a way downstream. This has made some locals see road water run-off as a nuissance rather than the pontential it holds.

Figure 19: Gullying as a result of erosion by runoff from roads

Erosion by road runoff intensifies creating channels which form streams during rainy seasons.

The following paragraphs take a look into the awareness on road water harvesting and how farmers implement these techniques in their farms.

6.2 Awareness of Rain Water Harvesting Technologies

Only 14.5% of the respondents indicated of being aware (this small percentage had at least heard of road run-off harvesting) of RRH with the remaining 85.5% having never heard of RRH. Those who were aware of RRH had heard of it from County government of Kitui (3.2%), government agencies/ministry of agriculture (3.2%), MetaMeta (4.8%) and from neighbors (3.2%). Some of the most widely known and practiced RRH technologies in Mbitini include terrace harvesting, on-farm ponds and retention ditches. Those who are currently practicing RRH, only 24.2% knew of other people practicing RRH in Mbitini. Only 8.1% of those practicing RRH had received formal training on road run-off harvesting technologies from N.G.O's, like SASOL, and research institutions like MetaMeta. Measuring the component of adoption rates among those who had been trained on RRH was hard to establish as training done by Metameta was carried out a week before the survey exercise. Therefore farmers had no time to prepare and implement what they learnt from the workshop. Other bodies that had trained Mbitini farmers on RRH only touched on the subject roughly as their training focused more on their mandates like soil conservation and farming practices.

6.3 Cost of constructing RRH system

For a farmer to invest in a RRH system, the benefits derived from the system must outweigh the costs involved in constructing the system. In Mbitini RRH systems are constructed by use of simple farm tools like hoes, fork hoes, wheelbarrows and shovels. With majority of farmers owning three to six acres of land in Mbitini, high mechanization for constructing RRH systems is not necessary. Simple tools used in farming and land preparation can as well be used to construct RRH systems that are efficient and reliable due to small farm sizes. When asked about the source of labor for constructing RRH system, respondents mentioned 8.1% was hired labor, 30.6% of labor was self (the farmers did the whole work by themselves) and 11.3% had no labor involved. This is shown in figure 15 below.

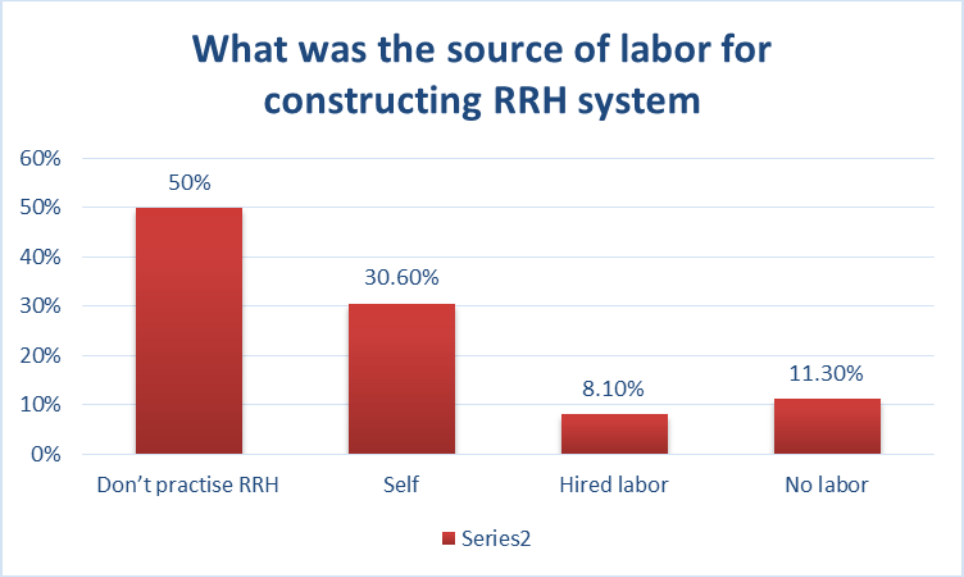


Figure 20: Source of labor for constructing RRH systems in Mbitini

On an average basis, it takes one farmer 10 days to construct RRH systems in his/her farm. Average costs incurred for constructing the RRH systems on a single farm are 2,440 Ksh. During field interviews the maximum expenditure incurred to construct RRH systems was 63,000Ksh where the farm owner employed 3 farmers paying them 350 Ksh per day for 2 months to construct terraces in his farm. Those farmers who utilized family labor for constructing their own RRH systems without employing anyone incurred no expenditure (0 Ksh) as they had access to free labor.

6.4 RRH system designs

The most common method of conveying water from the road to the farm was via canals/trenches accounting for 74.2% of those who practice RRH. The remaining 25.8% had road runoff being conveyed into their farms by rills. The difference between the two is that, canals were constructed by the farmers (RRH adopters) to deliberately divert road runoff into their farms while rills were channels that were created by the road runoff as it sought a way of flowing downstream. The construction of canals and trenches can be incorporated with other soil conservation methods like terracing and on-farm ponds to produce efficient systems that minimize soil erosion and harvest a lot of road runoff.

In regards to controlling siltation, 19.4% of those who carry out RRH; do not control siltation, 3.2% carry out de-silting of sediments in the terraces and 61.3% of respondents use their farm fences while 16.1% plant vegetation to trap sediments.

Figure 21: Sediment from runoff harvested from roads is trapped by farm fence

Of the total respondents practicing RRH, 48.4% do not store, 12.9% store the runoff on farm ponds, and 38.7% store the water in the terraces. The medium of storage does not change depending on seasons whether long or short or rain season. The reason given as to why a high number do not store the road run-off is because of the huge costs and time involved in constructing storage structure like on-farm ponds and terraces. Also, some do not construct storage structures to allow for road runoff to get to the plant by flood irrigation. All respondents who practice road run off harvesting interviewed said that they do not cover the RRH storage

structures to prevent evaporation. The storage structures are not lined either to prevent seepage of water. Reasons given for this was the unaffordability of liners and a cover for shade. Planting of trees along the terraces and ponds to minimize evaporation was not done, since farmers see trees as an obstruction to the farming activities. Figure 16 below shows how RRH adopters in Mbitini store road run-off.

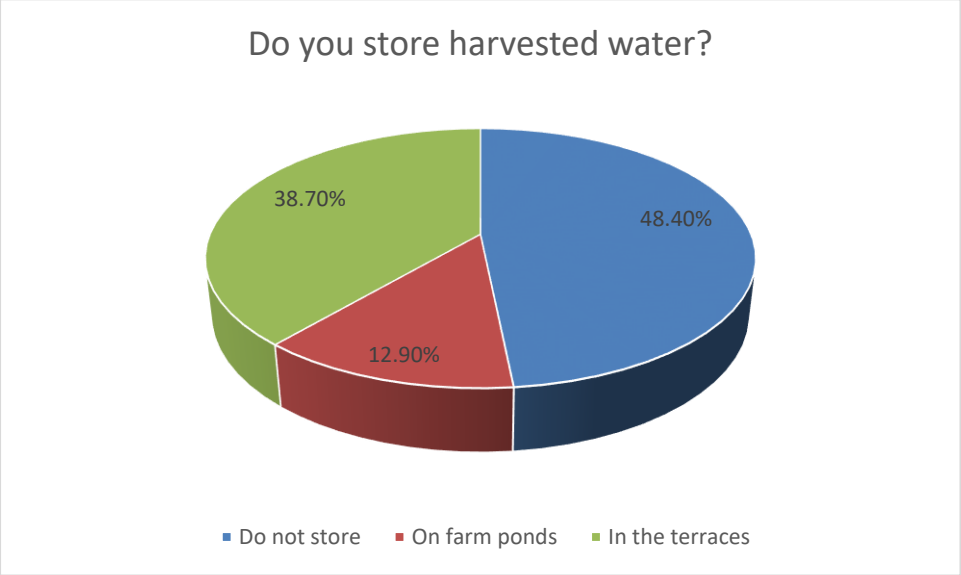


Figure 22: How RRH adopters store harvested water in Mbitini

6.5 Road run-off water use

Harvested water from road run-off is mainly used for irrigation of crops, brick making and for domestic use mainly for watering livestock. There are a few dams in Mbitini who get a sizeable contribution of road runoff into their system by road runoff, however it is not their main source of water. Most often rainwater harvesting is practiced, though it can be argued that road run-off is part of rainwater harvesting, though collecting it in a different way.

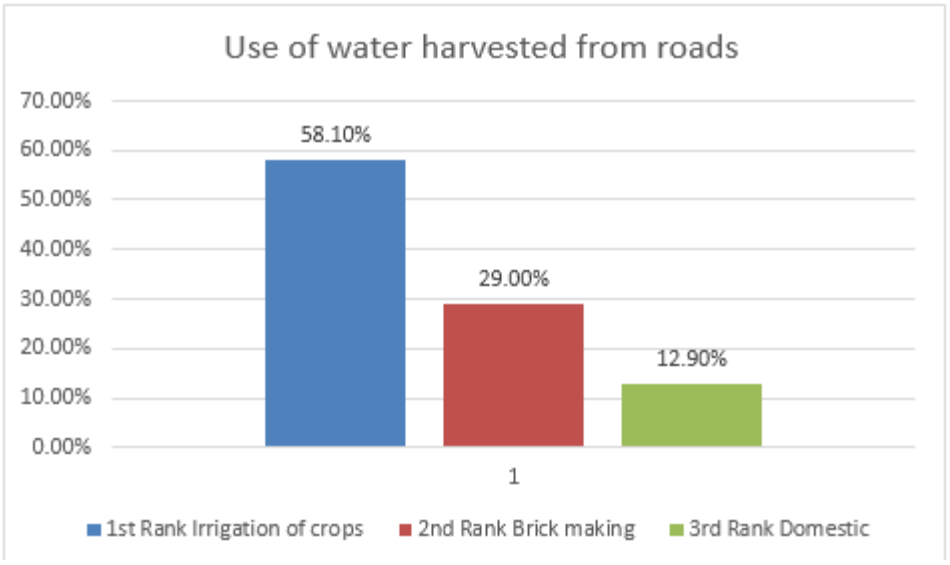


Figure 23: Major uses of water harvested from roads in Mbitini

Road water is used to irrigate the following type of crops in Mbitini; Maize, beans, cowpeas, green grams, pigeon peas and dolichos. Fruits and vegetables that are irrigated with water harvested from roads include Mangoes, kales, spinach, onions and tomatoes. The water gets to the plants through flood irrigation where the road water flows under gravity and floods farmlands allowing for ample time for infiltration of the water and absorption by plants. When asked if the road runoff harvested was sufficient for irrigation during the dry season, all respondents said that it was not sufficient for irrigation throughout the entire dry season. This is because only simple RRH designs exist in Mbitini which are not efficient enough to tap completely into the potential of road water and distribute it well in the farm for maximum yield to be achieved. It's also attributed to lack of training of the farmers by extension officers, government agencies and NGOs. The existing RRH designs in Mbitini are farmers own innovations and therefore training is necessary to upgrade their simple road water harvesting practices to more efficient designs that have better performance.

Error! Reference source not found. Figure 25: Advanced RRH structures in Makuenimakes a comparison between simple and advanced road water harvesting designs in Mbitini, Kitui County and Makueni County respectively. Main differences between the two, is that advanced RRH designs, are more durable, more stable (are lined with cement), more efficient, harvest more water, have storage reservoirs, have silt traps and allow for water to be distributed well within the farm.

Figure 24: Cutoff drain channeling water to the farm

Error! Reference source not found.4: A cut off drain that channels water from the road into the farm. Majority of those who practice road water harvesting in Mbitini construct simple RRH designs such as the one shown on the photograph. Though construction of such a design takes little time and resources (Finances & labor), it is not very efficient since it does not capture and redirect all the road water into the farm and the structure is easily destroyed by siltation. (Source: Bobsammy Munyoki, 2017)

Figure 25: Advanced RRH structures in Makueni

Figure 25: Advanced RRH structures in Makueni5: An advanced RRH structure lined with canals and a sieve gate for trapping silt. The structure takes water into a reservoir. This is an advanced RRH system which belongs to Charity Nomads who stays in Makueni County. A lot of runoff is harvested since the structure draws water from the culvert and also the road.

(Source: Caroline Wachiuri, 2016)

Conclusion:

In Mbitini RRH is used for flooding the farm (irrigation) or stored for brick making, watering livestock or supplemental irrigation. The type of RRH designs utilized in the area are simple in nature and mainly involve constructing soil bunds across roadside drains and excavating channels which provide a route for the road water to get into the farms. The benefit of road runoff harvesting is not felt as much as it should due to a lot of losses of water that occur through infiltration and evaporation. Siltation along the RRH channels and destruction of the soil bunds due to high runoff is also a reason why maximum benefit on RRH has not been felt. Advanced

RRH structures where the channels are cemented, silt traps are put in place and storage reservoirs are properly lined and covered will allow farmers to maximize on RRH.

Still, the road water harvesting techniques practiced in Mbitini have a positive impact on agricultural production and consequently food security. It is critical for those who stay near roads and culverts to take advantage of this road water potential and put it into a good use. This will create a win-win situation where: soils are conserved, soil moisture is replenished, and ground water is recharged. This leads to improved crop production by utilizing the harvested road water for irrigation. The following chapter narrates of case studies from two farmers who are benefiting a lot from road water harvesting in Mbitini.

CHAPTER SEVEN: CASE STUDIES

Two case studies of farmers living in Mbitini are explained in this chapter. From their stories and experience, generally RRH has improved their food security and income generation at the household level. These case studies show a more detailed account of how individual households initiate road water harvesting and how this contributes to their livelihood.

7.1 Mutie Maluki

Figure 25: Maluki's brick making business

Mutie Maluki is a farmer in Mbitini ward in Kitui County. However, he harvests road water mainly for making bricks and watering his livestock. He relies on road run-off water after the long rain season which makes his business thrive. The water harvesting design that he uses comprises of a canal that channels road water into a pond that is located adjacent to the road.

He has constructed an extra pond a few meters from the first pond, so that when road water fills the first pond, it moves via a canal to the second pond where his brickmaking work station is. The ponds also capture rain water. He has a dam liner that he only uses during dry seasons in order to keep his business running even when there is no rain. He lines the second pond only when he is buying water to prevent seepage and removes the liner immediately after he is done with brick making and keeps it in a store. The reason why he does this is that when the liner is exposed to intense sun rays such as those experienced in Mbitini, it breaks easily and that is why he removes the liner after he is done with brick making. The liner is 3 meters by 5 meters long. The first pond only serves as a reservoir for storage and for livestock to drink water from there. When the water in the second pond is used up, Maluki transfers water from the first pond to the second pond where his work station is. After the rains, he is only able to use his ponds for a month before drying up.

7.1.1 Brick-making business

During dry season after his ponds dry up, Maluki is forced to buy water from a local named Saula who owns a borehole. He buys a 20-liter jerry can for 5Ksh. He uses a cart driven by a donkey and a bull to transport water from Saula's borehole which is about 2 kilometers from his home. He buys one hundred 20-liter jerry cans per day for his brick making business. He has

employed two workers whom he pays 1Ksh for every brick they make. The workers make 400 bricks per day. Together with Maluki, the trio makes 1200 bricks per day.

Maluki makes more profit utilizing the road run-off for his business as compared to buying water from Saula. No costs were incurred by Maluki when constructing the ponds and the canals (RRH systems). Maluki did all the work by himself. When using road water, the only costs he incurs are labor costs (800Ksh per day). The price for one brick ranges between 6 – 7Ksh (Averagely 6.5Ksh/brick). If the client wants the bricks delivered to his house he charges an extra 2 Ksh per brick. Generally Maluki makes a profit of 7000 per day {1200 * 6.5= (7800) minus labor costs (800)}

During dry season when Maluki buys water from Saula, he makes a profit of 6500 per day {(7800 – (labor costs-800) + 500-water). Also considering the price of the liner which he bought at 450 Ksh which he installs only during dry season, overall; Maluki loses more money when he is not using road runoff.

Maluki was of the opinion that RRH is very profitable citing June and July as seasons when his business peaks. This is partly water collected from the long rain season, which last him for slightly over a month in his brick making business. Another reason given for why his business peaks in June and July is that most of his clients start constructing their houses in this period (During this period there is usually less work to be done on the farm and hence locals can concentrate on other activities). RRH for Maluki came as self-innovation and he has never been trained on the same. There is still a big potential for Maluki to harness and use road water for brick making, livestock keeping and irrigating crops with better RRH designs and lining all his ponds.

7.2 Daniel Mbiti

Figure 27: Mbiti diverts road water from culvert to his farm

Figure 28: The water flows through a trench into on-farm pond

Figure 27: Mbiti diverts road water from culvert to his farm7 shows the RRH design that Daniel Mbiti uses on his farm to capture road runoff from the culvert to his farm. **Error! Reference source not found.**8 shows the trench/terrace that takes water to ponds. In **Error! Reference source not found.**8, the black pipe takes water to from one terrace to another enabling good distribution of road water in Daniels farm.

Daniel Mbiti is a well-known farmer in Mbitini mainly because of how unique and attractive his farm is. The RRH systems and his farm productivity captures your attention when you pass by his farm. He directs water from a culvert situated next to his farm through a ditch/canal into his farm. The canal connects to a terrace which takes water into a reservoir/pond which discharges its water into another pond after it gets filled up. The ponds are not lined. The RRH system in his farm allows for equal distribution of harvested road water for a big portion of his land. He has also installed a pipe that drains water from the terrace that is connected to the culvert to other terraces of his farm which prevents destruction of the main terrace and contour bund connected to the culvert. He has also created a furrow from the footpath that goes to his home from the road; to channel the runoff from the footpath to his farm. He uses the harvested road water to plant crops and fruit trees. On his farm, Daniel has ten banana trees, eight pawpaw trees, five mango trees and four *matomoko* trees. Crops grown by Daniel include maize, beans, pigeon peas, green grams, cowpeas and cassava. Selling Mangoes is one of his biggest income generating activity, last season alone he earned 13,250 Ksh from sale of mangoes.

Figure 29: Banana trees thriving because of RRH

Figure 30: Mango trees are very productive due to RRH

The amazing thing, is that Daniel incurred no costs to put up the RRH systems on his farm. He utilized free labor from his brother to construct the ponds, the canals, the terraces and the contour bunds. The work took only two weeks to complete. He controls siltation by manual removal or placing thorny bushes at the inlet of the canal to trap silt and allow water to flow to the farm. He has as well utilized an old pipe installed by government to supply piped water to Mbitini as it has been non-functional for a long time allowing him to easily transfer water from one portion of the

land to another. Daniel remarked that the work he put on the farm has paid five-fold and that road water harvesting is very profitable. According to Daniel, his yields are now three times more than what they used to be since he started practicing RRH. Benefits of Daniel's RRH systems includes increased water availability for crops and trees, increased yield and productivity due to increased moisture retention of soil as more water infiltrates the soil, the family is more food secure, increased cash crop production and increased income for Daniel's household.

Inspiration for doing road water harvesting came from learning through observation from other farmers in Kitui and using that to innovate a system that would work well for his farm. He has never been trained on road water harvesting, however; his wife was trained on the same by an extension worker from the ministry of agriculture.

Conclusion:

These two case studies described provide examples of how road runoff harvesting systems are used in households and which benefits it gives. From the narrations of the two case studies, it's clear that RRH has a huge positive impact for farmers who have made an extra effort of designing systems that are more advanced and efficient. Crops like banana trees which require a lot of water to thrive can do so with RRH. As highlighted in the case studies, RRH supports livelihoods like brick making and crop production which means higher and diversified income, and therefore enough food available in the home. With proper RRH in place, households are more food secure and earn income to support household needs. The next chapter takes the general discussion of all the farmers on how they benefit from road runoff systems, compared to those who don't.

CHAPTER EIGHT: COST-BENEFIT ANALYSIS

In this chapter the results from the cost-benefit analysis are presented and discussed. Comparisons are made between those who do runoff harvesting, and those farmers who don't. Also, for farmers who do RRH the return on investment is analyzed. This is done by establishing the costs of construction of RRH systems, and by comparing yields and profits from before and after RRH interventions. In this way the impact of RRH can be assessed in terms of crop yields and economic impact.

8.1 Economic viability of RRH systems

Majority of respondents (83.8%) interviewed incurred no costs in construction of RRH systems in Mbitini. They constructed the structures themselves or either utilized free labor from their families. The average total costs for road water harvesting among these farmers is 2440 KSH. This figure takes into account all costs incurred by farmers in constructing the road water harvesting structures inclusive of labor and materials used. The huge bulk of these costs leaned on labor especially with the construction of terraces for the entire farm.

Results from the study shows that RRH improves productivity in both the short and long rain seasons. Among those practicing RRH, a bigger percentage (77.4%) expressed that they get higher yields since adopting RRH with the remaining 22.6% being of the opinion that with RRH, there has been no change in crop yield from their farms. Respondents who expressed that they get higher yields since adopting RRH, mentioned maize, beans, green grams, pigeon peas and cowpeas as the crops that they often cultivate. It is these crops which yield has been increasing since the farmers started practicing RRH.

The average increase of income of the farmers is 7,273 Ksh, this increase is derived from the increase in crop yields after one cropping season. The difference between before and after was computed and valued in terms of income. The average number of bags that adopters used to harvest before they started practiced RRH was approximately 1 bag. With RRH harvesting, adopters now harvest 2.6 bags. This shows that with RRH, the yield has more than doubled (farmers now harvest almost 3 times more than they used to without RRH). This is shown in table 5 below.

Table 3: Comparison of productivity between adopters and non-adopters of RRH during long and short rain seasons

		How much was your harvest from last season's crop (Kgs)	What was the total value of production in (Ksh)	From sales of crops of last season, what was your total income (Ksh)
Long rain season (March – May)	N	62	62	62
	Households that practice Road water harvesting.	363	16,476	**5,374**
	Households that do not practice Road water harvesting	225	9,735	**3,359**
Short rain season (October – December)	N	12	12	12
	Households that practice Road water harvesting.	584	29,625	**9,329**
	Households that do not practice Road water harvesting	308	29,850	**5,325**

The average income from difference in yield before and after RRH for the survey that was conducted before the short rains is 9,713 Ksh while the average income figure for the survey that was conducted after the short rains is 9,280Ksh. This shows that there were no significant differences between the two rain seasons. This however should not be taken as proof that RRH impacts both long and short rain season in the same degree. More on this is discussed in details in chapter nine of this study.

8.2 Comparison of RRH and Non-RRH

Results from the surveys show that there is clear difference between households practicing RRH and households not practicing RRH. The major indicator for this difference is the income from crop sales between households practicing and not practicing RRH. The assumptions are that a

farmer only sells the excess after storing enough food for the household until the next season and that market prices are non-biased towards adopters and non-adopters.

From surveys conducted *before* the short rains, those practicing RRH earned an average income of 5,374Ksh as compared to non-adopters of RRH who had an average income of 3,359Ksh from sale of produce. This means that RRH adopters earn 2015Ksh more than non-adopters. From the second round of surveys that were conducted *after* the short rain season, RRH adopters earned an average income of 9329Ksh as compared to non-adopters of RRH who earned 5325Ksh from sale of produce. This shows that there is a potential for more income from farm produce, both during short and long rains with road harvesting in place.

During the field exercise there was a clear distinction between portions of farmlands that had been exposed to road run-off and those that do not receive road water as shown in figure 31 below.

Figure 31: Maize crop height difference between portions of land that access RRH and those that don't

In figure 31, yellow line represents a portion of land that had no access to road water while the red line represents a portion of land that had access to road water. The maize crop height in the portion with road water is double the size of maize crop height with no road water. The owner of the farm was amazed that such a small drain channel could cause such a big difference in crop height. Owner of the farm also explained that the maize crop (was subjected to same conditions during planting) was of the same type and was planted in the same day and therefore the crop height was only because of the road runoff.

Portions of farmland that access road water had faster growth of crops (the crops were taller (e.g. height of maize crop) and more dense in population). This indicates a major increase in income for the adopters such that their initial investment in RRH structures is recovered within one season. The exact figures as obtained from the respondents are captured in **Error! Reference source not found.**.

8.3 Profitability of RRH

Profitability of RRH was arrived at by subtracting average cost of constructing RRH systems from average income from difference in yield before and after RRH. The benefit is summarized in **Error! Reference source not found.**4 below.

Table 4: Average benefit of RRH in Mbitini

	Examples of farmers	**Average increase of farmers income (KSH)**	**Average Construction Cost Per Farmer (KSH)**	**Average benefit Per Farmer (KSH)**
	Average (over 24 farmers)	9.713	2.440	7.273
		= 97 USD	24 USD	= 73 USD
Benefit				**= 7.273 KSH**

Average income from difference in yield before and after RRH - average cost of constructing RRH systems = Profit/Benefit

9,713 – 2440 = 7273 Benefit/person.

(7273/9713) * 100 = 74.87% profit

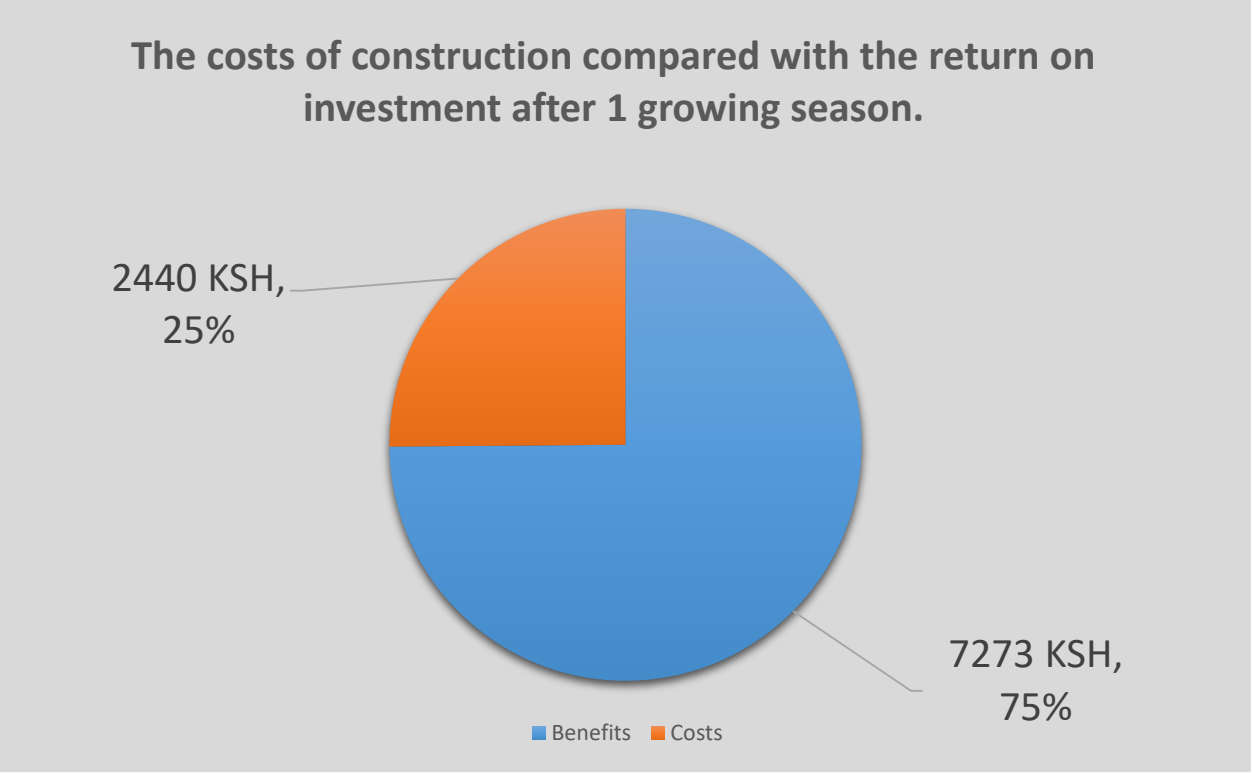


Figure 32: Return on investment of RRH structures after one growing season

The return on investment is 7273 Ksh (75% gain) which means that RRH structures yield profit to the farmers. This is so because of low construction costs as most adopters utilize free labor from family members. Also the simple RRH structures do not require a lot of costly inputs to construct them.

All the farmers who practice RRH interviewed, had settled next to the roads and had direct access to water from the roads. There was no respondent who had experienced conflicts with their neighbors due to RRH. Road upgrading was mentioned as being important to recharging farmer's pond capacity, accessing irrigation water and a means to improving crop yield. Reason given for these responses was that amount of water harvested increase with upgrading of roads. 30.6% of adopters interviewed were of the opinion that RRH is very profitable, 16.1% said its profitable with only 3.2% saying that RRH has not profited them. After performing cost-benefit analysis, results indicate a percentage profit of 74.8%. This benefit means that households

practicing RRH in Mbitini are slightly more food secure than their counterparts who don't utilize road water.

Conclusion:

From discussions in this chapter, it's clear that RRH is a low cost technology and the benefit it yields is immense. Due to increased crop production, farmers could improve their income. Therefore, RRH has a positive impact on households' food security for those that have adopted this technology. From the results it emerges that farmers practicing RRH are more food secure than those who don't benefit from road water. This benefit would shoot up if farmers in Mbitini adopt more advanced RRH systems as compared to the simple structures they now have where they just construct canals to divert road water into their farms. . The MetaMeta having held a workshop on October, 2016 where they trained farmers on RRH; the study presumes that follow up studies will find more people getting into RRH, the designs of the systems will be more advanced and the benefit of RRH will have increased tremendously.

CHAPTER NINE: DISCUSSIONS

9.1 Research methodology

The research was carried out in two phases; before the onset of short rains (November) and after the short rain season (February) which allowed for a clear distinction of how RRH impacts on households food security situation in both short and long rain seasons. This was an effective approach to help advice adopters and those who want to start practicing RRH, of periods when they can maximize on the benefit of road water. Purposive sampling was used to target equal number of adopters and non-adopters of RRH. This was an efficient plan for this study in order to quantify the benefit (profit) by comparing those who carry out RRH and those who don't. For adopters, the study targeted those who stay along major roads of Mbitini and utilized road runoff harvesting. For non-adopters, the study targeted those who stay further away from the roads and had no have direct access to road water and those who those who had settled next to the roads but had not tapped into RRH.

Respondents were interviewed across ten villages of Mbitini ward which shows that there was good representation of the entire ward. The villages were chosen by random sampling hence there was no bias. Sixty two respondents were interviewed during the first survey exercise in November, 2016 while a dozen more were interviewed after short rains in February, 2017.

In both surveys, comparisons between those practicing RRH and those who don't practice were clearly established. However, comparisons of how RRH impacts both short and long rain seasons could not be established clearly partly due to differences in sample size selected during the two exercises. Due to logistical challenges of cost, time and reaching respondents, a smaller sample size of twelve respondents was chosen for the second survey exercise. As a result, the real impact of RRH on both short and long rain seasons could not be established with clarity (No significant differences were identified). Ideally, the two surveys should have had the same sample size of sixty two respondents to have a large sample size to allow for clearer distinctions of RRH between the two seasons to be made. However, this did not affect any other aspect of the study.

9.2 Results

Road runoff harvesting (RRH) is a simple and a reliable technology provided that there is rain and the farms utilizing road runoff are situated within a vicinity of a road. One of the striking findings of the study is that there were no significant differences of how RRH impacts on the two rain seasons. This however should not be taken as proof that RRH impacts both long and short rain season in the same degree. The study had anticipated for higher productivity from the short rain season as usual. The erratic weather conditions messed up the normal situation. The short rains were scanty causing low productivity and the severe drought situation that the country is grappling with now. With RRH, you still need adequate supply of rains to get enough runoff to be collected by farmers and this could be one of the reasons why average income from differences in yields before and after RRH was nearly the same for the two rain seasons (No significant differences).

Also, as discussed in the paragraph above; the result could be due to differences in sample size selected from the two seasons hence clear comparisons could not be made. However, it is important to note that RRH had a bigger positive impact on income earned from yields of short rains (9,280Ksh) as compared to that of long rains (9,713 Ksh). However, the study theorizes that road runoff harvesting has a bigger (significant) impact on short rain seasons as they are wetter and the rainfall is more reliable and predictable. This allows farmers to be better prepared (to construct RRH structures in advance and prepare their farms).

Moreover, RRH has a significant positive impact on household's food security. The technology can be used as a tool of fighting drought for other Arid and semi-arid lands who have similar rainfall conditions as Mbitini. Preferably, RRH technologies are better suited to areas that receive an average rainfall of over 250 mm per year. Farmers who have settled next to roads in ASALs should tap into road water harvesting to increase their resilience to droughts and food security in the home. Other studies on productivity of road water harvesting for irrigation attest to viability of the technology as an improvement on rain fed agriculture to improve food security (Ngigi, 2003a). With the benefits highlighted in this study, RRH is welcome in Mbitini.

However, there is need for training on RRH to improve on adoption rates and the designs utilized by farmers. The study agrees with Kubbinga (2012) that the technology is applicable on the

greater sub-Saharan Africa region and could benefit 2.2 million households or 11.7 million people.

CHAPTER TEN: CONCLUSION AND RECOMMENDATIONS

This chapter provides guidance on some of the interventions and steps that can be taken to promote better road water harvesting technologies, increase adoption rates, and mitigate negative soil and water issues associated with RRH.

10.1 Conclusion

The study focused on answering whether RRH has a significant impact on household's water and food security situations and if the impact is positive or negative. Steps taken to investigate this involved determining current water and food conditions of Mbitini ward, types of RRH interventions taken and how they impact on availability of water and food in homes of Mbitini.

RRH is profitable in Mbitini and has a huge positive impact (75% rise in income) on household's food, water and socio-economic situations. Majority of farmers in Mbitini have gotten into RRH through self-innovation and only a small percentage have been formally trained on RRH. Some of the constraints that have been preventing locals from getting into RRH are outlined below;

1. Weather Vagaries – Unpredictability of weather is one major constraint to RRH as some amount of rainfall is necessary in order for RRH to be successful. With climate change, droughts have become more common where total rain failure events are now being experienced in ASALs more frequently. Where there is no rain, RRH cannot be successful.

2. Accessibility of farmland to roads – Farms that are located next to the roads can easily access road water without any conflicts or having to incur the burden of asking neighbors to allow them to access road water that passes through their farms. Therefore, farms that are not situated next to roads find it hard to get into RRH.

3. Limited Knowledge in RRH – limited knowledge and expertise of RRH in ASALs is another constraint to road water harvesting. RRH is a slightly new concept in the country and the lack of expertise in this field is another constraint of failure of adoption of RRH in ASALs of Kenya.

Due to lack of training most of these RRH initiatives in Mbitini lack maximum efficiency. However, examples of failures with RRH were not identified during or before fieldwork. RRH adopters directly benefit from using road water through improved water distribution in soils and

conservation, improved water use efficiency, less siltation of pond, selling of bricks and water available for supplemental irrigation. The overall result of these benefits are improved crop and livestock production, intensification of agriculture, diversification of sources of livelihoods and improved standard of living from sale of bricks, animals and crops. This means that RRH adopters are better off interms of food security, nutrition and socio-economics as compared to those who don't carry out road water harvesting.

However, with the high profits the people of Mbitini stand to gain, the awareness of RRH as a technology that can change their lives for the better has not been realized. The area has a huge unutilized potential for road water harvesting for improvement of agricultural productivity. Little knowledge and attention is given and available on road water harvesting, whereas the area is fit for RRH technologies implementation. From the results in this report, road runoff harvesting has a positive impact on crop yield in the study area and households that practice RRH are more food secure. Overall, the benefits of RRH significantly exceed the costs incurred in constructing RRH structures and this means better livelihoods for RRH adopters in Mbitini.

10.2 Recommendations

Road runoff harvesting remains primarily on individual farmer level with an outstanding majority of RRH adopters practicing simple RRH systems which are not so efficient and do not maximize on the road water harvesting potential of Mbitini. Also, failure to do RRH means that households will be more vulnerable to crop failure, droughts, soil erosion and food insecurity. The following recommendations are made to advice solutions to issues highlighted in the research

10.2.1 Research gaps

Research institutions like universities, MetaMeta and other research bodies can facilitate students and researchers to investigate more on the following research gaps in Mbitini

- Document more on the current RRH designs used in Mbitini and how they can be up-scaled.
- Monitor annual runoff flows to estimate actual runoff volumes and the impact they have on crop performance. This should be done in a very detailed and comprehensive manner. Technical, economic, cultural, environmental and social aspects of road runoff harvesting should be included and the monitoring should be done on an annual basis.

- Monitor the contribution and impact of both long and short rain seasons on RRH and determine which season yields a greater benefit to farmers who carry out RRH.
- Investigate whether and how RRH can contribute in increasing resilience in terms of being better buffered to drought situations

10.2.2 Maximizing on the benefits of RRH

The Potential for road water harvesting in Mbitini is high. The County government has been involved in construction of culverts along the major roads of Mbitini and the work is still on-going. All the culverts are designed and placed in such a way that they concentrate and channel water from the roads into the neighboring farms. During the fieldwork some locals complained that the County is putting an extra burden on them by channeling road run-off to their farms which erodes and carries away fertile soil. The challenge for farmers, County officials and Road constructors alike, is to turn this negative character around by road water harvesting. Based on the research, the following recommendation are made to address various concerns highlighted throughout the study report.

Training on RRH techniques and horizontal learning

Institutions like MetaMeta and the County ministry of water and agriculture can educate farmers near the roads, to use the potential of RRH for cultivation. So to sensitize farmers and discuss and share on the different technologies to implement. After an initial workshop, follow-ups should be done by extension officers to help farmers in the technical design and laying of structures (ponds, terraces, trenches, canals, cut-off drains and furrows). Also technical support on controlling evaporation, erosion and seepage is necessary. Furthermore, monitoring efforts will map the impact of the RRH on farms and how effective the technology proves to be.

During trainings and workshops, model farmers who have been benefiting from utilizing RRH technology can be invited to narrate of their experiences with RRH. Their cases can be used as example to encourage more farmers to adopt RRH. Organize farmers to form groups that will be involved in exchanging ideas to improve on their farming with RRH. Each group should be led by a model farmer who already utilizes RRH and has felt a positive benefit of RRH. Social gatherings like the chief's *baraza* to also be used to discuss and organize learning experiences among farmers. Religious and community leaders can also be trained on the technology, so they

become ambassadors of the technology to the farmers to create awareness and sensitization of RRH.

Multi-disciplinary integration

Road runoff harvesting to be adopted/incorporated into relevant sectors that deal with road infrastructure, water and agriculture components. This will allow for proper planning and budgetary allocation for activities that relate to RRH as opposed to irresponsible draining of road water.

Road water harvesting to be incorporated in road construction and design

Kenya rural roads authority (KERRA) can carry out an inventory of all sites that they are planning to construct culverts and invite locals from those areas and train them on how to utilize the road water channeled to their farms to prevent erosion and improve on farming. KeRRA can also itself incorporate water harvesting in their design and construction of roads. And they can assist farmers with their machinery when they upgrade/maintain the road.

Impact monitoring and promotion

Monitoring and evaluation (M&E) on adoption and performance of RRH to be also done at the level of policy implementation at the County level.

- Furthermore, MetaMeta can support monitoring efforts which will map the impact of the RRH on farms and how effective the technology proves to be. Documentation of the impact and best practices can help in further promoting RRH to other ASALs to increase resilience. Use of media and magazines is recommended to promote and make farmers aware of road runoff harvesting. The media should as well be used to advertise workshops and trainings for interested farmers to attend and access information on RRH. This can be a way to invite farmers from other areas to share and learn through discussions in the media.

Financial arrangements

Both governmental and non-governmental organizations should identify suitable funding mechanisms for improving RRH in Mbitini since it's been identified in this report that RRH is beneficial to farmers. The funds can be invested in training programs and promoting awareness of RRH through media. Cash incentives can also be used to attract competition among farmers of

the best RRH designs. Both governmental and non-governmental organizations should intervene in providing locals with pond liners to reduce seepage of water from ponds.

County and national governments to find donors who will invest in promoting development of RRH in dry lands of Kenya. This will be achieved through capacity building by doing trainings, workshops, visiting model farmers to learn from them and provision of necessary inputs for construction of RRH systems. This will ensure that farmers do not only have the skills but they replicate the best designs that they have learned and innovated on their farms.

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Annex 1: House Hold Survey Questionnaire

Socio-economic Effects and Impacts of Run-off Harvesting in Arid and Semi-Arid Lands: Case of Mbitini Ward, Kitui County.

Interviewer …… QUESTIONNAIRE NO……..

Place of Interview/Village …… GPS Coordinates X…..... Y……

Consent from respondents (To be read to each respondent).

We are students of SEKU carrying out a survey on socio-economic impacts of run-off harvesting in Mbitini area. Your household has selected for this interview to gauge your knowledge, adoption and the effect that use on non-use of road water harvesting has had on your household. Your participation is very important and valuable to help more people with road water harvesting. Feel free to share the information you want. We estimate to only take 60 minutes of your time and your cooperation is highly appreciated.

Consent from respondent given _____

Household practices road water harvesting (RRH)? (1) Yes ☐ (2) No ☐

A. 1.0 RESPONDENTS PERSONAL DETAILS

1.1 Name of respondent _____ 1.2 Date _____

1.3 Gender {1} Male ☐ {2} Female ☐

1.4 Age (years) _____

1.5 Marital status: {1} Single ☐ {2} Married ☐ {3} Divorced ☐ {4} Widow/Widower ☐
. {99} Others *(Specify)* ☐

1.6 Relationship of respondent to head of household:

{1} Self ☐ {2} Spouse ☐ {3} Son ☐ {4} Daughter ☐ {99} Other relatives *(specify)* ☐

1.7 Number of Household members: (including the head) _____

1.7.1 How many Male adults? _____

1.7.2 How many Female adults? _____

1.7.3. How many Male children? _____

1.7.4 How many Female children _____

1.8.0 Geographical Location _____ 1.8.1 Sub-location _____

1.9 Main occupation of household head:

: {1} Farmer ☐ {2} Casual Worker ☐ {3} Employed ☐ {4} Unemployed ☐

{5} Businessman ☐ {6} Self-employed ☐ {7} Retired ☐ {8} Housewife ☐

{9} Others (Specify) e.g. sand seller, sand broker, charcoal burner/seller, basket weaving etc, _____

1.10 Level of formal education for the household head:

{1} Illiterate ☐ {2} Primary ☐ {3} Secondary ☐ {4} Polytechnic ☐ {5} College ☐
{6} University ☐

1.11 Number of household members in school? _____

Level of education	Primary school		Polytechnic		Secondary school		Tertiary (College/University)	
Gender	M	F	M	F	M	F	M	F
Total number								

B. 2.0 Farming and production

2.1 What is the size of your land?

{1} Less than 3 acres ☐ {2} 3-6 acres ☐ {3} 7-10 acres ☐

{4} 11-15 acres ☐ {5} 16-20 acres ☐ {6} Above 20 acres ☐

2.2 How is the land used? (in terms of land use and acreage)

	Land Use	Size in acres
1	Used for agriculture	
2	Used for pasture	
3	Used for homestead	
4	Left fallow	
5	Other (specify)	

2.3 Do you have a title deed for your land? {1} Yes ☐ {2} No ☐

2.4 How did your household come to acquire the land?

{1} inheritance ☐ {2} Rental ☐ {3} Leasing ☐ {4} Purchased/bought ☐

{5} Don't know ☐ {6} others *(Specify)* ☐

2.5 What crops do you grow on your farm; which animals do you keep? Please indicate if the crops/animals are for domestic consumption or for sale, or both.

	Crops/animals	Domestic consumption	Sale
1			
2			
3			
4			
5			
6			

2.6 Rank in order of most important, the top 5 constraints that you and your household face in your farming? (Multiple answers accepted) (Rank 1-Most important, 5-Least important)

Constraints	In crop production	Livestock production
(1) Diseases		
(2) Pest/parasites		
(3) High cost of inputs		
(4) Insufficient water for irrigation		
(5) Lack of markets		
(6) Poor infrastructure		
(7) Unreliable rainfall		
(8) Human diseases		
(9) Lack of labour-force		

(10) Theft		
(11) Insufficient Knowledge & Skills		
(99) Others *(Specify)*		

C. 3.0 Water Access and use

3.1 What are the characteristics of household's main sources of water?

Source of water	{a} Distance (Km)	{b} Walking time to water source (Minutes)	{c} Type of water source – Permanent (P) or Seasonal (S)	{d} Status- (P) Protected =1 (U) Unprotected =2	{e} Treatment Method Used	{f} Quality – 1} Very poor 2} Poor 3} Fair 4) Good 5} Very Good
(1) Rock catchment						
(2)Stream/River						
(3)Pond/Dam/Lake						
(4)Spring water						
(5)Shallow well						
(6)Borehole						
(7)Piped/tap water						

(8)Harvested rain water						
(9) Road drainage						
(10)Water vendors (Buy)						
(11)Bottled water (Buy)						
(12)Buy from water kiosks						
(13)Others *(specify)*						

3.2 Do you buy water?

{1} Yes ☐ {2} No ☐

If no skip to question 3.5

3.3 If yes, approximately how much do you spend on buying water per day?

_____

3.4 What are your reasons for buying water?

_____

_____

_____

3.5 Which challenges do you face in accessing water within your locality (Rank in order of importance. 1-biggest challenge …… 5-least challenge)

(1) Long walking distance ☐ (2) Unsafe water points ☐ (3) Water related diseases ☐
(4) Water scarcity/Droughts ☐ (5) Harsh Terrain ☐ (6) Poverty ☐ (7) Unaffordable H_2O ☐
(8) Others *(specify)* …… ☐

3.6 How do you overcome these challenges? _____

3.7 Has any member of your household been diagnosed with the following water related diseases within the past 1 year?

(1) Typhoid ☐ (2) Amoeba ☐ (3) Giardiasis ☐

(4) Cholera ☐ (5) Bilharzia ☐ (99) Others *(Specify)* ☐

4.0 Socio-economics

4.1 In the last one year, what has been your main source of income for your household?

(1) Crop cultivation ☐ (2) Livestock keeping ☐ (3) Mixed farming ☐ (4) Fishing ☐
(5) Employment ☐ (6) Casual labor ☐ (5) Own Business ☐ (6) Others *(specify)* ☐

4.2 Do you harvest any crop? Which ones?

For each crop harvested during the last season can you answer the following:

CROP	How much was your harvest from last season's crop?	
	Quantity	Total value of production in KES

4.3 Do you buy food?

(1) Yes ☐ (2) No ☐

4.4 If yes, what are your reasons for buying food?

_____
_____
_____

4.5 Do you have enough food for yourself and your family throughout the year?

(1) Yes ☐ (2) No ☐

4.6 If no, how do you cope with food insecurity?

(1) Buy food ☐ (2) work for food ☐ (3) Reduce number of meals taken per day/less than 3 meals per day ☐ (4) reduce diversity of food ☐ (5) Sleep hungry ☐ (6) Buy food on credit ☐
(7) Food aid/mwolyo ☐ (8) other(specify) . . . . . .

4.7 Has food security improved in the last 5 years in your household

(1) strongly agree ☐ (2) agree ☐ (3) disagree ☐ (4) strongly disagree ☐

4.8 Do you have extra farm produce for sale? (1) Yes ☐ (2) No ☐

4.9 If yes, how far is the market where you sell the produce?

	Produce	Distance to market (km)	
1	Cereals (Maize, beans…..)		
2	Vegetables		
3	Milk		
4	Other (specify)		

5.0 Road run-off Harvesting

5.1 Have you heard of road runoff harvesting? (1) Yes ☐ (2) No ☐

5.2 If yes, how/by who? _____

5.3 Do you know people who practice road runoff harvesting? _____

5.4 Do you practice RRH?

(1) Yes ☐ (2) No ☐

5.5 Have you ever received training on road run-off harvesting?

(1) Yes ☐

(2) No ☐

5.6 If yes, who trained you?

(1) Government extension workers ☐

(2) NGO's/CBO's ☐

(3) Research institutions ☐

(4) Neighbors & friends ☐

(5) Media ☐

(6) Private organizations ☐

(7) Others (Specify) ☐

5.7 Did you adopt RRH technologies (After undergoing training)?

(1) Yes ☐ (2) No ☐

Questions specific to ONLY those practicing RRH

5.8 How did you construct the road runoff harvesting system?

Labour	How long	Cost
Self		
Household members		
Together with neighbours		
Hired labour		
Other (specify)		

5.9 How does the harvested water move from the road to your farm? (include picture) . . . . . .
. . . . . .
. . . . . .
. . . . . .

5.10 How do you control siltation? . . . . . .
. . . . . .
. . . . . .
. . . . . .

5.11 How do you store harvested water? . . . . . .
. . . . . .
. . . . . .

5.12 Is the storage structure covered? (1) Yes ☐ (2) No ☐

5.13 How would you rate the road runoff harvested water use, in terms of highest water user to lowest water user? Rate 1 indicates the highest user.

Water Use	Rate
Domestic	
Agriculture	
Sale of water	
Brick making	
Other	

5.14 Is your livestock using the water? Which livestock, how many? . . . . . .
. . . . . .
. . . . . .

5.15 What crops do you irrigate? . . . . . .
. . . . . .
. .

5.16 How does the harvested road runoff get to the plants for irrigation? . . . . . .
. . . . . .
. . . . . .
. . .

5.17 Is the harvested road runoff sufficient for irrigation during the dry season?

(1) Yes ☐ (2) No ☐

5.18 Do you get higher yields since adopting the technology?

(1) Yes ☐ (2) No ☐

5.19 If yes, how much higher is the yield

Crop	Yield before road water harvesting	Yield after road water harvesting	Price (per kg/other unit)
Maize			
Beans			

5.20 How profitable is the use of road runoff for irrigation?

(1) Highly profitable ☐ (2) Profitable ☐ (3) Not profitable ☐

(4) Loss making ☐

5.21 What help do you need to improve harvesting road runoff for irrigating crops during the dry season? . . . . . .

. . . . . .

. . . . . .

. . . . . .

. .

5.22 Do you know other people practicing road runoff harvesting?

(1) Yes (2) No

Information	Other person 1	Other person 2	Other person 3	Other person 4
Relation				
Distance from farmer (in walking minutes)				
Main use of harvested water				

5.23 Have you trained/educated other farmers on the technology?

(1) Yes ☐ (2) No ☐

5.24 What do you consider a challenge in using this technology? . . . . . .

. . . . . .

. . . . . .

5.25 Is your farm next to the road? (1) Yes ☐ (2) No ☐

5.26 How does road development affect household's food and water security?.....
.....

5.27 If NO, what do you do to get the water to your farm? (need to cross other farm/land?) . . . . .

. . . . . .

. . . . . .

. . . . . .

5.28 Have you experienced conflict with your neighbours because of harvesting road runoff?

(1) Yes ☐ (2) No ☐

5.29 How did you deal/.resolve with this conflict? . . . . . .

. . . . . .

. . . . . .

5.30 How important do you consider ROAD upgrading as a means to improving farmers' **pond re-charging capacity/ access potable water supply services?**

(1) Very important ☐ (2) Important ☐ (3) Neither important nor unimportant ☐
(4) Unimportant ☐ (5) Very unimportant ☐

5.31 How important do you consider ROAD upgrading as a means to improving farmers' **access to irrigation water availability?**

(1) Very important ☐ (2) Important ☐ (3) Neither important nor unimportant ☐
(4) Unimportant ☐ (5) Very unimportant ☐

5.32 How important do you consider ROAD upgrading as a means **to improving crop yield**?

(1) Very important ☐ (2) Important ☐ (3) Neither important nor unimportant ☐
(4) Unimportant ☐ (5) Very unimportant ☐

5.33 How important do you consider ROAD upgrading as a means **to improving farmers' food security**?

(1) Very important ☐ (2) Important ☐ (3) Neither important nor unimportant ☐
(4) Unimportant ☐ (5) Very unimportant ☐

5.34 What are the positive impacts of using RRH on your farming?

_____

_____

_____

_____
_____

5.35 What are the negative impacts of using RRH on your farming?
_____

_____
_____
_____
_____

5.36 Based on your experience, what is your recommendation towards improving RRH technologies used in the area?
_____
_____
_____
_____

Annex 2: Difference between HH practicing RHW and those not practicing RWH

	Questionnaire code	How much was your harvest from last season's crop (in Kgs)	What was the total value of production (in Ksh)	From sales of crops of last season, what was your total income (in Ksh)
Household practices Road water harvesting	1	370	13,250.00	6,750.00
	2	120	4,550.00	.00
	3	555	16,950.00	3,450.00
	4	590	19,470.00	9,920.00
	5	90	6,300.00	.00
	6	120	4,550.00	.00
	7	130	7,100.00	.00
	8	600	24,650.00	.00
	9	360	16,200.00	7,200.00
	10	200	16,000.00	8,000.00
	11	415	16,325.00	11,150.00
	12	900	36,000.00	11,250.00
	13	270	8,550.00	.00
	14	320	20,650.00	11,200.00
	15	570	25,400.00	9,950.00
	16	200	8,850.00	.00
	17	210	6,150.00	4,675.00

	18	700	25,280.00	7,800.00
	19	120	9,450.00	4,000.00
	20	490	22,000.00	10,800.00
	21	400	18,850.00	.00
	22	630	39,150.00	.00
	23	450	18,900.00	8,550.00
	24	600	35,950.00	10,700.00
	25	560	33,975.00	20,850.00
	26	380	15,800.00	10,800.00
	27	190	8,800.00	2,800.00
	28	525	22,800.00	6,750.00
	29	0	.00	.00
	30	200	8,850.00	.00
	31	0	.00	.00
	N	31	31	31
	Mean	363.39	16,475.8065	5,374.0323
Total	Sum	11265	510,750.00	166,595.00
Household does not practice Road water harvesting	1	120	7,900.00	4,500.00
	2	223	6,720.00	4,500.00
	3	120	4,550.00	.00
	4	120	4,550.00	.00
	5	210	6,150.00	4,675.00

	6	210	6,150.00	4,675.00
	7	90	6,300.00	.00
	8	120	4,550.00	.00
	9	130	7,100.00	.00
	10	320	16,200.00	7,200.00
	11	360	16,200.00	.00
	12	90	6,300.00	4,675.00
	13	415	16,325.00	.00
	14	90	6,150.00	4,675.00
	15	270	8,550.00	.00
	16	320	16,200.00	7,200.00
	17	90	6,300.00	4,675.00
	18	200	8,850.00	.00
	19	210	6,150.00	4,675.00
	20	415	16,325.00	7,800.00
	21	210	9,450.00	4,000.00
	22	490	22,000.00	10,800.00
	23	400	18,850.00	.00
	24	320	16,200.00	.00
	25	210	6,150.00	4,675.00
	26	415	16,325.00	7,800.00
	27	120	6,150.00	4,000.00

	28	380	15,800.00	10,800.00
	29	190	8,800.00	2,800.00
	30	120	4,550.00	.00
	31	0	.00	.00
	N	31	31	31
	Mean	225.10	9,735.3226	3,358.8710
	Sum	6978	301,795.00	104,125.00

Annex 3: Cost-benefit analysis of farmers practicing RRH in Mbitini ward, Kitui County.

Whether HH gets higher yields with RRH	HH number	What crops do you get higher yields, since adopting RRH	What was the yield before you started practicing RRH	What is the yield after RRH	What cost did you incur to construct the RRH system (Ksh)	What is the income from difference in yield before and after RRH (Ksh)
Do you get higher yields since adopting RRH **(Yes)**	1	Maize, Beans	2 bags	4 bags	00(NO COST).	6,750
	2	Maize, Ndangithi	2 bags	4 bags	.00	9,450
	3	Maize	1 bags	1.5 bags	.00	1,125
	4	Maize, Beans	2 bags	4 bags	9,000.00	8,550
	5	Maize, Beans	2 bags	3.5 bags	.00	4,500
	6	Maize, Cowpeas,	3 bags	7 bags	00.	13,050

		Green grams				
	7	Maize, Beans, Green grams	3 bags	7 bags	00.	16,200
	8	Pigeon peas	1 bag	2 bags	.00	1,800
	9	Maize, Pigeon peas, Green grams	0 bag	2.5 bag	.00	12,550
	10	Maize	1 bag	2 bag	.00	2,250
	11	Pigeon peas, Green grams	0 bag	2.4 bag	.00	17,600
	12	Maize, Beans, Pigeon peas	0 bag	3 bags	.00	14,950
	13	Maize, Pigeon peas, Green grams	0 bag	3 bags	.00	14,950

	14	Maize, Beans	2 bags	3 bags	.00	3,375
	15	Maize, Pigeon peas	0 bag	3 bags	.00	18,500
	16	Maize, Green grams	2 bags	3 bags	300.00	4,275
	17	Maize, Beans,	2 bags	3 bags	.00	4,275
	18	Maize, Beans	0 bags	2 bags	2,100.00	6,750
	19	Mchicha, Pigeon peas	0 bags	4.1 bags	.00	29,000
	20	Maize, Green grams	2 bags	4 bags	00.	9,450
	21	Maize, Beans, Pigeon peas	0 bags	4 bags	1,250.00	13,950
	22	Maize, Beans	2 bags	3 bags	.00	3,625

	23	Maize, Beans, Pigeon peas	0 bag	2 bags	.00	6,750
	24	Maize, Ndangithi	2 bags	4 bags	.00	9,450
	N	24	24	24	31	24
	Minimum	N/A	0 bag	1.5 bags	.00	1,125
	Maximum	N/A	3 bags	7 bags	63000.00	29,000
	Mean	N/A	0.93548 bags	2.6129 bags	2440.3226	9,713.54
	Sum	N/A	29 bags	81 bags	75650.00	233,125
Do you get higher yields since adopting RRH **(NO)**	N (7)	7	7	7	7	7
Total	N	31	31	31	0	24
	Minimum	N/A			0	1,125
	Maximum	N/A	3 bags	7 bags	0	29,000
	Mean				0	9,713.54
	Sum				0	233,125
a. Limited to first 100 cases.						


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Roads for Water