ASSESSMENT OF SMALL-SCALE WATER HARVESTING AND SAVING TECHNOLOGIES AND THEIR APPLICATION IN MITABONI LOCATION, MACHAKOS COUNTY

Ruth Mwongeli Munyao (B.A. Community Development)

N50/10253/06

A Thesis submitted in partial fulfilment for the Degree of Master of Environmental Studies (Community Development) in the School of Environmental Studies of Kenyatta University

JUNE 2014
DECLARATION

This Thesis is my original work and has not been submitted for a degree in any other University.

Signed………………………………………………………………..Date……………………
Ruth Mwongeli Munyao

This thesis has been submitted with our approval as University Supervisors.

Dr. Simon M. Maingi

Signature…………………………………………………………………………
Date………………
Department of Water & Environmental Engineering

Dr. Fuchaka Waswa

Signature…………………………………………………………………………
Date………………
Department of Agricultural Resources Management
DEDICATION

To the Almighty God for giving me strength to conduct this study. To my family for their patience and to my friends and all those who encouraged and walked by my side as I struggled through this challenging journey.
ACKNOWLEDGEMENTS

The author wishes to acknowledge Dr. Simon Maingi and Dr. Fuchaka Waswa for their valuable contribution and encouragement as supervisors during the study. The help and encouragement from my family, course mates and friends is highly appreciated. The Officers in the Ministries of Water and Irrigation, Agriculture, the Water Resources Management Authority staff in Machakos, the Administration staff at Mitaboni Location, the farming community in the study area, the Self Help Groups at the study sites, and the ABC Church at Mitaboni for information and adequate primary and secondary data. Last and not least to a retired teacher and volunteer at the ABC Mitaboni Water development project, Mr.Kaswii for his commitment and assistance in preparing and facilitating Focus Group discussions and for the arrangements of the logistics in the field at Mitaboni.
# TABLE OF CONTENTS

DECLARATION .................................................................................................................. i
DEDICATION ..................................................................................................................... ii
ACKNOWLEDGEMENTS .................................................................................................. iii
TABLE OF CONTENTS ................................................................................................... iv
LIST OF TABLES ............................................................................................................. vi
LIST OF FIGURES .......................................................................................................... vii
LIST OF PLATES ............................................................................................................. viii
ABBREVIATIONS AND ACRONYMS .......................................................................... ix
ABSTRACT ....................................................................................................................... xi

## CHAPTER 1: INTRODUCTION .................................................................................... 1

1.1 Background ............................................................................................................. 1
1.2 Problem Statement and Justification ...................................................................... 4
1.3 Objectives of Study ............................................................................................... 5
1.4 Research Questions ............................................................................................... 5
1.5 Assumptions ........................................................................................................... 6
1.6 Significance of the Study ....................................................................................... 6
1.7 Conceptual Framework ......................................................................................... 7
1.8 Definition of Terms as used in this Study ............................................................... 9

## CHAPTER 2: LITERATURE REVIEW ...................................................................... 11

2.1 Trends in Water Harvesting and Saving Technologies ........................................... 11
2.2 Large Scale Water Harvesting and Saving Technologies ....................................... 13
2.3 Challenges of Large Scale Water Harvesting and Saving Technologies ............. 14
2.4 Small-scale Water Harvesting and Saving Technologies ....................................... 15
2.5 Opportunities of Small-scale Water Harvesting and Saving Technologies ........... 15
2.6 Emerging Scenarios of Water Supply and Demand ................................................ 21
2.7 Social, Economic and Environmental Impact of Water Harvesting Structures ..... 28
2.8 Summary of Gaps Identified .................................................................................. 31

## CHAPTER 3: METHODOLOGY ............................................................................... 32

3.1 Study Area ............................................................................................................. 32
3.2 Research Design .................................................................................................... 34
3.3 Target Population and Sampling Procedure ......................................................... 35
3.4 Data Collection Methods ..................................................................................... 36
3.5 Data Analysis ........................................................................................................ 37
3.6 Validity and Reliability of Data .......................................................................... 37
3.7 Ethical Dimension ................................................................................................. 38

## CHAPTER 4: RESULTS AND DISCUSSIONS ...................................................... 39

4.1 Socio-Economic Attributes of Study Area ............................................................ 39
4.2 Assess the Utilisation of the Water Harvesting and Saving Technologies ............ 43
   4.2.1 Existing Water Harvesting Technologies ......................................................... 45
4.3 Coping Mechanisms of Water Shortages and their Effects ..................................... 48
4.5 Assess the Potential of other Water Harvesting and Saving Technologies ......... 52
4.5 Factors that Hinder Investment in Small Scale Water Harvesting Technologies

4.5.1 Root causes of persistent water shortages in the study area

4.5.2 Factor that Hinder investment in water harvesting and saving technologies

4.6 Addressing the Water Shortage Problem

4.7 Role of Different Stakeholders

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

5.2 Conclusions

5.3 Recommendations

6. REFERENCES

7. APPENDICES

7.1 Household Questionnaire

7.2 Institutional Questionnaire

7.3 Images of Potential Water Harvesting and Saving Structures in other areas
LIST OF TABLES

Table 2.1: Daily Domestic Consumption of Water (litres) for Rainfall in Different Zones.................................................................17
Table 2.2: Estimated Water Demand in Kenya.................................................................................................................................25
Table 2.3: Analysis of 47 years Rainfall Data at Katumani Research Station ..................25
Table 2.4: Droughts, External and Local Interventions in Greater Machakos District.....27
Table 3.1: Population by Sex, Number of household, Area and Density ......................34
Table 4.1: Level of Education and Most Commonly Used Water Technologies ........40
Table 4.2: Sources of Income and Most Commonly Used Water Technologies ........42
Table 4.3: Total Arable Land and Most Commonly Used Water Technologies ........43
Table 4.4: Small water harvesting technologies in the three sub-locations...............45
Table 4.5: Utility Rates of Water Harvesting and Saving Technologies (WHTs) in the Study Area..................................................................................................................47
Table 4.6: Potential Water Harvesting and Saving Structures ..................................54
LIST OF FIGURES

Figure 1.1: Assessment of Water Harvesting and Saving Technologies ......................8
Figure 2.1: Rainfall data at Kathiani District ...........................................................26
Figure 3.1: Kathiani District showing three study areas ...........................................33
Figure 4.1: Levels of Education of Household Heads .............................................40
Figure 4.2: Sources of Income .................................................................................41
Figure 4.3: Status of Water Availability in the Study Area ........................................44
Figure 4.4: Coping Strategies of Water Shortages in the area ......................................48
Figure 4.5: Existing Small scale Water Harvesting and Saving Technologies .............52
Figure 4.6: Farmer’s Opinion on the Root Causes of Water Shortages in the Study Area ........................................................................................................................................55
Figure 4.7: Farmers’ Opinion on the Factors that Hinder Investment in WHTs .........57
Figure 4.8: Farmers’ Opinions on Solutions to Water Shortages ...............................60
Figure 4.9: Farmer’s Opinion on the Role of Different Stakeholders ..........................62
Figure 4.10: Farmer’s Opinion on the Role of the Government ..................................63
Figure 4.11: Farmer’s Opinion on the Role of Community Members .........................64
LIST OF PLATES

Plate 1: Rock Catchment Water Harvesting in Kathiani District .............................................. 19
Plate 2: Plastic dam Liners Installed at Mitaboni Sub-Location .............................................. 19
Plate 3: The sub-surface dyke built across the Vennar in Tiruvarur district, India ................. 84
Plate 4: Sub-surface dams being constructed, Makueni, Kenya ............................................. 84
Plate 5: Spate Irrigation, Eritrea .................................................................................................. 85
Plate 6: Sub-surface Dyke, India ................................................................................................. 85
Plate 7: Khadin method with earthen embankment built across the hill slopes ......................... 85
Plate 8: Check Dam .................................................................................................................. 85
Plate 9: Ramteck Model of Water Harvesting ............................................................................. 86
Plate 10: 1-2-1 Method of Water Harvesting, Ganzu, China ..................................................... 86
# ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Africa Brotherhood Church</td>
</tr>
<tr>
<td>AFC</td>
<td>Agricultural Finance Corporation</td>
</tr>
<tr>
<td>ASAL</td>
<td>Arid &amp; Semi-Arid Lands</td>
</tr>
<tr>
<td>AMCON</td>
<td>African Ministerial Council</td>
</tr>
<tr>
<td>AWTF</td>
<td>African Water Task Force</td>
</tr>
<tr>
<td>CBOs</td>
<td>Community Based Organisations</td>
</tr>
<tr>
<td>CDF</td>
<td>Constituency Development Funds</td>
</tr>
<tr>
<td>DAO</td>
<td>District Agricultural Officer</td>
</tr>
<tr>
<td>DHS</td>
<td>Demographic Health Surveys</td>
</tr>
<tr>
<td>DSO</td>
<td>District Statistics Office</td>
</tr>
<tr>
<td>ECA</td>
<td>Economic Commission for Africa</td>
</tr>
<tr>
<td>EMCA</td>
<td>Environmental Management &amp; Coordination Act</td>
</tr>
<tr>
<td>ESCWA</td>
<td>Economic and Social Commission for Western Asia</td>
</tr>
<tr>
<td>FAO</td>
<td>Food Agricultural Organisation</td>
</tr>
<tr>
<td>FGDs</td>
<td>Focus Group Discussions</td>
</tr>
<tr>
<td>GEO</td>
<td>Global Environment Outlook</td>
</tr>
<tr>
<td>GoK</td>
<td>Government of Kenya</td>
</tr>
<tr>
<td>GRIWAC</td>
<td>Gansu Research Institute for Water Conservancy</td>
</tr>
<tr>
<td>ICRAF</td>
<td>International Centre for Research on Agro-Forestry</td>
</tr>
<tr>
<td>IEA</td>
<td>Institute of Economic Affairs</td>
</tr>
<tr>
<td>JMA</td>
<td>Joint Monitoring Program</td>
</tr>
<tr>
<td>KNBS</td>
<td>Kenya National Bureau of Statistics</td>
</tr>
<tr>
<td>MEA</td>
<td>Millennium Ecosystem Assessment</td>
</tr>
<tr>
<td>MCM</td>
<td>Million Cubic Meters</td>
</tr>
<tr>
<td>MDGs</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>MICS</td>
<td>Multiple Indicators Cluster Surveys</td>
</tr>
<tr>
<td>MIDP</td>
<td>Machakos Integrated Development Program</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetres</td>
</tr>
<tr>
<td>MoA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>MWRI</td>
<td>Ministry of Water and Irrigation</td>
</tr>
<tr>
<td>NWRMS</td>
<td>Natural Water Resources Management Strategy</td>
</tr>
<tr>
<td>MWRMD</td>
<td>Ministry of Water Resources Management and Development</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>NEPAD</td>
<td>New Partnership for African Development</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-Governmental Organisations</td>
</tr>
<tr>
<td>NSWCP</td>
<td>National Soil and Water Conservation Project</td>
</tr>
<tr>
<td>PEN</td>
<td>Poverty Eradication Network</td>
</tr>
<tr>
<td>PRA</td>
<td>Participatory Rural Appraisal</td>
</tr>
<tr>
<td>PRSP</td>
<td>Poverty Reduction Strategy Paper</td>
</tr>
<tr>
<td>RELMA</td>
<td>Regional Land Management Unit</td>
</tr>
<tr>
<td>RTI</td>
<td>Radar Technologies International</td>
</tr>
<tr>
<td>RWH</td>
<td>Rain Water Harvesting</td>
</tr>
<tr>
<td>SASOL</td>
<td>Sahelian Solutions Foundation</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for Social Sciences</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational Scientific and Cultural Organisation</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations Children Fund</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Program</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environmental Program</td>
</tr>
<tr>
<td>UNFPA</td>
<td>United Nations Fund for Population Activities</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>WHTs</td>
<td>Water Harvesting Technologies</td>
</tr>
<tr>
<td>WRMA</td>
<td>Water Resources Management Authority</td>
</tr>
<tr>
<td>WRUAs</td>
<td>Water Resource Users Association</td>
</tr>
<tr>
<td>WWDR</td>
<td>World Water Development Report</td>
</tr>
</tbody>
</table>
ABSTRACT

Water scarcity remains a major development challenge in Kenya and particularly in the Arid and Semi-Arid lands (ASALs) like the Machakos County. Existence of few dams like Muoni dam, near the Kathiani market, has failed to deliver sustainable supply of water to the Mitaboni residents. Despite the emergence of small-scale water harvesting technologies, 54% of the households in Mitaboni still take more than one hour to carry water to their homes. This study sought to assess the existing small-scale water harvesting and saving technologies and their application in order to suggest ways of maximising their effectiveness. A total number of 200 households were randomly selected and heads of households were interviewed. Proportionate sampling was used to determine the sample size from each of the three sub locations. The study had 20 key informants selected based on their involvement in water management. Both qualitative and quantitative data were collected and analysed using descriptive and inferential analysis. Pearson’s Chi-Square was used to assess the relationships between selected variables in the study. Results showed that the commonly used small-scale water harvesting structures included the shallow wells, water weirs, water tanks and water pans due to their affordability and low requirement of specialised skills. Although unreliable rainfall remains a key concern, lack of adequate water harvesting structures denied farmers access to water during the few rainy days. Factors that hinder the investment in water harvesting structures included the lack of funds, unreliable rainfall and lack of appropriate skills. As such this study concluded that although existing technologies are useful, they fall short of satisfying household water requirements to the next rains - a period of about three months. Most households cope with persistent water shortages by accessing water from open dams, which are equally far away. Drudgery and health risks due to the poor quality of water remain risks households must contend with. Other hitherto missing technologies that could increase water availability in the households and the challenges that reduced farmers’ propensity to maximise benefits from small-scale water harvesting technologies were identified. To increase access to water by households, this study recommends investments in more and closely distanced small-scale water harvesting technologies as well as capacity development in cost-effective water harvesting technologies. The sustainability of water security requires involvement of target communities in resource mobilisation for effective structural and capacity development investment.
CHAPTER 1: INTRODUCTION

1.1 Background

Water is one of the key natural resources for man’s survival, and an essential for all development endeavours. Currently water scarcity remains one of the main causes of poor livelihoods and health. Globally, more than 125 million children under five years of age live in households without access to an improved water source and more than 280 million children under five years live in households without access to improved sanitation facilities. Unsafe drinking water and inadequate availability of water for hygiene contribute to 88% of deaths from diarrhoeal diseases resulting to deaths of more than 1.5 million children below five years of age (WHO/UNICEF, 2002).

Globally, people are becoming aware of the world’s degraded water resources. In adopting the Millennium Development Goals (MDGs) in 2002, countries made a commitment to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015. According to UNEP, the 4th Global Environmental Outlook (GEO 4) paints a bleak assessment on the state of fresh water worldwide. By the year 2025, it is estimated that 1.8 billion people will live in countries with absolute water scarcity and the demand of fresh water will have risen by 50% in developing countries and 18% in the industrialised countries if nothing is done about it (UNEP, 2007).

In the past, concerns in the global environment tended to view water issues in isolation yet an integrated approach which involves multiple stakeholders at all stages of the project cycle is of dire need. Despite this global scenario, local set ups have demonstrated the existence of many opportunities for sustainable water resources development and management (SASOL and Maji na Ufanisi, 1999). The Poverty Reduction Strategy Paper (PRSP) recognises water as a basic need and an important catalyst for both economic and social development of a country (GoK, 2005).

The Africa continent has the highest population growth rate of 2.6% as compared to Asia’s 2.1% in the developing world and yet the level of food production is usually determined by the quality and quantity of available water as a resource (www.travel-
A study on rainwater harvesting potential in Africa shows that 330 million people in Africa are living under “water scarcity” (Khaka et al., 2006). The increased competition between human, livestock and the environment in the Arid and Semi-Arid Lands (ASALs) will contribute towards constraints in social, economic and environmental benefits.

More local initiatives have demonstrated the existence of many opportunities for sustainable water resources development where low cost and simple technologies can change around lives of the rural people to increase human well-being (Khaka et al., 2006). For instance, Lari Division is one of the driest divisions in Central Kenya where rainfall patterns have been disrupted causing serious food shortages. In the year 2000, no maize was harvested in this area due to poor rainfall. But in the 2001/2002 season, farmers from Lari Division joined a rainwater harvesting village project and managed to raise their agricultural production from 590 USD/ha per season to 3540 USD/ha per season.

The Millennium Ecosystem Assessment (MEA) report of 2005, conducted by 1,300 experts from 95 countries, specifically states that the ongoing degradation of ecosystem services is a barrier to achieving the Millennium Development Goals (MDGs) as agreed to by the world leaders at the United Nations in 2000. According to the MEA report, over the past 50 years humans have changed ecosystems more rapidly, and this has contributed to substantial net gains in human well-being and economic development. However, these gains have been achieved at growing costs in the form of the degradation of many ecosystem services and the increase of poverty for some groups of people (WHO, 2005).

Following the implementation of Agenda 21 and the MDGs on water, the government of Kenya has initiated a number of policy reforms with the aim of improving the provision of water in sufficient quantity and quality and with a reasonable distance. These institutional framework reforms resulted in the establishment of the National Water Policy of 1999, the Water Act of 2002, and the Environmental Management & Coordination Act (EMCA) of 1999. The government of Kenya has encouraged communities to be part of the process through the establishment of community based water projects (Gatundu, 2003). Water scarcity, water security, water quality, water
catchment management, and poor physical planning among others were identified as some of the major challenges that impede the provision of acceptable quality and adequate quantity of water to the communities (MWI, 2008).

Kathiani District is one of the newly established districts in the Machakos County in Eastern Province. It is among the ASAL districts in Machakos County where water scarcity is prevalent, and where more than 80% of the people practice rain fed subsistence farming as their livelihood. The area experiences erratic and highly variable rainfall coupled with long dry spells after which the existing water sources become inadequate. On average, the District receives a biannual rainfall of 600 mm per year, falling in November - December and again in March – April, but with wide fluctuations from year to year.

Failure of the 2009 long-rains season brought in the fourth consecutive poor or failed season in the highly drought prone areas. According to the Kenya Food Security Outlook report (July-December 2009), the drought situation resulted in the deterioration of crop yields as well as livestock conditions. During the dry spells, the time and energy spent in water collection has had a major implication on nutrition, the environment, health and for children’s education especially on the girl child.

Land has been subdivided into units which are not economical to farm. These subsistence farming practices have become a threat to the high populations whose livelihood depends on agriculture. The main food crops grown in the area include maize, beans, pigeon peas, cowpeas, sorghum and cassava. The average farms range between 2-5 acres. Local cattle, goats, sheep and bees are kept for meat, honey and milk. With adequate water harvesting and saving technologies, this area has enough land to practice intensive farming for value crops such as vegetables and fruits for home consumption and for sale. Small scale water harvesting and saving projects would be suitable in meeting the needs of the people, if they are done by communities using practical and affordable technologies.

In Kenya, water is fetched each day by women or children and it is estimated that 3 million women in Kenya each spend an average of 3 hours a day on fetching water, which comes to 9 million hours daily spent on water alone (UNDP, 1985). More
current analysis of the Multiple Indicators Cluster Surveys (MICS) and Demographic and Health Surveys (DHS) conducted in 24 countries of the Sub-Saharan Africa, show that more than a quarter of the population spends longer than 30 minutes per round trip to collect water (WHO/UNICEF, 2010). A small scale water harvesting and saving technology that is simple, low cost, and within the reach of the community members can help mitigate the effects of erratic rainfall, dependency on food aid, and the risks of dry spells that characterise the water-scarce regions.

1.2 Problem Statement and Justification

Until September 2013, Kenya was categorised as a water scarce country with a renewable inland water sources amounting to 21 billion cubic meters, and an average share per individual at 647 m$^3$ annually (MWRMD, 2004). This per capita availability was projected to fall to 235 m$^3$ by 2025 as the population increased and could be less, if the resource base continued to deplete. This was alarming as when compared to the neighbouring countries, Uganda’s and Tanzania’s whose average share per individual is 1,205 m$^3$ and 1,930 m$^3$ per year respectively. A country is considered as one with water scarcity when the average share per individual is between 500-1000 cubic meters (www.english.ahram.org.eg/News/100257.aspx).

In September 2013, Kenya discovered two new aquifers; Lotikipi Basin aquifer and Lodwar Basin aquifer, in the arid region of Turkana. According to Radar Technology International (RTI), the firm that made the discoveries, the aquifers have minimum reserve of 250 billion cubic meters of water, and which is replenished at a rate of 3.4 billion cubic meters from rainfall. According to United Nations Educational Scientific and Cultural Organisation (UNESCO) Kenya is expected to have enough water to meet the country’s needs for the next 70 years (www.sabahionline.com/en_GB/...feature-02).

More than 25% of Kenya’s population spends an average of 30 minutes on one water collection round trip. This, according to the Joint Monitoring Programme (JMP) report, has a huge cost implication in terms of people’s time to perform other economic activities such as farming for adults and children in attending school. The
distance to the nearest water points pose a challenge particularly to women and girls who bear the responsibility of fetching water. With recurring droughts and water shortages in Mitaboni area, time spent finding and collecting water has a high cost in terms of lost production, income, food gathering and missed education for children.

Mitaboni’s adoption to small scale water harvesting and saving technologies has remained rather low, despite the fact that Kenya’s socio-economic development goals are highly dependent on availability of good quality and quantity water. This study sought to assess the existing water harvesting and saving technologies and their application in Mitaboni, the mechanisms used to cope with persistent water shortages and their effects, the potential of other water harvesting strategies and factors that hinder investment in small scale water harvesting and saving technologies.

1.3 Objectives of Study

The overall objective was to assess the existing water harvesting and saving technologies, and their application in Mitaboni Location, in order to suggest ways of maximising their effectiveness. The specific objectives were to:

i. Assess the utilisation of the existing water harvesting and saving technologies in the study area.

ii. Assess the mechanisms used to cope with the persistent water shortages and their effects.

iii. Assess the potential of other water harvesting and saving technologies not yet applied in Mitaboni Location.

iv. Determine the factors that hinder investment in small-scale water harvesting and saving technologies.

1.4 Research Questions

i. How useful have the existing water harvesting and saving technologies been to the community?

ii. How are farmers coping with persistent water shortages in Mitaboni?
iii. What are the effects of the coping mechanisms used by farmers in Mitaboni?
iv. Which other technologies have worked elsewhere and could benefit communities in Mitaboni?
v. Why are communities not investing in small-scale water harvesting and saving technologies?

1.5 Assumptions

This research was based on the following assumptions:

i. Contrary to popular expectation, small-scale water harvesting and saving technologies in Mitaboni have had little positive impacts on communities’ livelihoods and environment.

ii. Community livelihoods can be enhanced after appropriate investment into potentially significant water harvesting and saving technologies that farmers are yet to take advantage of.

1.6 Significance of the Study

This study was envisaged to bring about the following short and long term benefits:

i. Increased information on water availability to households for both domestic and agricultural purposes.

ii. Documentation of the available small scale water harvesting and saving technologies for policy formulation on rural water supply and use.

iii. Increased knowledge of other water harvesting and saving technologies not used in the study area.

iv. Present an opportunity to share knowledge with community members and other significant stakeholders.
1.7 Conceptual Framework

Through research, it has been established that a number of farmers in the ASALs districts, who have adopted the use of water harvesting technologies and innovations, have realised increased yields of crops and improved livelihoods (Mutunga, 1998). According to Kithinji (1999), water conservation, harvesting management, the rainfall amount, distribution and duration in the ASAL, is highly variable and the main limiting factor. To tap and get advantage of the rain, water harvesting structures are required to avoid much water going to waste. With the introduction of small scale water harvesting technologies, the amount of water from the roof and surface runoff can be collected and stored to improve water supply in Mitaboni Location.

The study identified gaps in the area which included financial constraints, lack of documentation and research on the small water harvesting and saving technologies, and poor application of the already proven technologies such as the shallow wells, water weirs, roof tanks and water pans. There was little documentation on the potential of other small scale water harvesting technologies that are under use in the other areas of the country. Looking into the gaps of water harvesting and saving technologies would provide appropriate entry points for technical and managerial interventions for enhancing water supply for domestic and other uses.

The conceptual framework shown below (Figure 1.1) shows the relationship between the dependent variable which is improved water supply and the independent variable, increased resource mobilisation. Increased resource mobilisation, which involves both human and capital resources, would increase the number of small scale water harvesting technologies. Increased number of small scale water harvesting would shorten distances from the current distance of 5km to 2km. The dotted arrows in the Figure indicate intervention paths towards improved water supply for the people of Mitaboni Location. The interventions identified by the study include involvement of different stakeholders in mobilisation of available resources and educating communities on simple and practical skills of increasing and maintaining water harvesting and saving structures.
Legend:
Current Situation:  
Point of intervention  

Figure 1.1: Assessment of Water Harvesting and Saving Technologies
1.8 Definition of Terms as used in this Study

i. “Fanya juu” terrace: “Fanya juu” is constructed by digging a ditch manually along a contour line of a slope. The soil is thrown uphill so that an embankment is formed. This helps to slow the speed of the water down stream and hence the water is conserved.

ii. Assessment: In this study, assessment is used to bring out the findings of the existence, the effects, the use, the adoption and the limitations of the water harvesting and saving technologies as found in Mitaboni.

iii. Utility: In this study, utility is used to refer to the usefulness or the total satisfaction of the consumers of the service rendered by the specific water harvesting and saving technologies available.

iv. Water harvesting and Water Saving Technologies: In this study, water harvesting and water saving technologies are used interchangeably; they serve a dual function in this study. Water harvesting or water saving is used as an umbrella term to describe a range of methods of collecting and conserving various forms of runoff and rain water for productive purposes.

v. Small-scale Water Harvesting and Saving Technology: This study follows the standards given by the Kathiani District reports, that any harvesting and storage structure is usually considered small scale if the concentration of the storage of water is not more than 20,000 m\(^3\).

vi. Large-scale Water Harvesting Technology: Refers to any water harvesting and saving structure that can hold the concentration of water more than 20,000 m\(^3\).

vii. Water Stressed Countries: Globally, a country is categorised as ‘water stressed’ if its annual renewable freshwater supplies are between 1,000 and 1,700 m\(^3\) per capita per annum.

viii. Water Scarce Countries: Any country is considered ‘water scarce’ if it has a national endowment of renewable fresh water of less than 1000m\(^3\) per capita per annum. This brings a situation where demand outstrips the stock of renewable freshwater.

ix. In-situ Rain Water Harvesting Technology: refers to all activities in which rainwater is harvested and stored within the soil profile for crop production. This type of micro-catchment farming provides high percentage of water per
unit catchment area as plants grow with too little rainfall. This is a convenient practice because it includes making structures such as contour farming, minimum tillage, cover cropping, micro-catchment farming, crop rotation, ‘fanya juu’ terracing among others. Examples of structures that enhance in-situ RWH include pitting methods, bunds, contour farming and terracing.
CHAPTER 2: LITERATURE REVIEW

2.1 Trends in Water Harvesting and Saving Technologies

Water harvesting is the collection of surface water for productive purposes. Instead of runoff being left to go to the sea, it is harvested and utilised. The first water harvesting and saving technologies originated from Iraq over 5000 years ago in the Fertile Crescent and since then, many civilizations have further developed more or less simple or sophisticated means of harvesting water to meet their various needs (Falkenmark et al., 2001). Water harvesting structures have been used since ancient times, and evidence of roof catchment systems date back to early Roman times. Roman villas and cities were designed to take advantage of rain water as the principal water source for both domestic and agricultural purposes since at least 2000 BC. In the Negev desert in Israel, tanks for storing runoff from hillsides for both domestic and agricultural purposes have allowed habitation and cultivation in areas with as little as 100mm of rainfall per year (www.unwac.org/new_unwac/pdf/WATSAN_narrative_Pubs/Blue_Drop_Series_02_-_Capacity_Building.pdf).

The earliest known evidence of the use of rain water harvesting technology in Africa comes from Northern Egypt, where tanks ranging from 200m$^3$-2000m$^3$ have been used for at least 2000 years and many are still functioning to date. The small scale collection of rainwater from the roofs into traditional jars and pots has been practiced in Africa and Asia for thousands of years.

Today, there is a growing interest in rainwater harvesting all over the world. Improved water harvesting technologies have been used to increase the efficiency and the amount of water collected at a given time. For instance, the “Thai Jar” programme of the Thai government remains as unparalleled rain harvesting movement of the world. From 1985, the country constructed six million jars to harvest rain for drinking purposes. As a result, 36 million people had minimum amount of good drinking water at the household. In Germany, grants and subsidies are available to encourage
households to construct rainwater tanks. In October 1998, the Berlin government introduced rainwater utilisation systems to be part of the large scale urban re-development in order to control urban flooding, save city water, and create a better micro-climate. Frankfurt Airport, the biggest airport in the European continent, has built complexes at the airport with systems for rainwater harvesting. All the water from the roof tops is collected in the basement where six tanks have been put up, each with a storage capacity of 100 cubic meters. Brazil, has integrated part of the education programs on water harvesting and sustainable living in the semi-arid regions.

Water harvesting has become an increasingly important tool in the attempt to improve crop yields in the arid and semi-arid lands (ASALS) of sub Saharan Africa. Both crop and livestock yields and reliability of production, especially in semi-arid drought prone areas, can be significantly improved by using this method. Water harvesting is important to the communities and to farmers because it provides free water, mitigates the impacts of drought and its implications on livelihood, enhances water availability and eases demand for various purposes, promotes access to quality water for good health and sanitation, and supplements erratic and unreliable rainfall for agricultural purposes.

The rain water harvested has also provided a source of water for household use, institutions [such as schools, and community centres], agriculture where it provides full or supplemental irrigation, environment conservation, and prevention of flood damage. Mitaboni Location is no exception to the effects of drought on its livelihood sources. The amount of rainfall received in the area is not only low but poorly distributed across the cropping season. Therefore, a study to address the harvesting and utilisation of the rainfall runoff will bridge the gaps and guarantee full production potentials. Involvement of local communities in the management of water resources through formation of Water Resource Users Association (WRUAs) can result in reduced illegal abstractions, reduced catchments encroachment, rehabilitation of catchments areas, and river bank protection. A positive outcome has been observed in River Ewaso-Nyiro North which is flowing up to 110 km as opposed to previous flow of 40 km, and the flow is for a longer period of time (GOK, 2008a).
Water harvesting and saving technologies may be grouped into two categories: the large and small scale water harvesting and saving technologies. The large scale water harvesting and saving technologies include boreholes, earth dams and piped water supplies while the small scale water harvesting technologies are the sand/subsurface dams, roof catchment tanks, earth pans/ponds, and the in-situ methods.

2.2 Large Scale Water Harvesting and Saving Technologies

Large scale water harvesting technologies are those that are able to store more than 20,000 m$^3$ litres of water for a longer period and they mainly include boreholes, earth dams and piped water systems (GoK, 2010). Boreholes are an example of large scale water harvesting technology which involves ground water exploration and abstraction. It is a technology that is faced with several challenges such as high cost of installation, rundown of existing boreholes, and lack of rehabilitation and maintenance. There is evidence of the water being highly saline and of poor quality for domestic use. In Mitaboni, it is hard to invest in boreholes due to the geological formation; the metamorphic rocks in eastern Kenya are older and have fewer aquifers compared to other areas with younger volcanic formations such as central Kenya (SASOL and Maji na Ufanisi, 1999). Therefore, this gives limitations on the adoption of this water harvesting structures because of its uncertainty and cost implications required.

Earth dams are constructed to collect water from river valleys. They also need a high cost of construction, and are usually built through donor funds. Despite its poor quality, the water collected from dams is able to cater for a community’s livestock and domestic purposes. The failure of dams in the ASALs reflects a serious problem of land degradation, and heavy pressure of livestock that have denuded the groundcover. Earth dams have a short life span due to high rates of evaporation (SASOL and Maji na Ufanisi, 1999). According to Falkenmark et al. (2001), in the ASALs, evaporation of open water storage can have a water loss that amounts to 0.9-1.4m within a period of 6 months. Mitaboni Location falls in the ASALs region, and it is out of this fact that the area faces great water shortage. The available open water
storage, though common, cannot sustain water for a long time due to the high rate of evaporation.

_Piped water supplies_ in most rural areas of the ASALs face serious challenges due to shortages of water and poor maintenance of the supply systems. One of the main issues with piping water to water scarce areas is the cost. According to the 2010 Kenya Population and Housing Census report, it shows that only 30% of households in Kenya have access to piped water supply (GoK, 2010). While Nairobi province has 75.5% of the households served with piped water, other provinces suffer. In Nyanza it is at 8.5%, North Eastern (11.6%), Western (7%), Eastern (28.5%), Rift Valley (22.8%), Coast (46.3%) and Central (39.8%). Another problem is that not all areas in need of water can afford to pay for piping it to rural areas. Most of times, electricity supplying pumping stations is cut off due to the inability to pay electric bills. One more problem with water pipes is there upkeep and maintenance. There are often long delays in fixing damaged pipes and equipment resulting in low supply. Much of the existing pipeline is not water tight allowing much water to leak out before it gets to its destination. Another main issue in piping water to water scarce areas is vandalism of pipes. Vandals often steal valuable parts such as valves that they can sell to make a profit. With this system, the people living on poor developments pay more for their water than those residents who are connected to city water.

Eastern province is among the five provinces with the worst service delivery, where 54% of the households spend up to 1 hour carrying water (GoK, 2010). This can be attributed to the unequal distribution of resources, where some parts of the country are highly developed than others. This has high implication on the people’s social, economic and environmental production. In turn, it has slowed the development phase of the ASALs.

2.3 Challenges of Large Scale Water Harvesting and Saving Technologies

While many new water supplies have been built, a significant number have failed due to poor management and inadequate maintenance, as well as over-exploitation, pollution or salinization of water sources. The technology and/or approach used for its
implementation have been technically, economically, socially, or environmentally inappropriate. For instance, at village level, past experience has shown that water systems which are dependent on external sources of fuel, spare parts, or expertise for maintenance and repair are less likely to be sustainable than those dependent only on local inputs unless well developed and reliable systems are in place for providing any external requirements.

There has been a tendency in many developing countries to equate improved water supplies with modern technologies consisting of highly centralised water supply systems with heavy investments in both financial resources and skilled personnel. They have minimal involvement of local communities, which makes it difficult to sustain the projects in later years. Agenda 21 of 1992 recommends the commitment and genuine involvement of all social groups as critical to the effective implementation of the agreement by governments in all program areas (UNEP, 1995). Programs of action in the ‘African strategies for the implementation of Agenda 21’, point out the need to implement safe water supply for the rural poor using appropriate technologies, equitable financial mechanisms and community participation (ECA, 1992).

The construction of major water projects such as dam schemes, irrigated agriculture, flood control schemes among others, are also known to have negative effects on the environment and human life. Effective mitigation measures need to be employed to reduce such effects, and such are never considered during the planning and budgeting phase.

2.4 Small-scale Water Harvesting and Saving Technologies

According to the Kathiani District agricultural report, any harvesting and storage structure is considered small scale if the capacity storage of water is not more than 20,000 m³. Small scale water harvesting structures include sand dams, sub-surface dams, water ponds/pan, underground water storage tanks, roof catchment and in-situ technologies. In this study the researcher’s interest is in the small scale water harvesting structures, which are common in the study site because of their ease of
construction, they are less expensive, and require less labour compared to the large scale water harvesting structures. Mutunga (1998) adds that the small scale water harvesting structures have high collection efficiency than the large ones as water is deeply pounded, more evenly spread, and evaporation losses are low making them suitable for the semi-arid areas.

*Sand dams and sub-surface dams* are two types of sand river storage technology commonly used in parts of Eastern province. *Sand dams* have the dam wall protruding above the surface of the land; while in a *sub-surface dam*, the dam wall is level with the sand surface (Waswa et al., 2006). Sand and sub-surface dams are small sized Rain Water Harvesting (RWH) structures whose potential depends on the availability of sand in ephemeral riverbeds. In the ASALs, rivers are seasonal; water is seen flowing only when it is raining and sometimes a few weeks after the rains. Once the water subsides, the sandy riverbed is exposed, but water normally continues flowing slowly under the sand. By building a wall across the river channel, the slow flowing water can be accumulated upstream in a reservoir from where it is extracted through a pipe.

Mburu (1993) noted that, sand dams have certain advantages over other systems of water storage as they are efficient, relatively cheap, require minimum skilled labour, lead to less water contamination, have improved water retention, and evaporation is minimal. They are also known to have no direct negative impact on the surrounding environment as they act as a safe aquifer for water flowing below and through it. These are the commonly used water harvesting structures within the region even though not enough. They are highly relied upon despite of the unreliable rains. They solely depend on rains as the source. In Kitui, self-help groups from the semi-arid region in Eastern Kenya have adopted the use of small scale sand dams through the help of the Sahelian Solution Foundation (SASOL). SASOL provided cement and iron bars that are used for reinforcement of the sand dams, while the community provided unskilled labour and ferried water for building to the site. An analysis of data collected shows that after the sand dams were built, access to water improved. This was a way of bringing water closer to the households for access during dry session. The study was made so that ways of improving the quality and quantity of such affordable structures can be actualised. “As a result of these dams more children
“go to school” says Prof G. C. M. Mutiso, the Chairman of SASOL Foundation (SASOL and Maji na Ufanisi, 1999), Kenya.

Water pans/ponds are small earth dams whose storage capacities do not exceed 20,000 m$^3$ and have a shallow depth of less than 5m. Pans are suitable for livestock and irrigation (Waswa and Mpinduzi, 2007). Interventions oriented towards surface runoff collection into pan/ponds intervention can be implemented in most areas since the collection is from open surfaces such as roads, home compounds, hillsides, open pastures and gullies. Runoff harvesting depends on soil types to especially avoid seepage problem and this can be controlled through different interventions.

Rooftop catchment involves an appropriate catchment surface of corrugated iron sheets. Rooftop rain water harvesting is the easiest technology at household level as studies show that an area receiving just 200mm annual rainfall has as much potential as one receiving more. The daily water use per capita is within the range of 5-26 litres in areas with no piped water connection, according to a survey report by Kirori (1997) for seven developing countries. Khaka et al (2006) also show that a daily water consumption of 20litre/day/person will require an annual requirement of 7.3 m$^3$/year/person. This amount can be supplied by a roof catchment of 35.5 m$^2$ if only 200mm of rainfall per annum is available. If harvested hygienically, rooftop water harvesting does not need additional purification. Below is Table 2.1 that shows the daily domestic water consumption in litres for different zones.

<table>
<thead>
<tr>
<th></th>
<th>Human</th>
<th>Dairy Cattle</th>
<th>Local cattle</th>
<th>Sheep/ Goats</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Zone</td>
<td>20</td>
<td>50</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Medium Zone</td>
<td>15</td>
<td>50</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Low Zone</td>
<td>10</td>
<td>50</td>
<td>17</td>
<td>4</td>
</tr>
</tbody>
</table>

Sources: Barnes et al; 1983, Ministry of Water Development, 1992

Underground water storage Tanks are more suitable in the dry lands than reservoirs and ponds because they lose less water through evaporation. The type of tank to be built will depend on the water usage, the availability and cost of building materials,
skilled labour, the soil type and topology, and the information available on technical options. Tanks can be of any shape, made from various materials and built above or below the ground surface. Underground spherical (ball-shaped) and cylindrical (sausage) tanks made from baked bricks are well-suited for small-scale farmers in semi-arid areas. On a sloppy area, the tank can be built completely underground, and the water can flow into the tank by gravity and out through a pipe, avoiding the need to pump or draw the water out through a pipe. Part of the tank can be raised slightly above the ground and the sides supported by excavated soil.

In-situ rain water harvesting technology refers to all activities in which rainwater is harvested and stored within the soil profile for crop production. This type of micro-catchment farming provides high percentage of water per unit catchment area as plants grow with too little rainfall. This is a convenient practice because it includes making structures such as contour farming, minimum tillage, cover cropping, micro-catchment farming, crop rotation, terracing among others. Examples of structures that enhance in-situ RWH include pitting methods, bunds, contour farming and terracing.

Road runoff water harvesting is getting popular as farmers collect water which could pass over their farms and causes soil erosion. Surface runoff is held in retention ditches or retention basins. This water is collected in water ponds and later used for agriculture and livestock. According to SearNet, a publication of World Agroforestry Centre, farmers in Mwingi, Machakos and Kitui districts have more than doubled their banana/pawpaw production and their maize/beans yields. Fodder production has increased and soil loss reduced, as some farmers normally conserve soil in addition to runoff (http://www.worldagroforestry.org/projects/searnet/index.php?id=67). The results show improved food security and farm income resulting from improved yields/production and consequently improved livelihoods. A farmer along the Mwingi to Nairobi highway, about 10km from Mwingi town is practicing road runoff harvesting on 5 ha out of his 10 ha farm. He is harvesting road runoff from the tarmac road, that is about 300m away and distributing it in the farm using enlarged fanya juu terraces.

Rock catchment dams are masonry dams, for capturing runoff from rock surfaces or catchments with storage capacities ranging from 20–4000 m3. They are generally
used for domestic purposes, but can also be used for kitchen gardening to alleviate water shortages, for example in Kitui District (Ngure, 2002). This is a new innovation in Kathiani District because the District has only 2 such rock catchment (Plate 2).

The in-situ water harvesting technology is a potential water harvesting technology which provides high percentage of water per unit catchment area so that plants grow well with little rainfall. It involves water conservation that maximises soil infiltration and increased water holding capacity within the root zone. In-situ water harvesting technologies are distinct from runoff farming systems in that they do not include a runoff generation area, but instead aims at conserving the rainfall where it falls in the cropped area. In-situ water conservation technology is one of the simplest and cheapest and can be practiced in almost all areas. This includes tillage and cultural practices such as mulching, terracing, ridging, addition of manure, and tied ridges/bunds within cropping area. ‘Fanya juu’ is a form of terracing that is commonly practiced by farmers in the greater Machakos District since the 1930’s as a way of conserving water and prevent soil erosion. Among others, studies such as from Kenya and Ethiopia show that substantial increase in the annual crop yields have occurred as a result of proper terracing (Stahl, 1993).

Conservation agriculture (CA) is an example of the in-situ water harvesting technology. Unlike conventional farming system, CA minimises water loss from the soil. Rainwater is caught in-situ, conveyed, stored and used within the same soil profile. This means that all the components of rainwater harvesting occur at the same
place. Using the practices of the CA, which include minimum tillage, crop rotation and cover cropping, soil is conditioned to conserve moisture for ideal crop growth. In conventional farming, there is soil inversion with the plough or the hoe, and this causes soil erosion and soil desiccation. The plough pans are known to impede soil infiltration and root penetration. On the other hand, the CA is a non-inversion method that ranges from zero tillage to minimum tillage.

The effects of CA to the water is that there is the recharge of aquifer, improved water quality, more available water in soils and reduced water losses through evaporation. In CA, though not a new concept, there have been reports of recent successes where crop yields have increased due to conservation of water improvement such as Ghana, Nigeria, Zimbabwe, Tanzania, South Africa and Zambia (Elwell, 1993; Oldrieve, 1993). According to an evaluation report on conservation agriculture in Zimbabwe, maize yields increased dramatically under CA, averaging between 2.9 and 3.9 MT/ha during the 2011 cropping season, while conventional yields averaged between 0.5 and 0.7 MT/ha (Braul and Woodring, 2011).

Conservation tillage has several attractive effects on water productivity compared to traditional soil and water conservation systems such as *fanya juu* terracing as done in Machakos District. In addition to enhancing infiltration and moisture conservation, CA enables improved timing of tillage operations, which is crucial in semi-arid rain fed farming. The findings of the case studies in Laikipia and Machakos Districts of Kenya reveals that conservation tillage (sub-soiling and ridging) have improved yields by more than 50% (Kihara and Muni, 2002).

The potential of conservation tillage is tremendous, especially with communities already using animal drawn implements for their tillage operations. This is because conservation tillage implements are compatible with the conventional tools. In Dodoma, Tanzania, trench cultivation, a form of conservation tillage have been developed by innovative farmers, where shallow trenches are dug, filled with organic materials then covered by soil to form ridges on which crops are planted (Lameck, 2002). The organic furrows between the ridges capture water, which seeps into the covered trenches and is slowly extracted by the crops.
Terracing in a form of “fanya juu” or the “fanya chini” is a popular practice in Machakos District since the 1930’s when soil and water conservation was intensively enforced by the colonial government as a condition of cultivation. At a later date in 1974, the National Soil and Water Conservation Project (NSWCP) chose Machakos as a pilot area to launch a national campaign to protect land from surplus runoff and conserve water. By 1989, 60-70 % of arable land was terraced to protect it from soil erosion by the use of cut-off drains and “fanya juu” terraces. Machakos District recorded an increase in maize yields by 400kg (over 4 bags) per hectare in farms where terracing had been done compared with the un-terraced farms (GoK, 1989). Studies from Kenya and Ethiopia also show substantial increase in annual crop yields as a result of proper terracing (Stahl, 1993).

2.5 Opportunities of Small-scale Water Harvesting and Saving Technologies

The emergence of small scale water harvesting and saving technologies in Kenya represent the growing interest in alternative sources of water that are affordable and can be implemented using resources that are within the reach of the local people. A study by the Water Management Programme, working under the International Centre for Research on Agro forestry (ICRAF), argues that Kenya and the rest of Africa has enough water to support up to seven times its current population, and that the scarcity of water has nothing to do with lack of water but rather lack of investments in appropriate technologies (Butunyi, 2007).

Another study by Khaka et al., (2006) shows that there is a high potential of rain water harvesting in Africa. Three hundred and thirty (330) million people in Africa are known to be living under “water scarcity”, and about half of the population lack safe drinking water, yet Africa has 3991 km$^3$ / year of renewable fresh water resources. There is a renewed focus on water issues in Africa, particularly through regional bodies such as the African Ministerial Council on Water (AMCON), the New Partnership for Africa’s Development (NEPAD), the Economic Commission for Africa (ECA), the African Water Task Force (AWTF) among others. They have identified that rainwater and storage as among the important interventions necessary towards meeting the water problem in Africa.
Specifically in ASAL areas of Kenya, water harvesting has emerged as an appropriate technology that contributes positively towards improvement of annual and perennial crops’ yields (Mburu, 1993), increased survival and growth rate of tree seedlings (Tiffen et al; 1994), and soil conservation and control of erosion (Critchley et al, 1992). Although the costs of applying water harvesting techniques are higher than with the normal tillage, Mellis et al (1997) show that it is a worthwhile investment as the marginal benefits are higher. Thus, water harvesting can lead to improvement of farmers’ profits in ASAL areas, as well as their standards of living.

Previous attempts to develop Northern Kenya and other Arid Lands have not borne much fruits as policies were not accompanied by adequate resource provisions. Adequate provision of resources will create viable incentives to pastoralists’ settlement in order to accelerate economic growth. The experience the government has in policy implementation in the 1990s shows the need to focus on creating an enabling environment in which peoples opportunities and incomes could be raised in order to widen choices. This could empower people to utilise their capacities and knowledge in order to improve their standard of living.

The Sessional Paper No. 10 of 1965 on African Socialism (Government of Kenya, 1965) and its Application to Planning in Kenya presented the framework for development and equity in Kenya, but it also presented great dilemma when it noted public investment would go to areas of highest potential returns and people most responsive to change. This approach favoured the former white Highlands while perpetuating the marginalised areas like Northern Kenya and other arid lands.

The other policies that were developed thereafter also did not effectively address the unique needs of the arid lands. Most of them had a high degree of bias against pastoralism being a viable and a sustainable way of life. Because such policies were mainly top-down, discriminative, and with no consultation, they often failed, making ASALs to be considered generally unproductive and net consumers of the “national cake”. Northern Kenya and other Arid Lands have about 5 million Kenyans, and 80% of Kenya’s livestock worth 10 billion Kenya Shillings. There are 24 million hectares that can be used for livestock production. In addition, there are 9.2 million hectares
which have potential for crop production if irrigated. This irrigable land is equivalent to the total farmland in high and medium potential areas in the country.

Besides, investment in water harvesting and saving technology, there are other unutilised opportunities which have been practiced worldwide and could also be practiced in Kenya as water saving strategies. These include firstly, behavioural change among the water users especially at household levels, e.g. turning off tap waters instead of leaving them running. It evolves around having the right attitude for sustainable water management. Secondly, enforcing law on the maintenance and protection of the water resources would go a long way to improve the water availability. This ensures no misuse by private companies at the expense of others. Thirdly, enacting water conservation policies especially the costing of the commodity to avoid misuse; and lastly, building of support institutions to oversee the management of water resources.

2.6 Emerging Scenarios of Water Supply and Demand

Until September 2013, Kenya was considered a ‘water scarce’ country since demand outstripped the stock of the renewable freshwater. The water supply was inadequate with only 57 per cent of households using water from sources considered safe (http://www.hackenya.org). A stable fresh water supply is the basis for all human activity, and is critical for stable food supply; but only a small portion of water on Earth is usable fresh water. Of the roughly 1.4 billion km$^3$ of water on Earth, 97.5% is salt-water and the remaining 2.5% is fresh water. Of the fresh water, however, 70% is currently fixed in glaciers or permanent ice, with only 0.3% in lakes and rivers. A report by Rockstrom et.al, (2007), shows that food production requires enormous amounts of water and land to meet the global food demand. Most of the water is used for irrigation and this requires the investment in appropriate water saving technologies for irrigation purpose.

Global water usage showed a definite increase in the last half of the 20\textsuperscript{th} century and now, at the start of the 21\textsuperscript{st} century, humans use approximately 4,000 km$^3$ of water each year. The vast majority of that, roughly 80%, is used for crop irrigation, 20% is
used for industrial purposes, and the remaining 10% is for household use (WWDR, 2009)). It is evident from this study that the many sources of water are left unutilised hence bringing the supply down. The International Food Policy Research Institute (2010) estimates that 80% of the additional food supplies required to feed the world’s population over the next 30 years will depend on irrigation and yet irrigated agriculture remains the dominant user of water as it uses 80% of the global water. It is clear that disparity in the development of the various regions of our country is a direct consequence of the availability or lack of water. As a country develops, the demand for water to support these developing activities will continue rising.

Water is a cause for deep concern in many parts of the world as supplies are threatened by overuse, bad management, and changing weather patterns. The population is increasing rapidly resulting in a rapid increase in the demand for water. Drinking water supplies drawn from traditional wells and boreholes have been severely affected over recent decades by widespread over-abstraction of groundwater for irrigation. Some estimates show that by 2025, when the world population will have risen to over 8 billion, almost all of the economically accessible water in the world may be required to meet the needs of agriculture, households and industry and to maintain ecosystem needs (UN, 1997).

Kenya as a country faces enormous challenges in the development and management of limited water resources, where the magnitude and severity of the water crisis cut across most sectors of the economy, thus making water resources management a high priority that requires urgent attention. The available water is often inadequate for industrial, commercial, domestic as well as livestock and wildlife use. This scarcity has intensified competition among various users and often results to conflicts. A study on National Water master Plan of 1992 indicates that water demand in the important categories including irrigation, livestock, wildlife and hydropower water, will increase significantly from 2073 Million Cubic meters (MCM)/year in the year 1990 to 5817 MCM/year in the year 2010. Table 2.2 below details the water demand for 1995 and an estimated water demand in the year 2010 (UN, 2006a).
Table 2.2: Estimated Water Demand in Kenya

<table>
<thead>
<tr>
<th>Category</th>
<th>Demand (1,000m$^3$/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1995</td>
</tr>
<tr>
<td>Residential urban</td>
<td>747.8</td>
</tr>
<tr>
<td>Residential rural</td>
<td>468.2</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>1,216.0</strong></td>
</tr>
<tr>
<td>Non-residential, health facilities, school,</td>
<td>593.9</td>
</tr>
<tr>
<td>Industry and commerce</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,809.9</strong></td>
</tr>
<tr>
<td>Livestock</td>
<td>376.6</td>
</tr>
<tr>
<td>Irrigation</td>
<td>3.9M</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>2,186.6</strong></td>
</tr>
</tbody>
</table>

*Source: Ministry of Water and Irrigation, 2006*

Rainfall is the most important source of water in the ASALs because most of the areas are located long distances from the perennial rivers such as the River Athi. Table 2.3 shows an analysis of rainfall data for 47 years (1957-2003) at the Katumani Agricultural Research Institute (KARI) station (www.kari.org/index.php?q=content).

Table 2.3: Analysis of 47 years Rainfall Data at Katumani Research Station

<table>
<thead>
<tr>
<th>Years</th>
<th>Short &amp; Long rains (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957-1966</td>
<td>325</td>
</tr>
<tr>
<td>1967-1976</td>
<td>527</td>
</tr>
<tr>
<td>1977-1986</td>
<td>336</td>
</tr>
<tr>
<td>1987-1996</td>
<td>628</td>
</tr>
<tr>
<td>1997-2004</td>
<td>321</td>
</tr>
</tbody>
</table>

*Source: KARI- Katumani research station, Machakos.(1957- 2003)*

The study area experiences a bimodal rainfall pattern with two rainfall seasons, the long rains (March/April) and the short rains (October/November) while the rest of the year remains dry. According to district reports, the study area receives a mean rainfall of 600 mm per year. The rainfall data from the Kathiani District rainfall station from 2004 to 2011 (Figure 2.1) show an amount that is below the expected average of
rainfall. The figures for 2006 and 2008 were not available at the DAO’s office records.

![Rainfall data at Kathiani District](image)

**Figure 2.1: Rainfall data at Kathiani District**

(Units in mm)

*Source: DAO office, Kathiani District (2004-2011)*

Culturally the people of the area under study are closely attached to land, which is usually passed from one generation to another. The existing small land holdings have been over cultivated over the years, and the quality of the land is generally deteriorating due to unsustainable farming practices, with soil erosion as the main form of land degradation. As a result of shrinking holdings of land due to the population growth, and as a result of the static or declining productivity of agriculture on many poorer farms with no off-farm income, over 90 per cent of families are unable to feed themselves throughout the year from the food they harvest from the fields (Murtun, 1997). This was confirmed by the massive food relief distribution given out by the Government and Non-Governmental Organisations (NGOs) within the greater Machakos District from 2007-2009 (GoK, 2008a).

Recurring droughts have been taking place for a long time as seen in Table 2.4, which shows data on the years of drought, external and local interventions within 8 decades.
in the greater Machakos. The greater Machakos includes the current Machakos, Makueni, Kibwezi, Kangundo, Mwala, Mbooni, Kibwezi, Yatta, Makindu, Masinga and Kathiani Districts.

**Table 2.4: Droughts, External and Local Interventions in Greater Machakos District**

<table>
<thead>
<tr>
<th>Decade</th>
<th>Drought years</th>
<th>External and Local interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920s</td>
<td>1928/29</td>
<td>Appeal for famine relief dismissed by the governor. Incentives for destocking intensified. Intensified petitioning for Government to expand the Akamba Reserve.</td>
</tr>
<tr>
<td>1950s</td>
<td>1950 and 1954/55</td>
<td>Famine relief, soil conservation, resettlement, dam construction. Migration and settlement</td>
</tr>
<tr>
<td>1970s</td>
<td>1972/73/74</td>
<td>Food aid, promotion of drought resistant crops, livestock improvement programmes.</td>
</tr>
<tr>
<td>1980s</td>
<td>1980/81 and 1983/84</td>
<td>Previous bumper crop exported NGOs food for work programmes. Machakos Integrated Development Program (MIDP) assistance.</td>
</tr>
<tr>
<td>1990s</td>
<td>1994–95</td>
<td>Famine relief, food-for-work. Sold cattle.</td>
</tr>
</tbody>
</table>

*Source: Adapted from Tiffen et al., 1994: 40-41.*
2.7 Social, Economic and Environmental Impact of Water Harvesting Structures

Social impact involves aspects aimed at improving the quality of life; and ensures equity among people, community and the entire nation. According to Kenya’s Participatory Poverty Assessment report (World Bank, 1995), water availability is closely linked to poverty levels since; the access to safe fresh water for households, farming and small scale industrial activities improves living standards and can increase opportunities for the people to increase their income. Adequate water supplies can be used by communities as an entry point to activities to give immediate social impacts on health, family welfare and domestic production. Where water is provided at household level, it ensures long term and sustainable livelihoods. It is important to note that, provision of water at household levels cannot be achieved without the investment on water harvesting technologies. Availability of water harvesting structures provides ease of use of water for domestic, agriculture, livestock development and industrial utilisation with a view to realising an improved social well-being of the populace, an enhanced performance of the economy both nationally and regionally, and the promotion of national economic development.

A study done by Regional Land Management unit (RELMA) on “Technology Identification for Community Surfaces Rainwater Harvesting Options” in two selected districts; Machakos and Mwingi districts show that the most preferred water harvesting structure was the water pans, followed by water tanks, dams, shallow wells and lastly weirs (Kimeu,2008). The respondents from these districts took into consideration the cost of the WHT, the availability of materials, and unskilled labour provided by the community. For instance, water pans were the most popular in the area because they did not need a lot of technical input, but only locally available labour, and they were effective in supplying water to the household. This brings about the importance of active participation by the project beneficiaries.

Concerted efforts are required by both individuals and groups to ensure water availability. A case study by Maliti, of a community at Kola, Machakos District referred to as Utooni self-help group, is a good example of such efforts (http://www.utoonidevelopment.org/index.php?page=contact-us). Since the Group began, it has built 8,529 gutter and water tank systems and 105 dams over an area of
60 square kilometres in the Kola area. The reservoirs vary in size, the smallest being about 40 meters wide by one kilometre long. Clearly what has involved the group most is finding solutions to lack of water in Kola, which like much of Machakos District area, is semi-arid. There are no permanent rivers here. It receives less than 500mm of rain in a year. It has loam soil, and closer to river banks, sandy, stony soil. The stones are used for building, but of course are not conducive to agriculture. If efforts such as the Kola experience could be replicated in Mitaboni, then there would be increased water supply. The study was done to find out why such practices have not been well adopted in Mitaboni Location.

The provision of fresh water reduces people’s burden of collecting water and leaving time for other productive activities, which can provide opportunities to escape poverty, achieve food security and a high economic growth. A case study was initiated by the Gansu Research Institute for Water Conservancy (GRIWAC), China in 1999, and worked through a community to build 2.2 million small scale water saving tanks by 2001. One hundred and ninety thousand (190,000) hectares of land received irrigated water. As a result, their food harvest increased by 40%; cash crops and fruits that could not previously be grown had given the farmers improved economic situation (Falkenmark et al., 2001). The economic development of a country is highly dependent on water as the key to development in semi-arid and arid lands; yet making it available and accessible is a major undertaking.

A story of community water development and sand dams in Kitui District, tells how communities have been enabled through participatory training, to evaluate the resources available, to analyse the problems they face, and to develop strategies for development of water supplies. The aim was to create a network of sources so that no one need walk more than two kilometres to fetch water. The network includes tanks for harvesting rain water, shallow wells adjacent to schools, and sand storage dams in dry river beds (SASOL and Maji na Ufanisi, 1999). Therefore, the development of water resources has implications for the production of food, health and education. Because development cannot be associated with an individual, it requires collective efforts, in investing in these structures. Poor communities are the most vulnerable to the effects of environmental degradation, as they have fewer resources for adapting to and resolving environmental problems. Widespread poverty and inequity in these
communities are accelerated by environmental degradation, and the communities are compelled to overexploit local resources to survive.

Soil erosion problems in Machakos dates back to the 1930s, when it was realised that the area was experiencing high rates of erosion due to poor methods of cultivation and lack of soil conservation measures. Terracing in Machakos is popular due largely to the rapid benefits it gives in terms of improved crop performance (Kithiia, 1997). The existence of well-developed self-help groups is one of the main reasons for the success of conservation activities in Machakos. Elsewhere, experience has shown that it is very difficult to form effective groups if they do not already exist. The conservation technique used is not new to the area. It is technically sound, and because people have had experience of it for a number of years, they accept it more readily. New ideas are much more difficult to introduce.

Environmental impact of water harvesting structures emphasises on the protection and conservation of our natural environment. Human’s interference with the ecological sphere results into problems of health, loss of diversity, degradation of life support systems, global climatic changes, and ozone destruction. Small scale water harvesting and saving technologies increase the ground water recharge, and this could have a positive impact on overall water resource availability. Water harvesting technologies alter water and sediment flow in the sub-catchments, which results into numerous social and economic benefits for poverty alleviation and sustainable development.

Falkenmark et al., (2001) shows that tropical soils play the role as carbon sink, and that water harvesting technologies increase carbon sequestration through a boost in biomass productivity. With improved farming practices, soil nutrient management can increase farm yields, which in turn raises root production and above the ground organic matter to act as a carbon sink. The drilling of new boreholes, and their equipping with high maintenance pumping equipment, will only be undertaken but with thorough environmental impact assessments and consensus reached and agreed upon by communities and all relevant stakeholders. Emphasis will be laid on rehabilitating and implementing already existing boreholes, as opposed to drilling new ones. The potential for irrigation, especially in the semi-arid areas, will be
explored based on studies and relevant policies that have already been formulated by the Ministry of Water and Irrigation (http://www.hackenya.org).

2.8 Summary of Gaps Identified

In the context of small scale water harvesting and saving technologies, gaps in Mitaboni exist in the following areas:

- Poor adoption of already proven technologies such as shallow wells, water weirs, tanks and water pans.
- Financial constraints in the study area.
- The attitude of the people towards new and different innovations. People are afraid to venture in innovations that are not familiar.
- Poor community and uncoordinated resource mobilisation.
- Lack of research and documentation of existing water situation and their performance in the study area.

There is need to examine the various technologies in use with a view to selecting those that are appropriate to our local situations. This can only be done if there is an institution charged with this responsibility, and which combines the experience and research findings on the performance, adaptability, relevance and durability. Kithinji (1999) noted that, promotion of farmer innovations with improved research and extension linkages can lead to technology breakthrough in water harvesting for crop production in arid and semi arid lands. That is bound to lead to sustainable systems for improved food self-reliance and improved livelihoods for land users.
CHAPTER 3: METHODOLOGY

3.1 Study Area

The study was done in three sub locations of Mitaboni Location, Kathiani District in the Machakos County. Kathiani District is situated 172km south of the centre of Kenya and 160 km south east of the capital city, Nairobi. It boarders Matungulu District to the north, Kangundo District to the east, Mwala District to the southeast and Machakos District to the south. The district lies in a latitude of 37° 10’ East and a longitude of 1° 35’ South (www.traveljournals.net/explore).

The District has: one administrative division, namely Kathiani; four locations; and twenty one sub locations. The four locations include Mitaboni, Iveti, Kaewa and Kathiani. The District occupies an area of 213 km² within the agro-ecological zone of UM4-UM5 and an altitude of between 1500-2100 m above sea level (GoK, 2010). The area experiences erratic and highly variable rainfall coupled with long dry spells, after which the existing water sources become inadequate.

According to the 2009 Census, Mitaboni Location is divided into six sub locations: Mitaboni, Kinyau, Miumbuni, Mbee, Ngini and Ngoleni with a population of 30,055 persons (KNBS, 2009). The three sub locations, (Mitaboni, Kinyau and Miumbuni), were selected for the study due to their diversity of small scale water harvesting and saving technologies that are present in the area (Figure 3.1). Unlike the other three sub locations, the land users in the study area are generally poor and, on account of food shortages, there is dependency on food relief for survival (Kithinji, 1998). In the years 2005/2006 and again in 2010/2011, the area experienced one of the worst droughts on record (GoK, 2010).
As shown in Table 3.1, Mitaboni Sub-Location has a higher population density of 454 per km$^2$ as compared to Miumbuni with 393 per km$^2$ and Kinyau with 163 per.
Table 3.1: Population by Sex, Number of household, Area and Density

<table>
<thead>
<tr>
<th>Sub location</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
<th>Households</th>
<th>Area (km²)</th>
<th>Density (per km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitaboni</td>
<td>3304</td>
<td>3387</td>
<td>6691</td>
<td>1602</td>
<td>14.7</td>
<td>454</td>
</tr>
<tr>
<td>Miumbuni</td>
<td>2199</td>
<td>2316</td>
<td>4515</td>
<td>1021</td>
<td>11.5</td>
<td>393</td>
</tr>
<tr>
<td>Kinyau</td>
<td>2507</td>
<td>2634</td>
<td>5141</td>
<td>1161</td>
<td>31.6</td>
<td>163</td>
</tr>
</tbody>
</table>


A higher rainfall enables the Mitaboni Sub Location to have a diverse cropping system, and is a more food secure area than the other two sub locations. Kinyau Sub Location is termed as a range land where cultivation of food crops is minimal, and the practice of keeping livestock is higher as compared to Miumbuni and Mitaboni Sub Locations. Mitaboni Sub Location, unlike the other two has more availability of water sources, and people walk less distances to fetch it (GoK, 2008b). According to the Ministry of Water and Irrigation (2005), Kenya targeted to provide clean and portable water at sources less than a Kilometre in the high potential areas, and less than 5 Km in the ASALs by the year 2010.

According to the KNBS (2010), Kenya’s rapid population growth rate of 2.59% per annum continues to put pressure on the land, and this has contributed to the destruction of the environment, and land degradation is evident. According to a 60 year old study that was done in Machakos District from 1930 to 1990, it was observed that, despite a fivefold increase in the population at the time, there was indeed a fundamental change in socioeconomic output. This is found in the publication of ‘More people, less erosion’ (Tiffen et al., 1994). This means, apart from population pressure, there are other factors that contribute to soil degradation and land degradation.

3.2 Research Design

This study adopted a survey approach, which presented procedures for collecting, analysing and linking both quantitative and qualitative data to provide a better understanding of the variables used in the study. A survey approach using
Participatory Rural Appraisal tools allowed relatively more data to be collected in a short time, and was used to encourage community participation. Both primary and secondary data were collected from the farmers, government ministry staff, self-help groups, and administration personnel. According to Kombo and Tromp (2006), the descriptive design does not only report findings, but “may often result in the formulation of important principles of knowledge and solution to problem”.

3.3 Target Population and Sampling Procedure

The target population for data collection consisted of key stakeholders who included; individual farmers, Ministry of Water and Irrigation staff, agricultural extension workers, the provincial administration, self-help groups, and the civil society members involved in water harvesting activities. Among the selected population, households were used as the basic unit of analysis, and the household respondent as the unit of observation. Three sub locations, (Mitaboni, Kinyau and Miumbuni), were randomly selected for the study using simple random sampling.

A sample size of 200 respondents was selected from the accessible population of 3784 households in the farming community, and this constitutes to nearly five percent of the desired results. Although the expected percentage of the research is ten percent (Mugenda and Mugenda, 2003), the study found out that most of the water harvesting structures used were community based and communal in nature, so there were high chances of duplication of answers. Proportionate sampling was used to determine the sample size from each of the three sub locations, where 86 respondents were from Mitaboni, 60 from Kinyau, and 54 from Miumbuni. This was determined by the baseline information for households in Mitaboni Location (KNBS, 2010) which recorded 1602 households in Mitaboni Sub Location, 1161 households in Kinyau, and 1021 households in Miumbuni. Purposive sampling was used to identify key informants who were directly involved with communities and water projects.
3.4 Data Collection Methods

A structured questionnaire comprising both open and closed questions was used to gather data from 200 respondents (Appendix 7.1). The closed-ended questions gave out more specific and concrete responses. The questionnaires were the main survey method, which involved a visit to the sampled household with the guided assistance of a village elder who also coupled as one of the key informants. The study targeted any of the parents of the household who was to be interviewed.

A key informant questionnaire was used to collect data from 20 key informants’ who were extension service providers chosen purposively to represent both the private and public sectors (Appendix 7.2). The findings from the informants were used to clarify some of the responses taken from the household questionnaires.

Participatory Rural Appraisal (PRA) tools used included the key informant interviews, focus group discussions (FGDs), and personal observation. The main purpose of FGDs was to triangulate the findings obtained from the personal observation and the questionnaires administered. With the assistance of the key informants, selected participants were invited to FGDs sessions, and after introductions were made, FGDs participants were led through discussions and probing questions to verify and to enrich the obtained survey results. One FGD was conducted from each sampled sub location and twenty participants per sub location formed the participating group. The FGD participants were drawn from self-help groups who were found working at the Water Harvesting Technologies sites, farmers, small scale water service providers and community leaders who had lived in the area for over ten years and had an in-depth knowledge on the issues concerning the study objectives. The FGDs were composed of equal numbers of men and women in appreciating that, in the tradition of the study area, it is the work of women to collect water for household use. Discussions that were held dealt with the major causes of persistent water shortages, as well as brainstorming sessions on the different ways that the community can assist to solve the water problems in the area. Content analysis was used as a form of secondary data collection and this involved a detailed study of documents that were relevant to the study, such as books, local newspapers, journals, theses and existing databases of information.
3.5 Data Analysis
The questionnaires were first examined to ensure they were complete and had been consistently completed. Data from the questionnaires was coded and fed into the Statistical Package for Social Scientists (SPSS) spread sheet for analysis. Descriptive information was used to portray the sets of categories formed from the data and enabled the researcher to meaningfully describe a distribution of measurements. Descriptive analysis consisted of frequency distribution and percentages from the responses which were presented using graphs as a summary. The data from the interview schedule for the key informants was also analysed using descriptive statistics. Inferential analysis involved comparisons of the relationship between various socio-economic factors such as income levels, family size, land size, and household income with the availability of water in the area using Pearson’s correlation analysis. Qualitative data required the respondents to give opinions and suggestions, so it was discussed under themes consistent with the objectives of the study. A content analysis and in-depth probing were used to confirm the qualitative data including secondary data.

3.6 Validity and Reliability of Data
Validity refers to “the degree to which the evidence supports that the interpretation of the data is correct and the manner to which interpretations used are appropriate”, (Moskal, et. al., 2002). A study is valid when it is well designed and provides results that are appropriate to be generalised in the entire population of interest. Validity, therefore, has to do with how accurately the data obtained in the study represents the variables of the study. If such data is a true reflection of the variables, then inferences based on such data will be accurate and meaningful. Before using the research instrument, the content validity of the instruments was established by the researcher through discussing the items in the instrument with the supervisor and subjecting it to triangulation. To establish validity, results from the key informants, community members, and FGDs were compared to see if the results were similar.

Reliability refers to a measure of the degree to which a research instrument yields consistent results or data after repeated trials (Mugenda and Mugenda 2003). To test the reliability of the data, the researcher administered the same instrument twice to the
same group of subject. The questionnaires and observation schedules were administered using the same procedure where the researcher correlated the scores from both testing periods and found the coefficient of reliability to be positive which qualified the instrument as reliable.

3.7 Ethical Dimension
Prior to using the research instruments, an official letter was obtained from the learning institution as a permit to administer research in the area of interest. A visit was made to the provincial administration office to meet with the Mitaboni Location leaders and village elders. The permit letter was also read to the community members during a Chief’s baraza. This letter stayed pinned outside the Chief’s office during the entire research period.
CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Socio-Economic Attributes of Study Area

The sampled population in the study had 63% females and 37% males. The study ensured that women were part of the sampled population. There is need to address the integration of gender sensitive policies that take into considerations the varying social economic experiences of both men and women. In her paper, Nzomo (1992) emphasises on the restructuring of existing policies to involve women in policy formulation and implementation and to ensure their use and ownership of natural resources.

Kenya government report on poverty and inequality confirms that households headed by individuals with no education have the highest poverty incidences (Wandera, 2005). Low levels of education had a direct relationship with low level of income; for instance, individuals with primary education had more poverty compared with those of households headed by individuals with secondary education or above. In the study area, 48% of the respondents had primary education (Figure 4.1), 39% had secondary education, 5.5% had tertiary education, while 7% had no formal education.
A Chi Square test was carried out to see whether the level of education of the study area had any relationship with the availability of the commonly used water harvesting technologies (Table 4.1).

### Table 4.1: Level of Education and Most Commonly Used Water Technologies

<table>
<thead>
<tr>
<th>Level of Education</th>
<th>Most Commonly Used Water Technologies</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Tanks</td>
<td>Water Ponds</td>
</tr>
<tr>
<td>None</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Primary</td>
<td>86</td>
<td>78</td>
</tr>
<tr>
<td>Secondary</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Tertiary</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total (count)</strong></td>
<td><strong>165</strong></td>
<td><strong>158</strong></td>
</tr>
</tbody>
</table>

Chi-square (χ²) value = 0.562109; Degrees of Freedom (df) = (4-1)(3-1) = 3x2 = 6

From the results in Table 4.1, there is no sufficient evidence to reject the H₀ at the 0.05 significance level. The H₀ is accepted since χ²(of 0.562109) is less than the
critical value for 0.05 probability level (12.59). This means that there is no relationship between the levels of education and the availability of the commonly used water harvesting technologies in each household. For instance, households with no formal education have built more water tanks than those of both secondary and tertiary education.

The source of income in the study area is mainly from agriculture where over 50.5% of the respondents practice and depend on agricultural produce for their livelihood (Figure 4.2).

![Figure 4.2: Sources of Income](image)

Miumbuni Sub-Location has the highest dependency on income derived from agriculture as compared to income from salaries and business. This implies that whenever there is a crop failure, then the people from Miumbuni Sub-Location suffer more from shortage of food and income becomes low, and hence increased demand for famine relief is inevitable. Mitaboni has the highest dependency on salaries unlike Kinyau or Miumbuni. This is because Mitaboni Sub-Location hosts the Location’s agricultural market, where people from the location meet to buy and sell their agricultural produce and it is where people have higher chances of getting casual jobs in the market.
A Chi Square test of independence was carried out to determine whether there is a relationship between the sources of income within households and the availability of the most commonly used water technologies as found in Table 4.2.

### Table 4.2: Sources of Income and Most Commonly Used Water Technologies

<table>
<thead>
<tr>
<th>Sources of Income</th>
<th>Most Commonly Used Water Technologies</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Tanks</td>
<td>Water Ponds</td>
</tr>
<tr>
<td>Salary</td>
<td>47</td>
<td>41</td>
</tr>
<tr>
<td>Agriculture Produce</td>
<td>86</td>
<td>95</td>
</tr>
<tr>
<td>Business</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Family Members</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Others (specify)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong> (Count)</td>
<td><strong>165</strong></td>
<td><strong>158</strong></td>
</tr>
</tbody>
</table>

Chi-square ($\chi^2$) value = 0.051281; Degrees of Freedom (df) = (4-1)(4-1) = 3x3 = 9

From the results in Table 4.2, there is no sufficient evidence to reject the $H_0$ at the 0.05 significance level. The $H_0$ is accepted since our $\chi^2$ (0.051281) is less than the critical value for 0.05 probability level (16.92). This means that there is no relationship between the sources of income and the availability of the commonly used water harvesting technologies. Each of the variables is independent.

The average size of arable land in the study area was found to be 3.2 acres per household. A Chi Square test was done to determine whether there is a relationship between the sizes of arable land per household and the availability of the most commonly used water technologies as found in Table 4.3.
### Table 4.3: Total Arable Land and Most Commonly Used Water Technologies

<table>
<thead>
<tr>
<th>Total Arable Land (Acres)</th>
<th>Most Commonly Used Water Technologies</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Tanks</td>
<td>Water Ponds</td>
</tr>
<tr>
<td>Less than 1</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>1</td>
<td>41</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Over 5</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Total (count)</td>
<td>165</td>
<td>158</td>
</tr>
</tbody>
</table>

Chi-square ($\chi^2$) value = 0.335712; Degrees of Freedom (df) = 18

From the results in Table 4.3, there is no sufficient evidence to reject the $H_0$ at the 0.05 significance level. The $H_0$ is accepted since our $\chi^2$ (0.335712) is less than the critical value for 0.05 probability level (28.87). This means that there is no relationship between the size of arable land per household and the availability of the commonly used water harvesting technologies. Each of the variables is independent.

### 4.2 Assess the Utilisation of the Water Harvesting and Saving Technologies

Globally, a country is categorised as ‘water scarce’ if its renewable freshwater supplies are less than 1,000 cubic meters per capita per annum. Water scarcity in the study area remains evident as the renewable fresh water per capita is projected to fall from 647 cubic meters to 235 cubic meters by the year 2025 if the water supply does not match with the rise in population (GoK, 2008b). However, with the recent discovery of the two aquifers in Turkana County in 2013, then the future of the water situation may not be as bleak as presented in the study.
In the study area, the situation of water is shown to be ‘scarce’ across the three sub-locations. As Figure 4.3 shows, only 25.5% of the respondents described the water situation in the study area to be between ‘very adequate’ and ‘adequate. The rest of the 74.5% stated otherwise, describing it as either ‘scarce’ or ‘very scarce’.

![Figure 4.3: Status of Water Availability in the Study Area](image)

Discussions through FGDs revealed that those respondents with ‘very adequate’ and ‘adequate’ water sources are the few who have invested in water harvesting technologies, and have more than one source of water storage, and water is available to them throughout the year. Further discussions with focus groups confirmed that the average household consumes less than 10 litres of water per person per day. According to the World Health Organisation (WHO), the recommended daily consumption is between 50-100 litres of domestic water per person per day in order to ensure that most of the basic needs are met and few health concerns arise. WHO defines domestic water as being “water used for all usual domestic purposes including consumption, bathing and food preparation”. In Kenya, the average water use is 46 litres per person per day (UNDP, 2006) which is ranked low when compared to the average water use of the European countries which ranges between 200-300 litres.

Norms for quantities of water to be supplied have been proposed for certain specific conditions. For instance, the SPHERE project sets out 15 litres of water used per
capita per day as being a key indicator in meeting minimum standards for disaster relief (OXFAM, 2002). In their guidance manual prepared for the Department for International Development (UK), WELL (1998) suggested that a minimum criterion for water supply should be 20 litres per capita per day, whilst noting the importance of reducing distance and encouraging household connection. A similar figure has been suggested by other researchers such as Gleick (1996) that the international community adopt a figure of 50 litres per capita per day as a basic water requirement for domestic water supply.

4.2.1 Existing Water Harvesting Technologies

Small scale water harvesting structures are available in the study area as shown in Table 4.4.

Table 4.4: Small water harvesting technologies in the three sub-locations

<table>
<thead>
<tr>
<th>Small scale water harvesting Structures</th>
<th>Total No. (Kinyau)</th>
<th>Total No. (Mitaboni)</th>
<th>Total No. (Miumbuni)</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water ponds/pans</td>
<td>74</td>
<td>54</td>
<td>126</td>
<td>254</td>
</tr>
<tr>
<td>2. Water tanks</td>
<td>121</td>
<td>171</td>
<td>192</td>
<td>484</td>
</tr>
<tr>
<td>(Plastic/concrete/jars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Shallow wells</td>
<td>35</td>
<td>25</td>
<td>21</td>
<td>81</td>
</tr>
<tr>
<td>4. Weirs</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>5. Underground water tanks</td>
<td>8</td>
<td>6</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>6. Spring protection</td>
<td>1</td>
<td>3</td>
<td>Nil</td>
<td>4</td>
</tr>
<tr>
<td>7. Road runoff water harvesting</td>
<td>8</td>
<td>12</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: DAOs office, Kathiani District, 2011

Focus group discussions show that the existing small scale water harvesting structures in the study area do not give adequate water to households beyond the month of August, even in times of normal rains. Through FGDs, it was found that the water ponds lose much of their water through seepage due to poor soils and lack of lining materials. In times of dry months, the three sub-locations rely mostly on water pans, water tanks and shallow wells; although reports from the Athi River catchment (WRMA, 2008) show that most of the existing water pans are heavily silted, and so
they cannot store a substantial amount of water. At one time, one house could be using two or more sources of water in order to meet their basic needs.

A summary was done from the three sub locations showing the utility rates of the water harvesting and saving technologies in terms of their use, reasons for its choice and the limitations (Table 4.5).
### Table 4.5: Utility Rates of Water Harvesting and Saving Technologies (WHTs) in the Study Area

<table>
<thead>
<tr>
<th>Existing WHTs</th>
<th>Percentage of H/Hs using the WHT</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Boreholes</td>
<td>68%</td>
<td>Respondents use boreholes for domestic purposes, highly reliable and hygienic. <strong>Limitations:</strong> High cost (Ksh 150/m³). Not adequate for livestock and for irrigation. High salinity of water.</td>
</tr>
<tr>
<td>2. Earth Dams</td>
<td>60%</td>
<td>More diverse uses: domestic use, livestock, improves environment. No charges at delivery point. <strong>Limitations:</strong> Unhygienic for home use. Dries up during dry seasons. Long distances to cover.</td>
</tr>
<tr>
<td>3. Shallow wells</td>
<td>50%</td>
<td>For domestic use, have medium reliability and hygiene. Individually owned, cheaper to dig unlike the boreholes. <strong>Limitations:</strong> May dry up or water levels may drop. A fee is usually charged at delivery points.</td>
</tr>
<tr>
<td>4. Weirs</td>
<td>28%</td>
<td>Diverse uses: domestic, livestock improves environment, Raises water table, no charges. <strong>Limitations:</strong> Low reliability, siltation and drying. Unhygienic, long distances covered.</td>
</tr>
<tr>
<td>5. Roof Tanks</td>
<td>28%</td>
<td>For domestic use, highly hygienic, efficient and easy to manage. Cheaper to construct, saves time and energy of fetching water, growing of vegetable gardens and tree seedlings for home use. <strong>Limitations:</strong> Small amounts of available water to last households through out the year.</td>
</tr>
<tr>
<td>6. Water Pans</td>
<td>6%</td>
<td>Mainly used for livestock and improvement of the environment (tree nurseries and vegetable gardens). <strong>Limitations:</strong> Not reliable, due to the small volume of water, pans cannot last long.</td>
</tr>
</tbody>
</table>
4.3 Coping Mechanisms of Water Shortages and their Effects

This study identified four major coping strategies used during times of water shortages, which included walking long distances to fetch water, buying water from vendor or small scale water service providers, water rationing, and water recycling (Figure 4.4).

![Coping Strategies of Water Shortages in the area](image)

During the dry weather, 52% of the respondents practice water rationing as a coping mechanism in the study area. Water that is fetched or purchased from shallow wells and water tanks is considered ‘clean’ water, and is mainly preserved for drinking. In times of extreme water scarcity, water pans, weirs and water tanks may dry up leaving the people to ration the water. During the FGDs, the respondents confirmed that they usually take baths and wash their children and clothes at the rivers and dams. On their way home, they carry water for cooking on their backs. This has huge implications on the health of the family due to the type of water they use. Sometimes water from the dam is used for livestock as well as for cooking. The spread of water borne diseases is common in the area.

The study showed that 45% of respondents purchase water as a coping mechanism. Out of the income earned by the respondents, an in-depth study done on 200 households’ show that 26.3% of the average monthly income is spent on purchasing water or paying for labour to fetch water. This figure increases depending on the time
of the year and also the amount of rain falling within that season. Mitaboni Sub-
Location seems to have high incidence of purchasing water unlike Kinyau and
Miumbuni. Mitaboni was observed to have more salaried people (18.5%) compared to
Kinyau with 9% salaried people and 1% in Miumbuni. Within the market, Mitaboni
Sub-Location has five commercial shallow wells and two boreholes recently dug
through the Constituency development Funds (CDFs). The human rights to water,
Fact Sheet No. 35, states that everyone has a right to water and sanitation and that the
water and water facilities should be affordable to all. According to the United
Nations Development Program (UNDP), water cost should not exceed 3% of the
household income.

Due to the highly patriarchal society which encourages the domination of men in all
areas, water collection is among the basics that women have to put up with. As men
go out to work and enter into commerce, rural women are left behind as the invisible
workforce and the unacknowledged backbone of the family. Further interviews with
small scale water service providers in Mitaboni confirmed that the men whom we
found fetching water were mainly doing it for commercial purposes, while the women
were fetching water for domestic use. In times of extreme hardship, the men may
assist in the collection of water for domestic use, but they will bring it back using a
donkey or bicycle, while the women would carry it with 20-litre jerry cans on their
backs.

The Government of Kenya has put up reforms (GOK, 2007b) to attract private
investors and companies to finance water infrastructure and to manage water and
sewerage services with an aim for improved services. The quarterly progress report
(January-April 2009) of the Machakos Water & Sewerage Company Limited shows
that, charges for piped water within the Machakos town was at Ksh 76.00 per m$^3$
while in the study area respondents pay Ksh 150.00 per m$^3$ for water purchased with
jerry cans at the boreholes.

The Agenda 21 ‘Water for Sustainable Development in Africa’ document confirms
that, throughout Africa, water is unfairly allocated in many areas; the majority of
people pay an increasingly high price for water or for the lack of it. The highest price
is often paid by the poor majority in terms of: money to buy small quantities of water;
calories expended to fetch water from distant sources; impaired health; diminished livelihoods; and even most do not have reasonable access to safe water. Respondents explained that due to the high cost of water, Ksh 5 per 20 litre container, they are only able to purchase water for drinking while for other uses such as washing, cooking and watering of livestock, they walk long distances to fetch water from earth dams, weirs, and water pan, where they do not have to pay for them.

When most of the water harvesting structures dry up, the distances and time taken to fetch water increases. The study found that 35% of the respondents walked long distances to get to the water sources. The WHO recommendations for everyone’s right to water and sanitation services is that the physical accessibility to a water source has to be within 1000m (1 km) of the home, and collecting time should not exceed 30 minutes (WHO, 2010). Currently, the average distances that a woman in Africa and Asia walk to collect water is 6 km (UNFPA, 2002).

In the study area, there is no piping system to take water from the source to the households. Out of FGDs, the study confirmed that people walk 3km in Mitaboni and 5km in Miumbuni and Kinyau sub locations to fetch water from the government constructed dams and boreholes. This confirms findings from the study on “Water and Sanitation Service delivery in Kenya” by Mireri, et al (2007) that piped water supplies in most rural areas of the ASAL face serious shortages of water and poor maintenance. According to the 2010 Kenya Population and Housing Census report, it shows that only 30% of households in Kenya have access to piped water supply (GOK, 2010). While Nairobi province has 75.5% of the households served with piped water, other provinces suffer with Nyanza (8.5%), North Eastern (11.6%), Western (7%), Eastern (28.5%), Rift Valley (22.8%), Coast (46.3%) and Central (39.8%).

From the FGDs held at Mitaboni, the activity of collecting water takes 40% of a woman’s day which is about 5 hours a day because they sometimes go more than one trip to fetch water. This has huge implications on the woman’s health, time and wealth. According to the FGDs, most of these women suffer from chronic lower back problems later in life after years of carrying water containers on their backs. The time taken to go for water robs them ample time for more productive work such as the cultivation and timely harvest of their food crops.
Traditionally amongst the Akamba people, it is the work of the women and girls to fetch water for domestic use. This has a big effect on the girl child who may sometimes be forced to miss school. This later leads to poor performance in their studies and later influences choices of their future careers. According to a report by the Joint Monitoring Program (JMP) for water supply and sanitation (WHO/UNICEF, 2010), women shoulder the largest burden in collecting drinking water. Surveys carried out by JMP from 45 developing countries show that this is the case in almost two thirds of households, while in almost a quarter of the households, it is men who usually collect water.

Water recycling is also practiced by 28% of the respondents as a coping mechanism in the study area. FGDs confirmed that the water they use for washing is later used to clean the house and to water the kitchen gardens. The water used to wash clothes or dirty dishes is passed through charcoal for purification and later it is used to water their kitchen gardens. Some of them confessed that they never wear white clothes during the dry times, but instead wear dull colour clothes that can be repeatedly worn over and over again.

In conclusion, the study found out that the most common and popular coping strategy was rationing of the little water obtained; while the most common effects of the coping strategies included deteriorating and poor physical health, increased poverty, and inadequate education and livelihoods.
4.5 Assess the Potential of other Water Harvesting and Saving Technologies

Following the findings as shown in Figure 4.5, the most popular technologies include the water tanks, pans/ponds, shallow wells and the weirs. Out of 200 respondents, 195 are using water tanks as a source of water (97.5%). Tanks were mainly found in Mitaboni Sub-Location, and within homes where income levels were higher and rainfall was more reliable. Respondents who are using water from shallow wells were 173 (86.5%), 159 (or 79.5%) respondents have water pans/ponds, 118 (or 59%) respondents have access to weirs, 10 (or 5%) respondents used water from the River Kathaana, while 5 (or 2.5%) respondents have access to the spring water.

![Figure 4.5: Existing Small scale Water Harvesting and Saving Technologies]

There is potential for other water harvesting technologies that could be explored by the Mitaboni residents. This includes the creation of wetland conditions on a farmers’ land. In a water conservation project for the African Christian Church & Schools (ACC&S), a farmer, Wa Kariuki, has created a micro-climate in the middle of a dry land of Maai Mahiu, near Naivasha, Kenya. This involved digging out a pit of 7m wide, 7m long and 1m deep and lining it up with a plastic paper to prevent any water from escaping through seepage. The soil is then returned into the pit and awaits the runoff water from the roadside which accumulates and settles without any
seepage. In the middle of this dry land area, Wa Kariuki plants vegetables such as arrow roots which only thrive in very wet and swampy areas (ACC&S, 2012).

There are other potential water harvesting technologies which have not been practiced in the study area (Table 4:6) (www.rainwaterharvesting.org/Rural/Rura/html). The study found out that respondents do not perceive the following water harvesting technologies with much significance. Awareness will make the respondents begin to take serious measures on different ways of conserving water. This water will not just be useful during cooking, washing and drinking, but it will bring an integrated impact to increased soil and water conservation which will in turn bring increased crop yields, a rise in the water tables as well as environmental improvement.
Table 4.6: Potential Water Harvesting and Saving Structures

<table>
<thead>
<tr>
<th>Other potential Water Harvesting and Saving technologies</th>
<th>Success Stories</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sub-Surface Dykes</td>
<td>Referred to as underground check dams. Used in Gujarat, India. System was coupled with water tanks. The check dams are used for irrigation and 20 wells have been recharged.</td>
<td>System could be used to store rain water in Mitaboni for longer periods.</td>
</tr>
<tr>
<td>2. 1-2-1 water harvesting system</td>
<td>Used in Gansu province, Central China to collect and store rainwater. 1-2-1 is1 clay tiled roof catchment area, 2 upgraded cement cellars and 1 clay lined water cellar. System support to about 1 million people with water in 1995-96. (<a href="http://www.fao.org/prods/gap/database/gap/files/583">www.fao.org/prods/gap/database/gap/files/583</a>)</td>
<td>Effective and inexpensive method and can be effective in Mitaboni where there is lack of funds to construct structures.</td>
</tr>
<tr>
<td>3. Ramteck Model</td>
<td>Scientific analysis of network between ground water and surface water bodies connected through surface and underground channels. Conserves &gt;60% of total runoff. Used in Ramteck, India.</td>
<td>Water system designed to utilise every rain drop falling on the water shed.</td>
</tr>
<tr>
<td>4. Khadin</td>
<td>Indigenous method in India designed to harvest surface runoff for agriculture. Involves a long (200-300m) earthen embankment built across the hill slopes.</td>
<td>Best used for harvesting rainwater on the farmland.</td>
</tr>
<tr>
<td>5. Environmental conservation as water harvesting methods</td>
<td>Darewadi village, India combined technical treatments (contour, check dams, farm bunds, contour bunds) with bio-regeneration (seeding of grasses) to transform the degraded landscape to provide water for drinking and irrigation.</td>
<td>Degraded land can deplete water from the land. Practice can bring back the ground water in Mitaboni.</td>
</tr>
<tr>
<td>6. Spate irrigation</td>
<td>Involves diversion of flood flow from highlands into lowlands. Has a long history in Africa; still forms the livelihood base for rural communities of arid Eritrea and Ethiopia. (SIWI, 2001)</td>
<td>This method may be used to divert water from the Iveti hills to the lowlands.</td>
</tr>
</tbody>
</table>
4.5 Factors that Hinder Investment in Small Scale Water Harvesting Technologies

4.5.1 Root causes of persistent water shortages in the study area

The findings showed that the major causes of water shortages in the study area included: inadequate rainfall; lack of adequate storage structures; uncontrolled sand harvesting; and high seepage rates (Figure 4.6).

![Diagram showing farmer's opinion on the root causes of water shortages in the study area]

Figure 4.6: Farmer’s Opinion on the Root Causes of Water Shortages in the Study Area

Unreliable rainfall was cited as the main cause of the persistent water shortage by 27% of the respondents. From the FGDs, it was found that the existing structures do not store adequate water to sustain the population throughout the year. Even in the areas where water harvesting structures exist, the amount of water harvested is not enough for both domestic and agricultural use. Increased methods of collection of runoff are required so as to tap every drop of water that falls in the area of study.

Lack of adequate water storage structures was the second cause of water shortage across the three sub-locations. Through FGDs, it was found that there is no one
existing water storage structure in the area that would sustain one household with adequate water up to the end of the year. Each household at a time uses two to three different water storage structures so as to have sufficient water for them. For instance, one household may be using water from the water tank for drinking, the water from the shallow well for cooking, and then the cows are taken to the nearest dams to drink water as the respondent washes clothes and bathes at the same time.

During the period 2007-2010, rainfall distribution in the study area was not sufficient, and this caused weirs and dams to dry up (GoK, 2010). The area experiences a bimodal rainfall pattern, long rains during the months of March/April and short rains during the month of November/December, and water is collected in the WHTs. The rest of the months are usually dry, and the water collected cannot last until the rains fall in the next season.

Uncontrolled sand harvesting is a cause of water shortage, and has become a problem faced by the community. In a baseline survey conducted by Poverty Eradication Network (PEN) in 2009 (www.penkenya.org/pages/sand_harvesting.vrt) results showed that sand harvesting has become a major concern in the greater Machakos District and the lower eastern region of eastern province. As a result, streams around Machakos, Kangundo, Kathiani, and Mwala are badly affected, and the damage done has implications for the local area since with the very little income earned, none is being ploughed back to the local area for development. This environmental degradation is best witnessed along Thwake River which passes through Kathiani District and goes through the greater Machakos District. Much of the problem is lack of enforceable sand harvesting policy and the poor knowledge of the Environmental Management and Coordination Act (GoK, 1999a) by all stakeholders.

High water seepage rates within the water storage structures such as weirs and water pans contribute to the water shortage in the study area. Most of the soils have structures that do not hold water. This is due to the types of soils found in the study area. A study done by Gachene and Kimaru (2003), through the Regional Land Management Unit (RELMA), showed that the black cotton soils (vertisols) soil cover large parts of the study area. Vertisols have strong cracking characteristics which tend to occur during the dry season and when it eventually rains, the soil is not able to
retain the water as expected. Several interventions have taken place through the Ministry of agriculture to minimise seepage of water in the dams and ponds by installing plastic liners at the water storage area (Plate 2).

In addition to high seepages rates, water pans and weirs have a short life span due to the high evaporation rates caused by the large surface area of exposed water. Water pans are expected to be deep to minimise evaporation, while weirs form the subsurface dams which attempt to minimise evaporation. According to a report by Falkenmark et al (2001), the ASALs can lose water that amounts to 0.9-1.4m³ within a period of 6 months.

### 4.5.2 Factor that Hinder investment in water harvesting and saving technologies

Factors that hinder the investment in small scale water harvesting structures varied across the three sub locations. Lack of funds and inadequate skills were the most limiting factors that hindered investment in small scale water harvesting technologies in the study area as mentioned by 20.7% of respondents (Figure 4.7).

![Figure 4.7: Farmers’ Opinion on the Factors that Hinder Investment in WHTs](chart)

- **Lack of Land space**: 9.0%
- **Lack of Funds**: 20.7%
- **Inadequate Skills**: 17.1%
- **Inadequate rainfall**: 14.5%
- **Lack of Unity**: 9.0%
- **Inadequate Support**: 6.0%
- **Lack of Funds**: 9.0%
In Mitaboni and Kinyau sub locations, lack of funds was the major hindering factor as confirmed by 20.7% respondents. The study found out that the respondents needed the use of more than one different water harvesting and saving structure to provide adequate water for them throughout the year. During the FDGs, respondents mentioned that it was not worth investing heavily in structures which may not serve them until the next rainy season, which would still make them walk long distances to fetch water during the dry season. In the Session paper No. 1 (GoK, 1999b), the government of Kenya confirms that shortage of funds for development, operation and maintenance of water supplies and management of resources is one of the challenges in the water sector. Many farmers would benefit from low-cost water harvesting technologies that are more suited to their conditions and their needs and also those that ensure increase in water use, efficiency and conservation.

Lack of knowledge and skills to construct small scale water structures was one of the factors mentioned by 17.2% of respondents. Out of personal observation, many existing structures were found to be of appalling state due to poor maintenance. The respondent’s lack of skills was also mentioned by the FDGs who agreed that if people had the skills, then the cost of constructing the structures would be reduced and the structures would be affordable. This would increase the number of harvesting structures and hence the distances to water points would be shortened.

Technical skills including proper citing of the catchment areas, formulation of technical designs, and building of the structures were found lacking. Improved participation and mobilisation of the local people would create an understanding of the indigenous water harvesting technologies that have been implemented by the end users and make room for more improvement.

Out of the study, 14.5% of the respondents confirmed that lack of adequate and reliable rainfall was one of the factors hindering investment in water harvesting structures within the three sub locations. The unreliable amount of rainfall that falls every season has not yet convinced respondents to invest on a particular WHT without the risk of not getting efficient service from it. To invest in these structures in most cases is termed as waste of money and effort; because the rains perform poorly hence the structures don’t sustain them for a long time. As a result of the failed rains,
water for household use is increasingly getting scarce resulting in an increase in the price of the commodity and households trekking up to 3-5 km in search for water for both domestic and livestock. While livestock should mitigate crop losses, their poor body condition as a result of extended trekking in search of water and pasture can cause a decline in their value (GoK, 2008a).

Water harvesting directly from the rains can be an effective technology for improving the livelihoods of people in Mitaboni Location. According to Kutch (1982), annual rainfall is not the most important factor in water harvesting, especially looking at the technology used to sustain food production in the Negev desert of Israel with an annual rainfall of about 100 mm (Shanan and Tadmor, 1976). Most of the famine stricken areas of Africa receive much more than 100 mm of rainfall, and yet there is an acute shortage of water. For instance, Mitaboni receives an annual rainfall of 300-500 mm per annum. Many parts of the study area could tremendously improve food security through small scale water harvesting technologies which aim to supply the deficit between rainfall and evapotranspiration during the growing season.

Small scale water harvesting technologies are simple, relatively cheap, environmentally friendly, and can easily be managed with limited technical skills. Therefore, promotion of small scale water harvesting technologies should take into consideration the perceived low rates of financial investments, especially in runoff farming, compared to irrigated agriculture.

4.6 Addressing the Water Shortage Problem
Respondents confirmed that there are solutions to the existing water shortages within the 3 sub locations. The major solutions that they mentioned included public talks to create awareness, construction of water harvesting structures and provision of funds (Figure 4.8).
In Mitaboni Sub-Location, there is more awareness on the need to solve the water shortage problems followed by Kinyau and then Miumbuni Sub-Locations. As a result of high public awareness in Mitaboni Sub-Location, the respondents have already shown a higher response to acquire funds, as well as a higher response towards the need to construct water harvesting and saving technologies. There is need to empower communities to contribute towards identifying appropriate technologies that are suitable for their areas. In understanding their felt needs and alternative ways of water harvesting and saving technologies, they will evaluate the ones that exist and work towards their improvement.

The current water structures were seen to benefit only those who lived near them, so when the numbers are increased, respondents will take less time and energy in fetching water. If water is provided in sufficient quantities and quality, then it will have a direct benefit for human and livestock consumption as well as in cropping and agro-forestry.

Further interviews with FGDs brought out solutions that would address some causes of the persistent water shortages revealed earlier in the study (Figure 4.8). This included scooping of the existing water pans that were heavily silted, and using liners to control the high seepage rates, planting more trees to minimise deforestation, and
banning sand harvesting. In order to succeed, the FGDs emphasised on the unity of the people together with the government personnel so that the work can go on well. With unity, communities can work together to raise tree nurseries alongside the weirs and plant them during the rainy season.

4.7 Role of Different Stakeholders

The provision of water to the entire nation remains a major challenge, so it calls for full participation and collaboration with the government, donor community, NGOs, and private sector in mobilising human and financial resources required (GoK, 1999b). This was confirmed by the respondents who felt that each stakeholder had an important role to play in order to provide good quality and adequate quantity of water to all communities (Figure 4.9).

According to the respondents, the role of the community and that of the government were seen as more crucial in the study. The government scored the highest number of roles as compared to the community, the civil society, the private sector and the academia. Compared to Kinyau and Miumbuni Sub-Locations, respondents from Mitaboni highly recognised the role played by the communities in collaboration with the government to bring water to their communities. The private sector’s dominating role was to provide credit in the form of cash or materials for building the structures; the academia’s role was to educate the public on the importance of building water harvesting and saving structures, while the civil society’s role was to both educate the public and also to provide credit facilities to build more water harvesting and saving structures.
The government was recognised to play a major role in the provision of credit facilities and donations as shown in Figure 4.10. The government can provide both financial and material support in forms of credit or grants to assist the communities in building community small scale water harvesting structures that are urgently required in the study area. Respondents also mentioned the role of creating public awareness on the need to build small scale harvesting structures as another important role. Through education forums and public meetings or ‘barazas’, the government can provide the required support.

The government provides extension officers to mobilise and organise communities for the work. In addition, it can work on policies that enhance the provision of water within the respondent’s reach; and, could enforce the law to minimise sand harvesting and ensure that harvesting is done in a controlled manner. Through the district environmental committees, the communities can be actively involved and learn to understand how EMCA works to protect the environment, and the stipulated steps they can take to do environmental impact assessments. During the allocation of national treasury funds, the government was seen to have the capacity to influence decisions that prioritise the provision of water in the area. Through bilateral grants,
In order to increase the number of water harvesting structures, respondents need support of the government. This statement is confirmed by the China experience in 1988, when the Rain Water Harvesting (RWH) project which was initiated by the Gansu Research Institute for Water Conservancy (GRIWAC) became a success due to the wide participation of the farmers and firm support from the government. Unlike the key water projects owned by the state, most of the RWH systems in Gansu belong to the households themselves. With a little assistance from village technicians, 40,000 farmers from Gansu built their own RWH system by 1994 and 2.2 million storage tanks were built by 2001 (Falkenmark et al., 2001). However, in giving support to the communities, the government should avoid creating a dependency syndrome amongst the respondents. Mitaboni being a drought prone area, community members have looked at the government to provide to all needs. The community should be sensitised to take control of their destiny so that the government can just come in where it is necessary. A partnership should be set up between the government and the other stakeholders to encourage an integrated approach to water management.

The respondents also mentioned the roles of the community to be important. The major role of the community was mentioned as bringing communities to work
together towards the provision of water (Figure 4.11). People from the community need to participate actively so that at the end of the endeavour, the WHT will be a community owned project.

![Figure 4.11: Farmer’s Opinion on the Role of Community Members](image)

The success of community initiative and participation in local projects is confirmed by the recent work of the Poverty Eradication Network (PEN) in Machakos District, an area where the practice of irresponsible and unsustainable sand harvesting has caused environmental destruction and devastated scenery. Through the community’s initiative coupled with the assistance from PEN, four divisional community environmental committees have been formed and the committees are now playing a key activism role in agitating for responsible sand harvesting and conservation of rivers. In some areas, sand harvesting has been banned following these local initiatives (www.penkenya.org/pages/sand_harvesting.vrt).

The other role of the community included provision of labour, both skilled and non-skilled labour. Local artisans could be trained by the government so that the cost of building water structures becomes affordable to community members. This will increase the role of the community to be providers of both skilled and non-skilled personnel. This will create a spirit of community ownership of the project, which will be managed from the community level and with government technical supervision.
The government could partner with the rest of the stakeholders whose aim will be to complement one another. The civil society could play the advocacy role adequately to provide a voice to those communities who have no access to water services. Awareness creation to the public could be done well by the civil society.
CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

The focus of this research was to assess utilisation of existing small scale water harvesting technologies in Mitaboni Location. Findings of the research show that there are various useful small scale water harvesting and saving technologies in the area such as the shallow wells, water weirs, water tanks and water pans; and, the amount of available water was not adequate to last the households up to the next rainfall season, so farmers were found using more than three water harvesting technologies at one time.

The commonly used small scale water harvesting and saving technologies were shallow wells, water weirs, water tanks and water pans due to their affordability and low requirement of specialised skills. Shallow wells showed that 50% of the respondents used them mainly for domestic purposes. Weirs had diverse usage for the 28% of respondents. Water tanks were being used by 28% respondents mainly for domestic purposes due to their high quality. Water pans were mainly used for livestock and gardening by 6% of the respondents.

Farmers cope with shortages of water by purchasing it from small scale water service providers for domestic purposes, and also by trekking for more than 1 hour to fetch water from public dams and rivers. Buying water was a challenge to the community as their income levels were low. Rationing and recycling water was common in the area. The carrying of water on their backs has been a risk to the health of the women and girls who, later in life, suffer from chronic lower back problems. Poor quality of water from the rivers and the public dams pose a health threat to the respondents.

There were other water harvesting and saving technologies which had worked elsewhere and could be used in the study area. In Central China, 1-2-1 water system ensured support to about 1 million people with water in 1995-1996. It could be an effective and inexpensive system that could be used in Mitaboni area. Other potential
water harvesting structures included conservation farming, harvesting water from the road run-off and in-situ methods.

Communities were not investing in small scale water harvesting structures due to the lack of income and appropriate skills. Little practical information which could be applied on the site specific situations was not evident. All stakeholders, including the community members, the government, the academia, the civil society and the private sector, had specific roles to play in contributing towards water security in the area. The respondents came up with probable solutions for each stakeholder to enhance the availability of water.

5.2 Conclusions

This study concluded that although existing technologies are useful, they fall short of satisfying household water requirements to the next rains, which is a period of about three months. There was no single existing storage structure which could sustain one household with adequate water up to the end of the year. Farmers were using more than one water harvesting technology for different purposes at a given time.

Most households cope with persistent water shortages by accessing water from open dams, which are equally far away. Drudgery and health risks due to the poor quality of water remains some of the risks the households must contend with. Women and girl’s health suffered and there is lost productive time looking for water. A few farmers access water by buying it from water vendors, though the buying of water by respondents remained a challenge in an area where poverty levels are relatively high.

There are other potential small scale water harvesting technologies that could increase water availability, and have been found successful within areas with similar water scarcity challenges as Mitaboni Location. These missing technologies include conservation farming, harvesting of water from road runoff, and in-situ methods on site or off site.

Lack of financial capital, unreliable rains, and inadequate skills were the main challenges that reduced farmer’s propensity to maximise benefits from small scale
water harvesting technologies. There is a knowledge gap on the impact of small scale water harvesting technologies caused by unavailability of documentation within the area.

5.3 Recommendations

- There is need to improve utilisation of existing small-scale water harvesting and saving technologies by ensuring that investments in more and closely distanced small scale water harvesting technologies be budgeted for at the county government levels.

- There is need to shorten the distances to the water sources from 5 Km to 1 km in the study area by making capacity development in cost-effective water harvesting technologies a continuous process by local authorities and stakeholders. This will not only increase their quantity in numbers, but also the effectiveness and performance of the water harvesting technologies. A good example could be the Draft sector plan (GOK, 2008a) where Thwake River is one of the earmarked seasonal rivers for dam construction within the study area. The Constituency Development Funds (CDF) could fund the installation of water pipes that bring water from the source to village water kiosks.

- There is need to explore the potential of other existing water harvesting technologies such as conservation farming, harvesting of road runoff, and in-situ methods of collecting water. These missing technologies have been found successful in areas within the country and that have similar water scarcity challenges such as Mitaboni Location.

- There is need to enhance the involvement of stakeholders in resource mobilisation because each stalk holder has a role to play towards water availability. Past experiences show that the community’s involvement in the management of water resources has had positive results in sustenance of existing structures.

- There is need to encourage farmers to diversify their livelihoods to activities that have relatively less water demand like apiculture and small businesses. There is need of reviving institutions such as the Agricultural Finance Corporation (AFC),
which is a government owned non-bank development financial institution, for small scale farmers to access small loans and invest in small scale water harvesting technologies and income generating projects.

- For further research, a study to evaluate the various systems being used in the area and compare their performance with the prevailing local bio-physical conditions could be conducted. The research should further study the potential of other water harvesting and saving technologies that are affordable and easily sustained by the local communities and those that ensure an increase in water use efficiency and conservation.
6. REFERENCES

GOK, 1999a, Environmental Management and Coordination Act. Government
printers, Nairobi.
GOK, 1999b, Sessional paper No.1 National Water Policy of 1999, Ministry of Water
and Irrigation, Nairobi, Kenya.
of Water and Irrigation, Nairobi, Kenya.
GOK, 2007a, Kathiani District Agricultural annual report. Ministry of Agriculture,
Kathiani, Kenya.
press
GOK, 2008b, Kathiani District Agricultural annual report. Ministry of Agriculture,
Kathiani, Kenya.
GOK, 2010, Kathiani District agricultural annual report. of Agriculture, Kathiani,
Kenya.
International Food Policy Research Institute, Annual Report, 2010, Washington DC,
USA.
Khaka, E., Malesu, M., Mati, B., Oduor, A. and M. Nyabenge., 2006, Rainwater
Harvesting Potential in Africa: Spatial Perspectives. Paper presented at the
2nd workshop on agricultural water management in Eastern and Southern
in Laikipia District, Kenya. GHARP case study report. Greater Horn of Africa
Rainwater Partnership (GHARP), Kenya Rainwater Association, Nairobi,
Kenya.
Kimeu, P.M, 2008, Technology Identification for the Community Surface Rainwater
Harvesting option (Kenya). A report by the Lay volunteers International
Association.
www.Ivia.it/keny/LVIA%20report_technology_identification.pdf. (14th
January 2008).
development. Proceedings of the 13th Annual Symposium of the East African
Academy, September 1977.
and their effects on sediment transport and erosion within the Athi Drainage
basin, Kenya. Paper presented at Rabat Symposium S6, April 1997, IAHS.
Publication no. 245
Conservation Organisation meeting at Purdue University.
KNBS, 2009, Population and Housing Census: Counting our people for Development,
Volume 1. Population Distribution by Administration Areas and urban centres.
KNBS, 2010, Population and Housing Census: Counting our people for Development,
Introduction, Nairobi, Paulines Publications, Africa.
Geographical Studies No. 5. Trier, Germany.
Lameck, P., 2002. Evaluation of rainwater harvesting systems in Dodoma District,
Tanzania.GHARP case study report.Greater Horn of Africa Rainwater
Partnership (GHARP), Kenya Rainwater Association, Nairobi, Kenya.
study in Machakos District. Proceedings of the 4th National workshop in
assessment of crusting on tilled sandy clay loam soil. Soil use and
management, 12:72-75.
article.aspx (11th March 2008).
Ministry of Water and Irrigation, 2008, Catchment Management Strategy, Athi River,
WRMA, Machakos, Kenya.


Website: http://www.rainwaterharvesting.org/Rural/Rural/htm. (2nd February 2012)
Website: www.divagis.com. (6th May 18, 2014)
Website: www/english.ahram.org.eg/News/100257/aspx.
Website: www.hackkenya.org. (24th November 2011).
Website:www.kari.org/index.php?q=content. (20th November 2011)
Website:www.penkenya.org/pages/sand_Harvesting.vrt. (24th November 2011)
Website:www.traveljournals.net/explore/Kenya/map/m3105618/Kathiani.html. (2010).
Website:www.unwac.org/new_unwac/pdf/WATSAN_narrative_Pubs/Blue_Drop_Series_02_-_Capacity_Building.pdf. (23rd December 2010).

WEDC, Loughborough, UK.

WHO, 2005, Ecosystem and Human Well-Being: Health Synthesis, a report of the

WHO, 2010, Right to water, Fact Sheet No. 35, United Nations, OHCHR, UN-
HABITAT< WHO.UN publications, Geneva, Switzerland.

WHO/UNICEF, Progress on Sanitation and Drinking water. 2010 update publication
of the World health Organisation. WHO press, Geneva1211, 20 Avenue
Appia, Switzerland.

UNICEF, New York.

and Human Resources Division, Eastern Africa Department, Africa Region.
7. APPENDICES

7.1 Household Questionnaire
An assessment of Water Harvesting & Saving Technologies and their application in Mitaboni Location.

General information

1. Sample No……………………Location of household………………………………………

2. Sex of respondent: Male (…); Female (…) Family position of respondent………………

3. Education level of respondent
a. None ( ), b. Primary ( ); c. Secondary ( ), d. Tertiary ( ) Tick appropriately

4. Total family size…………………………
5. Total arable land (acres/hectares)…………………………

6. Sources of income

<table>
<thead>
<tr>
<th>Source</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1. Salary</td>
<td></td>
</tr>
<tr>
<td>2. wages</td>
<td></td>
</tr>
<tr>
<td>3. Businesses</td>
<td></td>
</tr>
<tr>
<td>4. Family members</td>
<td></td>
</tr>
<tr>
<td>5. Others (Specify)</td>
<td></td>
</tr>
</tbody>
</table>

Where: 4: very high; 3: High; 2: low; 1: very low
7. How would you rate the status of water availability for agricultural and domestic purposes on your farm (Tick appropriately)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Domestic/Agriculture use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very adequate</td>
<td></td>
</tr>
<tr>
<td>Adequate</td>
<td></td>
</tr>
<tr>
<td>Scarce</td>
<td></td>
</tr>
<tr>
<td>Extremely scarce</td>
<td></td>
</tr>
</tbody>
</table>

8. How do you cope with water shortages as a household?
   i. ........................................................................................................
   ii. .........................................................................................................
   iii. .........................................................................................................
   iv. .........................................................................................................

9. In order of importance list the root causes of persistent water shortages in your farm.
   i. ........................................................................................................
   ii. .........................................................................................................
   iii. .........................................................................................................
   iv. .........................................................................................................
10. How would you rate the importance of various water saving technologies you practice

<table>
<thead>
<tr>
<th>Water saving technology</th>
<th>Popularity (Importance rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Where: 5: very high; 4: high; 3: fairly high; 2: low; 1: very low

11. What are your reasons for liking (any 5 popular technologies in 4 above)?

<table>
<thead>
<tr>
<th>Water saving technology</th>
<th>Reasons for high rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td>2</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td>3</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td>4</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td>5</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
</tbody>
</table>
12. What are the reasons that prevent you from investing in water technologies that could improve your water situation?
   i. ...........................................................................................................................
   ii. ...........................................................................................................................
   iii. ...........................................................................................................................
   iv. ...........................................................................................................................

13. In which way do you think the water shortage problem can be solved in your area?
   i. ...........................................................................................................................
   ii. ...........................................................................................................................
   iii. ...........................................................................................................................
   iv. ...........................................................................................................................

14. Which stakeholders do you think can play an important role in helping to address community water problems?

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Main Role(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Government</td>
<td></td>
</tr>
<tr>
<td>2. Community members</td>
<td></td>
</tr>
<tr>
<td>3. Individual farmers</td>
<td></td>
</tr>
<tr>
<td>4. Professionals</td>
<td></td>
</tr>
<tr>
<td>5. Civil society (NGOs/CBOs)</td>
<td></td>
</tr>
<tr>
<td>6. Private sector</td>
<td></td>
</tr>
<tr>
<td>7. Specify others:</td>
<td></td>
</tr>
</tbody>
</table>
7.2 Institutional Questionnaire

Questionnaire designed for the key informants and institutions

1. Sample No………………………Sub Location ………………………………………

2. Name of Organisation………………………………………………………………………………

Root causes of persistent water shortages

Discuss in order of importance the root causes of persistent water shortages in this locality giving the reasons why?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

What do people do in this locality to get water in case the water shortage has persistent for long?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

In what way do you think these causes can be addressed?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
Adoption of small scale water harvesting and saving technologies

What are the common water harvesting and saving technologies in this area?

Why are they preferred than the rest?

How would you rate the importance of various water saving technologies practised in this locality?

<table>
<thead>
<tr>
<th>Water saving technology</th>
<th>Popularity (Importance rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Where: 5: very high; 4: high; 3: fairly high; 2: low; 1: very low

What do you think should be done to improve the adoption rate of the water harvesting structures in this locality?
Factors that hinder investing in small scale water harvesting and saving technologies?

What factors do you think hinder the investment of small scale water harvesting structures in this locality?

What role do you think you can play as an individual or organisation to reduce the factors mentioned above?
7.3 Images of Potential Water Harvesting and Saving Structures in other areas

Plate 3: The sub-surface dyke built across the Vennar in Tiruvarur district, India

Plate 4: Sub-surface dams being constructed, Makueni, Kenya.
Plate 5: Spate Irrigation, Eritrea

Plate 6: Sub-surface Dyke, India

Plate 7: Khadin method with earthen embankment built across the hill slopes

Plate 8: Check Dam
Plate 9: Ramteck Model of Water Harvesting

Plate 10: 1-2-1 Method of Water Harvesting, Ganzu, China.