

**ADAPTIVE ADOPTION OF RAINWATER STORAGE SYSTEMS BY
FARMERS: A CASE OF MAKANYA WARD IN SAME DISTRICT.**

BY

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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
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ABSTRACT

Water is vital for every human community and is essential resource for economic development, agricultural productivity, industrial growth and above all human well-being. Availability of clean, safe and secure water source will always be a major concern for human populations. Access to adequate fresh water is limited, yet crucial for the survival of the inhabitants. Rainwater harvesting and storage appears to be an alternative for supplying water in the face of increasing water scarcity and escalating water demand in Makanya. The main objective of this study was to assess the adaptive adoption of rainwater storage systems by farmers. The study was done in some villages at Makanya ward. The study objectives were: (i) to determine factors influenced adaptive adoption of rainwater storage systems to farmers (ii) to assess adaptive adoption of rainwater storage systems by farmers and (iii) to find out reasons for adaptation of rainwater storage. Sixty seven households were surveyed. Purposive sampling was used to select villages for data collection and simple random sampling was employed in selecting adopters of rainwater storage systems in the study area. The data were coded and analyzed. Data analysis entailed descriptive statistics including frequencies, cross tabulation and chi-square tests. A logit model was used to assess objective of this study. Results revealed that major factors influenced farmers' adaptation were water problems to adopters, education, sex, income and household size. It was revealed again that income, technological awareness and knowledge on technology have significantly influenced the adaptation of rainwater storage systems ($p < 0.05$). This suggests that the water problems and income level of farmers have facilitated the adaptation of rainwater storage system by farmers. Therefore, it recommended that farmers should be given an opportunity

to participate and decide to their needs rather than being required to accept what is not of their interest.

DECLARATION

I, DENIS GERALD MIHAYO, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been or concurrently submitted for a higher degree award in any other University.

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LIST OF ABBREVIATIONS / ACRONYMS

FAO	-	Food and Agriculture Organization
IWMI	-	International Water Management Institute
NIMP	-	National Irrigation Master Plan
PRSP	-	Poverty Reduction Strategy Paper
RWH	-	Rainwater Harvesting
SWC	-	Soil Water Conservation
SWRG	-	Soil Water Management Research Group
SUA	-	Sokoine University of Agriculture
URT	-	United Republic of Tanzania
UN	-	United Nations
UNDP	-	United Nations Development Programme

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Water is a basic natural resource required to sustain life and provide various social needs as well as for economic development. Many parts of the world face a water stress situation. According to UN projection, in 2025 the population on the earth will be 7.8 billion, a 38% increase of the present levels. Water resources, on the other hand, are decreasing at an alarming rate (Molden and Sakthivadivel, 1999). These changes may have strong impact on food requirement and food production. Growing water scarcity threatens food supply of nearly three billion people, as well as the health and productivity of major wetlands and other ecosystems around the world (World Water Forum, 2000).

It is estimated that 40% more food grains would be required to feed the world's growing population (IWMI, 2000). This requirement in increased food production certainly will increase the competition on water demand for agricultural production by other sectors, such as domestic, livestock and industrial sectors. Studies by IWMI predict that by the year 2025, 1.8 billion people will live in countries or regions with absolute water scarcity. This means that they will not have sufficient water resources to maintain their current level of per capita food production from irrigated agriculture. Water may have to be transferred from agriculture to other sectors, making countries or regions increasingly insecure in terms of food. Water is important for food production not only because of its direct effects on yields and cultivated area, but because reliable water supplies induce farmers to invest in other essential crop inputs (Rosegrant *et al.*, 1997). Water resources have a close

relationship to food security. Therefore, food security cannot be separated from other resources security (Tiep, 2002). Increasingly, scarce water resources will pose serious constraint to economic development in Southern Africa (Sally, 2002). Furthermore current crop yields being experienced in semi arid regions that range from 0.5 to 1.0 tons per hectare are a threat to food security to such regions (Rockstrom and Falkenmark, 2000).

There is presently an increase in water scarcity due to increased competition for the same water from non-agricultural sectors and, also from deteriorating standards of usable water due to pollution (Perry, 2001). Water scarcity confounds the sustainability of agriculture, if not managed properly, water adversely affects crop productivity and causes land degradation through runoff and associated soil loss (Wani *et al.*, 2003). The vital role of water in the socio-economic success or failure of human communities is becoming ever clearer. This is particularly true for the arid and semi-arid areas that face severe water scarcity.

1.2 The concept of Rainwater storage system

The concept of rainwater storage system is an important one in taking full advantage of collecting and conserving rainfall in order to maximize rainfall use efficiency (Ping Deng *et al.*, 2004). It is a system that provides farmers to have multi use of water according to their preference of interest. Water stored can be used for supplemental irrigation in agricultural production by the use of drip irrigation technology (Shan *et al.*, 2000). Due to the limited volume of water that can be stored, the technology is usually used to provide the precise amount of water for a particular plant.

Rainwater storage has been introduced so as to increase agricultural productivity and overcome water stress to farmers' in semi arid areas. Rockstrom *et al.* (2002) and Woyesa *et al.* (2005) argued that rainwater for agriculture would remain the dominant source of food production for the foreseeable future in sub-Saharan Africa because the rain-fed agriculture is practiced in approximately 95% of agricultural land, against irrigation.

1.3 The Role of Rainwater Storage System

Based on the 2002 population census, the population of Tanzania is currently 34 million people, and is projected to reach 59.8 million by the year 2025. The increase in population has direct effects on water resources. Turton and Warner (2002) argued that, in a situation where water resources are relatively finite within any given country, doubling of that country's population would cut into half the volume of water available per capita. Against a background of drought and uneven spatial distribution of water within Southern Africa, water stress is likely to hamper economic development and will increase the likelihood of major food access problems and malnutrition in the inevitable drought years (Haddad, 1997). In short, water has an active role in agricultural production, livestock and domestic use hence contributing to the elimination of hunger and reduction of poverty in rural areas (Tiep, 2002).

Water harvesting has been used for many years in different areas in the world (Awwad and Kharabsheh, 2000). In semi-arid areas, rainwater harvesting has gone hand-in-hand with horticultural production (Hatibu *et al.*, 2000). The rainwater storage for horticulture production has been shown to be a very good entry point for the promotion of soil and water conservation practices because in many semi-arid

areas there is a limitation of sources of cash income. If water is used in the production of horticultural cash crops like watermelon, vegetables and fruit trees will provide an even greater economic benefit to the farmer (Ping Deng *et al.*, 2004).

Rainwater storage systems for supplemental irrigation are becoming popular in semi-arid districts of Kenya (Ngigi, 2003). Rainwater storage systems offer the land user a tool for water stress control-dry spell mitigation. They reduce risks of crop failures, but their level of investment is high and requires some know-how especially on water management. In semi-arid parts of Kenya, underground water tanks have been promoted mainly for kitchen gardening. Farm ponds have also been used for watering livestock. Earth dams or water pans constructed to store large quantities of water, especially for livestock and small-scale irrigation at community level. Concrete/mortar lined underground tanks are used for domestic and some livestock in Somaliland (Ngigi, 2003).

Most farmers in semi arid areas have to be encouraged to rely as much as possible on rainwater storage systems, to introduce supplementary irrigation as per the crop needs and rainfall pattern. This seems practical in the semi arid areas, which receives rainfall below 600mm annually (Slaymaker *et al.*, 2002). Relying solely on rainfall for crop growth in semi arid areas does not achieve the best results as witnessed by very little to zero yields currently achieved. Although farmers have adopted the concept of rainwater harvesting, there still remains the problem of low yield due to insufficient water available to crops. This is why improved water storage systems techniques are necessary to improve yields especially in semi arid areas in sub-Saharan Africa (Sharma, 2001).

1.4 Problem Statement and Justification

Due to erratic rainfall in semi arid areas, there is growing competition between water needed for agriculture, livestock and water for domestic use in escalating farmers' societies. Increased competition for water in agricultural and non-agricultural sectors in developing countries will lead to reduced access to water by the farmers. The rising demand for water for non-agricultural uses (livestock and domestic) is proportionally reducing the water availability for crop production. Thus efficient management of rainwater through water harvesting and improved water use technologies helps increase productivity and maintains the natural resources in the semi-arid areas (Wani *et al.*, 2003). Despite the introduction of RWH technologies, the problem of water competition is still prevailing among individual farmers' societies.

Recognizing this fact and in overcoming the competition for water, rainwater storage systems was emphasized with the purpose of storing and conserving rainwater for agricultural production through drip irrigation systems and provide enough water to farmers. However, the implementation of rainwater storage system is faced with problems and challenges on the use of water. There have been different uses of water between farmers since the system has motivated farmers to have multi use of water than before because a large quantity is captured and stored. A number of researches have been conducted on several projects in rainwater harvesting. All the projects are on aspects of irrigation and management of natural resources under rainfed and irrigated agriculture. In the researches that have been done, single cereals and mostly maize and paddy were studied (NIMP, 2002). But the fact is, it is not only these crops that use water; other sectors like domestic, livestock and industry contribute a lot to water resources use.

This study, therefore, looked into the performance in which rainwater storage increases economic status through different use of water by farmers. The study re-examined farmer's adaptation in the use of rainwater storage system in order to understand why and for which purposes farmers have interest in using rainwater storage system. The findings from this study have assisted to assess whether adoption of rainwater storage systems and its subsequent use in domestic and livestock keeping proved to be an effective tool for increasing farmers' income and contributing towards increasing economic status of most farmers.

1.4.1 Objectives

1.4.2 Main Objective

- The main objective of the study is to assess the farmers' adaptive adoption of rainwater storage systems.

1.4.3 Specific Objectives

- To determine factors which influence the adaptation of rainwater storage system to farmers'
- To assess the adoption and adaptation of rainwater storage system for small holder farmers
- To find out the reasons for adoption / adaptation of rainwater harvesting with storage

1.4.4 Hypothesis

This study was guided by the following hypotheses

Hypothesis 1

Farmers' perception in the adoption and adaptation of rainwater storage system technologies is based on socio-economic gains

Hypothesis 2

Socio-economic factors have no influence on the adoption and adaptation of water-harvesting technologies

Hypothesis 3

The adoption and adaptation of rainwater harvesting and storage system have been motivated by key constraints facing farmers.

1.5 Organisation of the thesis

This study is structured into five chapters. **Chapter One** gives a brief overview of the problem this study is pursuing, and what it expects to achieve by the end of its discourse. **Chapter two** is literature review. The chapter highlights the works that have been previously in relation to what has been targeted for this study. It also gives a synopsis of the contribution of previous studies and literature on adoption and adaptation of rainwater storage systems to farmers and a discussion on appropriate estimation models for this study.

Chapter Three of this study provides methodology employed, location of the study area, population and social economic activities of the study area, data collection and sampling procedures. It then explains the hypothesized outcome for each independent variable of this study.

Chapter Four provides results and discussion. The Chapter highlights on the results obtained after data analysis and subsequent discussion. It explains independent variables of the study, descriptive statistics. The Chapter also discusses the findings as presented in various data of this study used (and the empirical methods for this study analysis).

Chapter Five presents conclusion and recommendations from the analysis of the results obtained and the ensuing discussion. It further suggests recommendations aimed at enhancing adoption and adaptation of rainwater storage systems.

1.6 Definition of terms as used in this dissertation

Adoption is defined as decisions to apply an innovation and continue to use it, or is a process as changes that take place within an individual with regard to an innovation from the moment he/she first becomes aware of the innovation to the final decision to use or not to use it (Van den Ban and Hawkins, 1988).

Adaptation is defined as a process of changing the technology to better conform to local environmental conditions or other external stimuli (<http://www.google.com>).

Rainwater harvesting is defined as a process of collecting and concentrating runoff water from a runoff area into a run-on area where the collected water is both directly applied to the cropping area and stored in an on-farm water reservoir for future productive uses such as domestic use, livestock watering, aquaculture irrigation (FAO, 2003).

Supplemental irrigation is defined as the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth, to increase and stabilize yield (Oweis *et al.*, 1999).

“*Ndiva*” is a **Pare** word meaning a large constructed rainwater storage facility used for irrigation purposes communally. “*Manoo*” is a name where *ndiva* is located.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

Water is an important natural resource required for mankind. It supports life and, as civilization grew, the value of water came to be recognized more and more for ensuring food security of the society (Kasambala, 2004; Sharma, 2001). Improved water management is one of the keys for producing enough food (FAO, 1996). Without investment in water, the prospects for improving food production are remote.

Most of the countries in sub-Saharan Africa (SSA) are experiencing profound socio-economic problems, the most dramatic being food crises and disruptive conflicts. Over 60% of the land in SSA falls under semi-arid where a majority of the inhabitants are pastoralists although agro pastoral and farming communities have been slowing settling in these areas due to population pressure in the high agricultural potential areas (Ngigi, 2003).

2.2 Profiles of rainwater resources in Tanzania

2.2.1 Agriculture

Water is one of the main factors that constrain their agricultural output, income and profitability. In Tanzania, 80% of the irrigated area was under traditional irrigation schemes; 20% were under large centrally managed irrigation schemes owned by public and private organizations and individuals during the base year 1995. According to UNDP (1997), about half of the poorest people in the world earn their

livelihood in areas where water constraint agricultural production. Crop production is the main agricultural sector in most countries. In most developing countries, crop production is carried out by smallholder farmers and is generally labor intensive.

Fresh water for agriculture is becoming increasingly scarce. In many Asian countries, per capita availability declined by 40-60% between 1955 and 1990, and is expected to decline further by 15-54% over the next 35 years (Gleick, 1993). The main reasons are diverse and location specific, but include increasing population growth, increasing urban and industrial demand, and decreasing availability because of pollution (chemicals, salts, silts) and resource depletion.

In agriculture, the situation is aggravated by the dramatically increasing demand for irrigation development over the past decades. Because of the combined increasing demand for food with increasing scarcity of water, producers face three major challenges: (1) to save water; (2) to increase productivity and (3) to produce more with less water (Bouman and Tuong, 2001). The decreasing availability of water for agricultural production threatens food security in general and the livelihood of farmers in particular. Also, the increasing scarcity of water means that the costs of its use and resource development are increasing dramatically (Postel, 1997).

2.2.2 Domestic water supply services

Rainwater storage system is used in a variety of both productive and consumptive activities and contributes to rural and urban livelihoods in many different ways. According to the Tanzania poverty reduction strategy (PRSP) (URT, 2000), about 68% of the urban population has access to water, while in rural areas only 48.5% of

the population has access to a safe water source. In the Gansu Province of China for example, the rainwater storage system was promoted to solve the problem of water shortages for agricultural production and domestic use (Xiao, 2003). It was concluded that, reservoirs for rainwater storage solve the problem of drinking water to farmers in the Gansu province of China.

2.2.3 Livestock keeping

Tanzania is rich in livestock resources, with abundance of water sources. Keeping livestock is one of the livelihood strategies of the poor and food insecure and directly affects the livelihood of the poor people. The contribution of water plays an important role in livestock keeping. In semi arid areas, water storage techniques facilitate farmers to keep livestock. It enables farmers to keep them so as to increase economic status.

2.3 Challenges and Opportunities of Water storage

In many areas, there are insufficient surface water or ground water sources to irrigate dry single crops, even in critical periods. The limited water resources are used for domestic supply, livestock and to irrigate private or community farms, which produce horticultural products for domestic needs and generate income through sales (Mugabe *et al.*, 2003).

Surface water resources depend on the runoff generated in the catchments, which in turn depend on the amount and distribution of rainfall in a given season. Typically, about 10% of rainfall is lost as runoff in the semi arid areas of Zimbabwe (Mugabe *et al.*, 2003). This runoff is sufficient to fill the small to medium earth dams on which

rural communities depend on, in most years except the very dry ones when there is no runoff or very little runoff (Mugabe *et al.*, 2003). The sustainable use of the limited water resources is constrained by insufficient knowledge of the resources, in terms of quantity and lack of management. In most cases the resource is not managed, and crisis management is employed at the last moment, when shortages are apparent (Mugabe *et al.*, 2003).

Gould (1999) on contributions relating to rainwater harvesting argues that, the provision of water at the point of consumption from rainwater tanks provides a range of immediate positive impacts on family welfare and domestic productivity. This results when saved water collection is utilized elsewhere. Some of the time saved may be used for productive activities such as agriculture with clearly tangible and easily valued economic benefits. Kihara (2002), from his study “evaluation of Rainwater Harvesting in four countries” (i.e. Ethiopia, Kenya, Tanzania and Uganda) concluded that despite the relatively high investment costs compared to insitu systems, the rainwater harvesting for supplemental irrigation is slowly being adapted with high degree of success.

The greatest challenge of improving rainwater management in the semi arid areas is not so much technical innovations, but rather innovative approaches that facilitate adaptation of well tested techniques (Masuki *et al.*, 2004). Masuki *et al.* (*op cit*) and Rockstrom *et al.* (2001) argue that there are large opportunities to improve farmer’s livelihoods through the adaptive adoption of water system innovations.

In Tanzania, rainwater storage is a crucial factor in the ability of farmers and pastoralists to produce food. Improving water storage systems in rain fed agriculture is one of the options to solve the problem of yield reduction due to low and erratic rainfall (JICA, 2002)

2.4 Farmers perceptions in technology characteristics

Adoption of water management practices is one of the subject areas that have been researched globally. However, as Ervin *et al.* (1982) and Feder *et al.* (1985) note, most of the studies related to adaptive adoption of conservation practices have simply used farm and farmer characteristics without providing the rationale for their inclusion based on theory. Some studies such as Swinton and Quiroz (2003) and Mara *et al.* (2001) have attempted to highlight the economic theory underlying farmer perceptions in decision- making over conservation practices. McConnell (1983) used production theory where a farmer has an objective to maximize profit. Ellison and Fundenberg (1993) employed a version of innovation diffusion whereas studies such as Swinton and Quiroz (2003) and Mara *et al.* (2001) used household model based on utility maximization.

In order to adequately determine factors that influence perception of water conservation technologies to farmers, the focus of the adaptation analysis needs to go beyond the characteristics of farmers and plots of land (CIMMYT, 1993). A farmer should be regarded as both a producer and a consumer (Sadoulet and de Janvry, 1995). This implies that a farmer takes into consideration “current consumption and production ends” (Clay *et al.*, 2002) and also policy and physical effects (CIMMYT, 1993; FAO, 2001). The consumption needs are satisfied through own production

though at times they are met through food purchases. Farmers make purchase using cash from crop sales or off-farm earnings. The need for cash is not only for food but also for other household requirements such as health and education.

A farmer may react in a number of ways towards declining production and/or variability in production that undermine consumption needs. Existing practices may be modified or new ones may altogether be adopted (FAO, 2001). A farmer may here depend on information diffusion from external parties to learn about a new technology (Shaw 1985; Ellison and Fudenberg 1993; Knox *et al.*, 1998; Mara *et al.*, 2001). Before investing in a water conservation practice brought to a farmer's attention, he/she looks at the monetary incentives, whether the capacity is there to implement the practice, and what constraints he/she is facing (Clay *et al.*, 2002). The increased level of the productivity is an important factor influencing the adoption of new technologies. Farmers' perceptions of the technologies impact on productivity played an important role in the adoption of technologies (Gain and Zurek, 2001)

One of the major concerns of a farmer is how long he/she has to wait before getting the benefits of water conservation investment (Field, 2001). Water conservation practices have different wait periods hence the perceived returns may be slower than the immediate impact of inputs (Reardon and Vosti, 1997). Most farmers in developing countries have high preference rates whereby today's consumption of resources is more valuable than the future's consumption (Field, 2001). Farmers are likely to have great preference for conservation practices that yield benefits in the shortest time possible. This desire for short term benefits also implies that water use rights that do not give a sense of permanency may promote conservation practices

that yield benefits in short term (Gebremedhin and Swinton, 2003). More still, farmers tend to be conscious about uncertainties that may arise from both the physical environment and a new technology (Knox *et al.*, 1998). Farmers in such a situation may feel more comfortable to continue with current practices despite noticing a decline in soil productivity. They regard such behavior as risk reduction strategies.

2.5 Relationship between adoption and factors that influence adoption

A number of studies have been carried out on the factors affecting technology adoption. Adoption of technologies is an exogenous scenario that affects production, consumption and marketing decisions (Masuki, 2006). In evaluating the determinants of farmers' decisions to adopt and adapt alley farming technology and its variants in the farming systems of Nigeria, (Adesina and Chianu, 2001) used the Logit model in understanding the factors affecting farmers' to adopt and adapt alley farming technology. The result showed that farmer characterization that influenced adoption is gender of a farmer, contact with extension agents, farmers' education, family size, farmers' age and education. For the adaptation the result showed that human capital variables were significant in explaining farmers' decisions to adapt and modify the technology. Semgalawe and Folmer (2000) studied on "Household adoption behavior of improved Soil Conservation in North Pare and West Usambara Mountain in Tanzania" using logit model in estimating perception of the erosion problems and of adoption of improved conservation measures. The result of their study shows that the participation in promotional activities of soil and water conservation (SWC) programmes influences the adoption decision process at all stages. According to Perret and Stevens (2003) in analyzing the adoption of water conservation

technologies by smallholder farmers in southern Africa, the technological adoption process was influenced by internal and external environments. They named the internal environment as wealth, labour, social and cultural factors and diversity of farmers' strategies and the external environment as information, infrastructure and agricultural and rural development policies.

Senkondo *et al.* (1998) examined on factors affecting the adoption of rainwater harvesting technologies in Western Pare Lowlands of Tanzania. The probit model was used in analyzing the socio-economic factors that influence the adoption of Rainwater Harvesting (RWH) in Western Pare Lowlands of Tanzania. The results of the research revealed that farm size, number of family members working in farm, experience in farming and the extent of knowledge in RWH techniques were significant in explaining the intensity of adoption of rainwater harvesting.

Chomba (2004) studied factors affecting small holder farmers' adoption of soil and water conservation in Zambia. In the study, Chomba used a logit regression model on the analysis of data obtained. The results of the study showed that the human capital and extension services were the main factors in improving the adoption of conservation practices. Gain and Zurek (2001) in the factors influencing technology adoption have highlighted that the cost associated is one of the most important factors influencing technology adoption. The findings by Gain and Zurek (2001) indicate that the implementation of mechanisms that allow farmers to capture some of the benefits that they can not capture new long term or external benefits will increase the rate of adoption and diminish the discrepancy between the current level of adoption and the socially desirable level.

There are other factors that may influence farmers' decision to adopt a particular technology. They are generally associated with economic forces affecting their production decision, performance of technology under local conditions and characteristics of farmers, innovation, environment and infrastructure (Benad, 1998). Farmers' characteristics include education, gender, ethnicity, resources and land tenure, which make additional factors to be receptive to adopt new technologies (CIMMYT, 1993).

2.6 Economics and economic analysis of RWH and storage system

Scarcity is one of the most important in considering the various socioeconomic tradeoffs in allocating water among different users. Allocation decisions determine who will have access to water and what impact this will on society and the economy. According to IWMI (2003), growing economic and physical scarcity of water compounded by rising costs of developing new and further sources to meet the increasing demands for water call for innovative ways of water use and development. Human actions bring about water scarcity in three ways: through population growth, misuse and inequitable access (Stringer, 1997). As population expands and economies grow, the competition for limited supplies will intensify, so will conflicts among water users. Competition for water among agriculture, industry and domestic is already constraining development efforts in many countries (Stringer, 1997).

The rainwater storage technique has played a major role in reducing the water competition and increasing the economic of farmers in the Indian Semi-Arid areas (Whitaker and Shenoi, 1997). The technology has motivated farmers to increase the agricultural production and promote efficient use of water in rain fed agriculture

through the use of irrigation systems. Rainwater harvesting with storage yield numerous social and economic benefits, and contributes to poverty alleviation and sustainable development. It has reduces women's burden of collecting water for domestic use, leaving time for other productive activities. Rainwater storage system gives opportunity for the girl child to attend school and provides a relatively safe and clean source of drinking water, minimizing incidences of water problems within societies.

Economic benefit of storage system depends linearly on the adoption of the innovation developed, as the benefit of the technology will be zero if the adoption of resulting innovations is zero (Batz *et al.*, 2002). Benefits are assumed to increase linearly with the number of adopters. The economics of stored water is determined by counting on the construction costs, operating costs, tank capacity and the purpose use of water in a reservoir. Catchments' area, water storage and irrigation facilities are three basic factors that impact on the cost of rainwater harvesting and supplemental irrigation agriculture (Yuan *et al.*, 2002).

2.6.1 Economic analysis

The net present value and internal rate of return are commonly used in analyzing the economics of rainwater with storage systems and measure the contribution of technology adoption to research performance. The net present value (NPV) and internal rate of return (IRR) are used to measure economic benefits of technologies adopted by adopters within the specified range of time. In addition to that, they are used to determine the adoption decision according to the investment incurred and level of benefits obtained from the technology adoption.

Yuan *et al.* (2002) used net present value (NPV) and internal rate of return (IRR) to compare each scheme of rainwater harvesting and supplemental irrigation. From their study, they concluded that the NPV's and IRR's for the compacted original earth catchments were obviously less than that of concrete catchments. That is concrete catchments have high returns to those adopted the technology. Batz *et al.* (2002) used NPV and IRR in their study "predicting technology adoption to improve research priority setting". They used NPV and IRR to measure the contribution of technology adoption to research performance. In their study, they concluded that innovations that show a higher speed of adoption are more profitable than those with low rates of adoption because the benefits occur faster and ceiling of adoption is achieved earlier.

Senkondo *et al.* (2004) used NPV, IRR and CB ratio in providing an understanding of the profitability of rainwater harvesting for agricultural production in semi arid areas of Tanzania. The results for investment analysis showed that the NPV for maize, paddy and onion were positive, the results implies that the investment in rainwater harvesting for crop production is profitable in the long run as farmers can pay investment and operational costs and yet attain profits (with respect to the investment analysis, all the crops have a favourable measures of project worth). They concluded that the rainwater harvesting should be prioritized in Tanzania, particularly in semi-arid areas, because it has a potential for poverty reduction and minimizing food security problems.

Profitability of technologies is expected to be an overriding factor in farmer's decision-making (Batz *et al.*, 2002). Farmers adopt technologies that give high returns to investment (Shrestha and Gopalakrishnan, 1993). High profitability accelerates speed of adoption and leads to a high ceiling of adaptation. Costs determine technology adoption decisions especially in the case of the resource poor smallholders (Batz *et al.*, 2002). Initial costs can become a limiting factor for adoption as farmers cannot adopt a highly profitable technology if they can not acquire it due to scarcity of capital. This means that when capital is scarce, the relationship between initial costs and profitability may explain adoption behavior better than the single variable would.

In rainwater harvesting handbook, Senkondo *et al.* (2003) looked at economics of bunded basin water shortage in semi-arid areas of Tanzania. They highlighted that RWH enables farmers to switch to high value crops, with very significant improvement of incomes and thus livelihood. With all types of crops studied, their NPV, CB ratio and IRR were positive thus they recommended that due to existing potential and profitability of RWH, RWH be prioritized in Tanzania particular in semi-arid areas.

2.7 The importance of water storage in agricultural production

Different people have different views on the aspect of increasing agricultural production by increasing physical output per unit of water, but the challenge is to grow more food with less water, and improving livelihoods of the poor (Kasambala, 2004). Water can be used as a tool for increasing agricultural production. In order for the increase to take place, there are three major applicable paths: (i) Developing more supplies by increasing storage and diversion facilities like dams, ponds, canals

and reservoirs; (ii) Depleting more of the developed primary water supply for beneficial purposes through water saving practices and (iii) Production of more output per unit of water depleted (Sharma, 2001).

Traditional lowland production in Asia requires much water: it consumes more than 50% of all water used in the region (Lampayanl *et al.*, 2004). Water resources are, however, increasingly getting scarce and expensive. There is a need to develop alternative production systems that require less water and increase water productivity. A number of water-saving technologies have thus been introduced for the purpose of solving water problems and improves agricultural production through irrigation technologies (Lampayanl *op cit*).

Many water storage technologies exist which help to improve water productivity. An example is drip irrigation, especially in areas that suffer from water scarcity. Irrigation technology like drip does indeed reduce the required diversion, but crop consumption remains the same or can even increase (Mutiro, 2005; Perry, 2001). The benefit achieved through high-technology irrigation is an increase in the productivity of water consumed by a crop that is, crop per drop and this benefit can be very large.

In India, for example, there are around 120 000 small-scale tanks irrigating about 4.12 million ha. In many areas (semi arid areas of India), the tank storage structure is the only water source to store rainwater and help farmers through crop growing period and provide stability to agricultural production (Anbumozhi *et al.*, 2001). Whitaker and Shenoi (1997) demonstrated that in India, the use of storage tanks lowers the cost of irrigation. Traditionally, villages have gathered rainwater in storage tanks, with each village having a system that designates how water is to be

divided among users, and who is responsible for the upkeep of the system. For example, drip irrigation is often promoted as a technology that can conserve water, increase crop production and improve crop quality (Skaggs, 2001). In many places where rainfall is insufficient to grow crops, storage tanks have been facilitated to store water for irrigation and overcoming water demands for farmers.

When drip irrigation is compared with surface or sprinkler irrigation technologies, its field application efficiency can be as high as 90%, compared to 60-80% for sprinkler and 50-60% for surface irrigation (Dasberg and Or, 1999). With frequent drip irrigation it is possible to maintain an optimal balance between soil water and control the amount of water required for plant. In China, for example, water consumption is expected to grow in three important sectors, which are agricultural, residential, and livestock keeping. In the agricultural sector, demand for irrigation water, now roughly 400 billion cubic meters per year, is expected to reach 665 billion tons in 2030 (Brown and Halweil, 1998).

2.8 Adaptation of rainwater storage systems

Adaptation is the critical importance for farmer's creativity. Without farmer's own creativity in experimenting, adapting and making a technology their own, the entire innovation / adoption initiative is quite meaningless (IWMI, 2006).

As agriculture remains largely rainfed and as water scarcity issues are receiving much more prominence in Africa, more work on technology development and adoption studies in this area is anticipated (Masuki *et al.*, 2004). The adaptation of drip irrigation technology was examined by Shrestha and Gopalakrishnan (1997) in Hawaii sugar industry. They stated that in Hawaii's sugar industry, the choice of drip was originally motivated by concern for water conservation, and then changed to

desires for yield increases, as growers became more experienced with advanced drip technology. The innovation of the adopted technology managed to increase the production of the industry. It also motivated more farmers to adopt it. Although the innovation of these technologies have been demonstrated to save water and increase water productivity, their adoption by farmers is low because of a lack of extension (Lampayanl *et al.*, 2004). Compared with the heavy investments needed to develop new water resources, the adoption of water-saving technologies by farmers is low-cost and has great potential to save water.

The technology adaptation has the impact on adoption process. It managed and motivates farmers / adapters to have more alternative use than when adopted. The innovation of the technology is done according to the farmers/adapters interest. The interest of the one adopted technology to have more/advanced use of the technology used to inspire someone to adapt the technology.

2.9 Potentiality of RWH with storage systems

In sub-Saharan Africa the potential of rainwater harvesting for improved crop production received great attention in the late 1970's and early 1980's in response to widespread droughts that left a trail of crop failures posing serious threats to human and livestock life (Ngigi, 2003; Mutekwa and Kusangaya, 2006).

The collection of rainwater for agriculture, livestock and domestic use has taken a new direction to most farmers due to different interests among them. Typically, rainwater harvesting for agriculture encompasses three different systems. The first system is referred to as rainwater conserved agriculture. The second system is a runoff agriculture that composes rainwater catchments areas and a command area. The third process is rainwater harvesting and supplemental irrigated agriculture.

The rainwater harvesting with storage has considerable potential as a source of alternative water supply. As a potential solution to the problem of water shortage and to increase land utilization for agricultural production in semi-arid areas of South Africa, the new production and water preservation techniques called rainwater storage that incorporate water conservation has been developed (Baiphethi *et al.*, 2006). In addition the technique has also been shown to increase farmers' income and reduce production risk significantly (Kundhlande *et al.*, 2004). In this system rainwater catchments are used with one or more reservoirs to store water within a command area (Yuan *et al.*, 2002).

The rainwater harvesting with storage has great potential to achieve sustainable agriculture in semi arid regions. The implementation of rainwater harvesting with storage has successfully solved drinking water problems in China and is being adapted to improve crop production and promoted to adjust agricultural structure to increase farmers' income and improve the living environment (Xiao, 2003).

Krishna (2003) highlighted the potential benefit of rainwater harvesting and storage system as: (1) to provide a source of free water-the only cost would be for storage, treatment and use; (2) to provide water to societies when there is no other source; (3) to provide good-quality water and water if tap charges are too high for water supply connection; (4) to provide good quality water for landscape irrigation; (5) to provide safe water for human consumption and (6) to save money for the consumer in utility bills.

Reservoirs for rainwater storage are essential in improving economic status for farmers. They facilitate not only agricultural production within individual farmers by the use of irrigation but also facilitate livestock keeping.

2.10 Empirical methods

2.10.1 Estimation adoption model for rainwater storage technology

To understand adoption behavior logit and probit models are commonly employed as two related multifactorial analytical practices. The two models can take one or two values adopt or don't adopt (CIMMYT, 1993).

The logit analysis coefficients are estimated using maximum likelihood. The interpretation of the coefficients is not as straight forward as in (OLS) ordinary least square regression analysis. The coefficients on their own do not tell much but the coefficients can be used to compute the marginal effects, which are useful in interpreting the effects of predictors on the change of probability. Also the signs of the coefficients can be used to indicate the direction of the change of the predicted probability arising from a change in the predictor.

Marginal effects

The main interest is to know what the effect of a change in a given predictor would be on the outcome. The marginal effect on the probability for an average individual due to small change in variable X_k under a logistic regression is

$$\frac{\delta \Pr(Y_i = 1)}{\delta X_k} = \frac{1}{1 + \exp(X'\beta)} \left(1 - \frac{1}{1 + \exp(X'\beta)} \right) \beta_k$$

The effect of a dummy variable has to be analyzed by comparing the effect of the variable when the value is one to when the value is zero. The difference of the effects on the probabilities between the two values, holding other variables constant, is the incremental effect for a dummy variable. As much as the marginal effect can be computed on an individual case by case, the general practice is to compare the marginal effects at the sample's value (Mukherjee *et al.*, 1998).

2.10.2 Econometric specification for rainwater adoption

In this study, the logit model is employed to allow outcomes and scaling of multiple responses (Greene, 2003). In estimating the adoption of technologies, it was felt that the multiple selections the household faced are inherently ordered (Maco and Orgut, 2003). For this reason count models or any non-ordered model cannot adequately estimate the adoption of many choices as the information conveyed by the ordered nature is ignored resulting in loss of efficiency (Borooah, 2001). The variables used in assessing farmers' adaptive adoption of rainwater storage systems enabled this research to adopt the use of logit model. And since the logit and probit models are most commonly used in adoption and adaptation researches, this study adopted the logit model because it relates with other studies done in adoption and adaptation.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the study area

3.1.1 Location

The study was conducted in Makanya ward, Moshi. Same District, Kilimanjaro region. Makanya is located in same District about 136 km from Moshi along Dar-Arusha road. In obtaining more data related to water storage techniques and irrigation purposes, the Chekeleni village in Korogwe District and Moshi Irrigation Zonal Office were used as case studies in supplementing the information on rainwater storage system and irrigation systems used.

3.1.2 Population and social economic activities

Referring to the 2002 national census, the population of Same District was 212325 out of which male and female was 103520 and 108805 respectively. The economic activities for people in this area include agriculture and livestock keeping (URT, 1999). Out of the total population in Same, Makanya ward has a population of 9146 of which male are 4482 and female are 4664.

3.2 Sampling procedures and Data collection

3.2.1 Sampling procedure and sample size

The sampling frame of the study was the individual households in the study areas. Purposive sampling method was used to select villages for data collection and a simple random sampling was employed in selecting adopters and non adopters of rainwater storage system, water harvesting innovations and irrigation system. The whole procedures made a sample of 67 farmers (households) for the study.

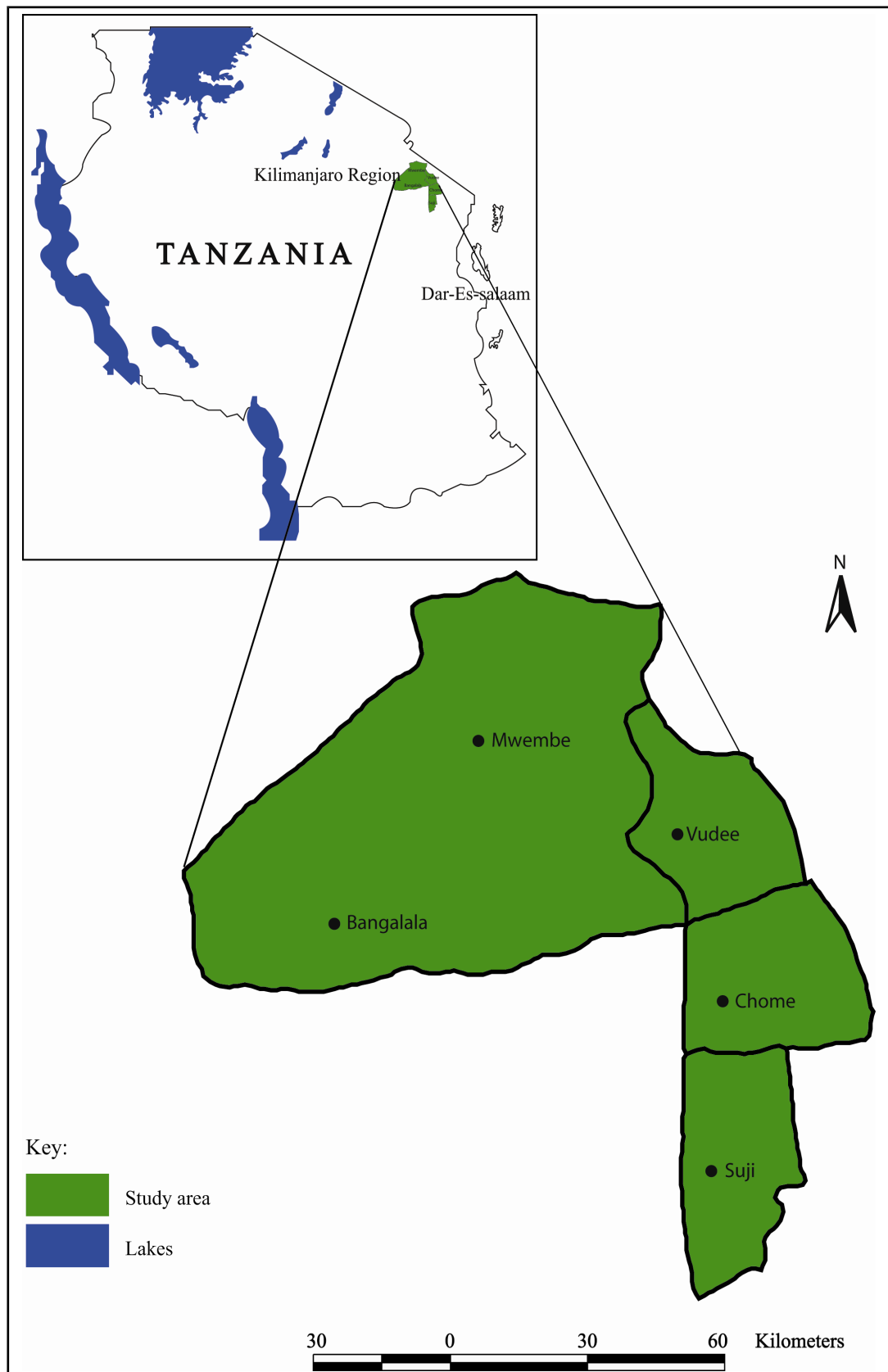


Figure 1: A map of Tanzania showing a study area in Same District – Kilimanjaro

3.2.2 Data collection

The major survey instrument used in the collection of primary information was a structured questionnaire. The questionnaire was designed to collect data intended to address the objectives of the study. In this regard, the questionnaire included questions properly set to collect information required in running all the anticipated statistical and econometric analysis for testing hypothesis. The information obtained in case studies are attached in appendix two.

The Data collection n process was conducted for four weeks from 12 February to 9 March 2007. A researcher assisted by three enumerators did the exercise. Prior to their active involvement in data collection, the enumerators received thorough instructions on how each question included in the survey instrument need to be asked.

3.3 Data analysis

The statistical package for Social Science (SPSS) and a Microsoft excel were used in computing and analyzing the data collected.

3.3.1 Descriptive Analysis and non-parametric tests

Descriptive statistics was used to present characteristics of studied households. It was also employed in the analysis of the characteristics of social capital arrangements used by the respondents in coping with technology adaptation. The descriptive statistics was used to measure objective number one and three of this study i.e. to determine factors influencing the adaptation of rainwater storage system to farmers and the reasons for farmers' adaptation / adoption of rainwater storage. Frequencies, percentage and means were used to display descriptive statistics such as knowledge, awareness and adoption. Cross tabulation and chi-square were used to test

associations between various variables against technology adaptation. Cross tabulation was used because it is both a powerful way of communicating information and the commonest form of data presentation (Casley and Kumar, 1988). In both cases the chi-square and correlation tested the level of statistical significant used was 5%.

3.3.2 Cost Benefit Analysis

The cost benefits analysis (NPV, C:B and IRR) were used to asses farmer's response regarding their preference in using rainwater storage systems. Decision of farmers to adopt rainwater storage system like any other investment decisions on the farm, is driven by profit motive (Lazaro *et al.*, 2000). The costs and benefits were used to compare various investments worth to farmers. Two dynamic economic measures, financial net present value (NPV) and financial internal rate of return (IRR) were used to compare economic of each scheme of rainwater storage system and supplemental irrigation.

3.3.2.1 Net Present Value

The net present value was used to analyse the worth value of rainwater storage system adopted by farmers. NPV was used to assess on how the adopted technologies have returns to the investment incurred, the profitability of the investment has to be measured and recognized in a range of time. Thus in analyzing and obtaining the investment costs of technologies, the NPV was used to assess the value of an investment in the present value of future cash to farmers in a specified range of time and the socio-economic gains to the adopters. NPV considers the time value of money.

3.4 The Logit regression Model

This model was meant for assessing objectives number one (1) of this study i.e. to assess the adaptive adoption of rainwater storage system for small holders' farmers.

(a) The Model

The proposed logit regression model (Table 1) for this study had the logic that the factors influenced the use of rainwater storage system to farmers and households adoption of rainwater storage (expressed as a dichotomous variable basing on household perception as 1= adopt, adapt, 0= otherwise). Specification of logit model for technology adaptation was as follows:

$$\text{ADAPT} = \beta_0 + \beta_1 (\text{WATUSE}) + \beta_2 (\text{AWARE}) + \beta_3 (\text{AVINC}) + \beta_4 (\text{KNOWL}) + \beta_5 (\text{WATPRO}) + \beta_6 (\text{EDUCAT}) + \beta_7 (\text{ACCESS}) + \beta_8 (\text{HHSIZE}) + \varepsilon$$

Where: ADAPT	=	Technology adaptation
WATUSE	=	Main use of water
AWARE	=	Technology awareness
AVINC	=	Average income at household
KNOW	=	Knowledge in technology
WATPRO	=	Water problems within households
EDUCAT	=	Education level
ACCESS	=	Access to clean and safe at household level
GHH	=	Gender of the household head
β_i	=	Parameters to be estimated corresponding to the matrix of explanatory variables x
β_0	=	Intercept
ε	=	Error term (assumed to be randomly and

independently distributed)

Table 1 Measurement of Dependent and Independent Variables

Independent Variables	Description	Measurement
ADAPT	Technology adaptation	Yes/Otherwise:1/0
AGE	Age of household respondents	Years
EDUCAT	Education level of respondents	Years
HHSIZE	Household size	Number
MAT	Marital status of the household head	Single/Married/Widow
GHH	Gender of the household head	Male/Otherwise:1/0
AVINC	Monthly income	‘000 Tshs
FASZ	Farm size	Acres
IRRSYS	Type of irrigation system used by farmers	Drip/Furrow
WATUSE	Main use of water stored	Crop production/Otherwise;1/0
DI	Dummy variable on access to safe and clean water at households.	Yes/Otherwise:1/0
D2	Dummy water problems at household.	Yes/Otherwise:1/0
D3	Dummy variable on the use of irrigation technology	Yes/Otherwise:1/0
D4	Dummy major source of income	Farming/Otherwise;1/0
D5	Dummy variable on knowledge and technology.	Yes/Otherwise;1/0
D6	Dummy variable on technology awareness	Yes/Otherwise;1/0

(b) Hypothesized outcome for independent variables

Coefficient β_0 : In the model represents autonomous odd ratio i.e. the value of odd ratio when all the independent variables are assumed to be equal to zero. It is expected that at the absence of all independent variables, the probability of the household (farmer) adapting rainwater storage system will be higher. The odd ratio will be positive and thus the expected sign of coefficient β_0 is positive.

WATUSE: In the model, the coefficient β_1 attached to WATUSE variable represents marginal change in odd ratio due to a unit change in adaptation. It is expected that as water use increases, the probability of the respondent to adapt rainwater storage system will increase. The odd ratio is expected to be negative thus the expected sign of β_1 will be negative.

AWARE: Coefficient β_2 attached to variable AWARE shows that as farmers' awareness increases the probability of respondent to adopt rainwater storage system will increase (P1). The odd ratio is expected to be positive and thus the expected sign of coefficient β_2 will be positive.

AVINC: In the model, the coefficient β_3 attached to AVINC stands for marginal change in the odd ratio resulting from a unit change in average income. It is assumed that as average income increases the probability of the respondent to adopt rainwater storage system will increase. Thus it is expected that as average income increase the

attribute $P_i/1-P_i$ becomes positive thus the expected sign of coefficient β_3 will be positive.

KNOW: The coefficient β_4 attached to KNOW variables stands a positive change in the odd ratio resulting a unit change in adoption. It is assumed that as technological knowledge increases in farmers the probability of farmers to adopt the given technology will increase. Thus it is expected that as technological knowledge increases the attribute $P_i/1-P_i$ becomes positive thus the expected sign of coefficient will be positive.

ACCESS: The coefficient β_5 attached to ACCESS in the model stands for access of safe and clean water at households. It is assumed that as access to safe and clean water prevails to most farmers the technology adaptation decreases. This is the fact that farmers will not have any other means to adapt the technology rather to carry on as adopted. Thus it is expected that as access to water increase the ratio becomes negative thus the sign for coefficient β_5 will be negative

EDUCAT: The coefficient β_6 attached to EDUCAT variables stands fir education level of the household head. It is assumed that as the level of education increases for most households head, the adoption level for technology increases too. Thus it is expected as the level of education increases the $P_i/1-P_i$ ratio becomes positive and thus the sign of coefficient β_6 becomes positive.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-economic characteristics of farmers

Socio-economics characteristics have important implications on the farming practices. They have important attributes to any society as they reflect its behavior in decision making and its probable expected responses to many stimuli exposed to it. Social-economic characteristics of sampled farmers who were interviewed during the study are summarized in Table 2.

Table 2: Summary of some socio-economic characteristics of sampled farmers in the study area (n=67)

Variable	Frequency	Percent
Sex		
Male	45	67.2
Female	22	32.9
Age of respondent		
0-29	8	11.9
30-59	51	76.1
60+	8	11.9
Number of years in schooling		
1-7	51	76.1
8-12	11	16.4
>12	5	7.4
Marital status		
Married	55	82.1
Single	12	17.9
Main Sources of Income		
Crop farming	48	71.6
Livestock keeping	10	14.9
Employment	6	9.0
Business	3	5.5
Other Sources of income		
Livestock keeping	26	36.8
Business	6	3.0
Crop farming	4	6.0
None	31	46.2

4.1.1 Sex of respondents

The results summarized in Table 2 show the respondents who were interviewed during the study. The majority (67.2%) of sampled farmers interviewed were males while female formed only 32.8%. From Table 3, 49.2% of male adopted the technology and 16.4% of the female indicated that they did not adopt the technology. Despite the percentages of male and female for technology adoption, from Table 4: 39.3% and 36.3% of females and males respectively have advanced from the adoption to adaptation rainwater storage system at their household. Former *et al.* (1999) reported the dominance of males in their study on household adoption behavior of improved water conservation in Togo. Male dominance in technologies adoption is an indication of the potential of their fighting against poverty and their will to increase their economic situation within their households.

4.1.2 Age of respondents

Table 3 reveals that most of the sampled farmers, who adopt rainwater storage system, fall in the economically active age group of between 30 to 59 years. This category constituted about 49.2%. Data for technology adaptation in Table 4 shows that 36.3% of the same age group i.e. 30-59 has adapted rainwater storage system. This implies that, adoption and adaptation of technologies have absorbed a large number of economically active populations.

Table 3: Summary of Technology Adoption (%)

Variable	Frequency	Percent
Sex		
Male	31	46.2
Female	10	14.9
Marital status		
Married	35	52.2
Single	5	7.3
Water use		
Domestic	29	43.2
Livestock/Irrigation	12	17.9
Storage facility		
Constructed tank	23	34.3
Charcoal dam	13	19.4
Ndiva	5	7.4
Ownership		
Communal	7	10.4
Individual	34	50.7
Years in schooling		
1-7	31	46.2
8-12	7	10.4
>12	3	4.4
Age		
0-29	2	2.9
30-59	33	49.2
60+	6	8.9

4.1.3 Education of respondents

Results in Table 3 show that the majority of the sampled farmers that have adopted rainwater storage systems have attended school between 1-7 years (46.2%) this implies that basic education is important for the technology adoption .In Table 4, the results shows that people of the same level of education (1-7 years) who adopted the

rainwater storage system have adapted the technology too. This implies that the basic knowledge to farmers is necessary for technological adoption and adaptation.

Table 4: Factors of Technology Adaptation

Variable	Adapters	%	Non adapters	%Non-
	N=17 Number	Adapters Percent	N=27 Numbers	Adapters Percent
Sex				
Male	13	39.3	20	460.6
Female	4	36.3	7	63.6
Marital status				
Married	13	33.3	24	63.6
Single	4	62.5	3	37.5
Education				
1-7	13	41.9	18	58.0
8-12	3	33.3	6	66.6
>12	1	25.0	3	75.0
Age				
<29	2	25	6	75
30-59	12	36.3	21	63.6
60+	3		0	100.0
Income				
0-100,000	4	33.3	8	66.6
100,000-200,000	8	40.0	12	60
>200,000	5	41.6	7	58.3
Main Source of income				
Crop farming/Livestock keeping	12	44.4	15	55.5
Employment/Business	5	29.4	12	70.3

4.1.4 Marital status

In this study respondents were also requested to state their marital status. Results in Table 2 show that 82.1% of respondents were married and 17.9% of the respondents were single. In Table 3, the results in adoption of rainwater storage system show that 52.2% of married respondents adopted the technology, 11.9% of single people were able to adopt. Data from Table 4 shows that 33.3% out of 52.2% of married people have adapted the system and 62.5% of singles' have adapted too. From the adopted

sample the percentage of married respondents is large than that of single respondents due to the fact that, marriage increases household size and therefore married respondents venture into other helpful technologies as a way of finding means of reliving financial problems facing their families and thus adapting new technologies.

4.1.5 Source of Income

Data in Table 2 shows that (71.6%) of respondents depend on crop farming as their main source of income. Agriculture dominates the source of income from all the respondents. This shows that most of the people in the areas where data were collected rely on agriculture and livestock keeping as their means of economic gain. In Table 4 data reveals that 44.4% of the respondents who depend on livestock keeping as their source of income now adapted the system. This is due to the fact that people who rely much on agriculture / livestock keeping have much use of water than those who have other means for their economic gains. In addition to that, people with high income (greater than 200,000), equals to 41.6% have managed to adapt the technology than people of low income. The high income at households has the influence in technological adaptation.

4.1.6 Rainwater Storage facility

The study reveals that, difference storage facilities have been adopted for the purpose of storing water. In Table 3, data show that out of 67 respondents only 23 (34.3%) have adopted the concrete / mortar-line tanks (constructed tanks). Only 13 respondents (19.4%) have adopted charcoal dam storage facility for rainwater and 5 respondents (7.4%) use “*ndiva ya manoo*” for water storage. It has been observed that the adopted rainwater storage facilities are used for storing water for different

purposes. The respondents who have constructed concrete /mortar lined tanks use water for domestic purposes and few for animal keeping and for gardening. Charcoal dams are used for livestock and few for domestic purpose. While the “*ndiva ya manoo*” is used for irrigation purposes by most farmers but few farmers are using it for watering animals and domestic purposes.

4.1.7 Factors Influencing adaptation of rainwater storage system

The study also looked at the factors influencing adoption of rainwater storage system to farmers. Table 5 shows that (38.6%) of respondents have adapted rainwater storage system because of overcoming water problems facing their households. The findings show that out of 65.6% of the sampled farmers who adopted rainwater storage system, 31.8% indicated that they adapted the technology to overcome / solve water problems at their households and 6.8% of respondent’s report that they adapted to diversify the use of water in which they can store through irrigation purposes. These results suggest that most of farmers have decided to adapt the technology for the purpose of solving water problems in their household. Not only that but also the animal keeping was another factor that motivated farmers to adapt the technology.

Table 5. Factors influencing the adaptation of rainwater storage system

Influenced adoption	Adapters	% adapters
Water problems at hh / Livestock keeping	14	31.8
Irrigation purpose	3	6.8

4.1.8 Benefits from technology adaptation

The study indicates that out of the motivation from the technology adaptation benefits obtained are shown in Table 6. About 57.1% of respondents who have

adapted the technology indicated to use water for domestic purposes in their families. 42.8% have revealed to have good relationship with their neighbors (social capital). This is because farmers who have adapted rainwater storage systems do provide water to their neighbors who have not adopted for different reasons (*“nashukuru kupata hii teknolojia sababu inanipa mahusiano mazuri na majirani ambao hawana, huwa nawapa maji wakati wanashida”*). Farmers said that out of the intended rainwater storage system, they have managed to get water for household uses.

Table 6. Benefits obtained by farmers in using rainwater storage systems

Benefits	Frequency	Percent
Good relationship with other people (Social capital)	6	42.8
Water availability for use	8	57.1
Construct new house	3	21.4

4.1.9 Irrigation technology

In the study and as shown in Table 7 it was observed that 88% of respondents have agreed to use furrow irrigation system for crop production. Most farmers (46.3%) said that they use furrow technology because the technology is cheap and easily adopted by most farmers. The investment cost of irrigation (drip irrigation) technology has been found to be a major constraint for farmers to adopt it. Farmers indicated that drip irrigation technology needs the owner to have money in rehabilitating the system and the initial cost is also high for most of them to afford this kind of technology. Although few farmers who use drip technology said that “the technology is good because it uses water efficiently at a particular point”, they agreed to lack knowledge in rehabilitating drip irrigation once it collapses. Out of all the farmers interviewed, 76.1% agreed that irrigation technology adopted has

increased the production while 23.9% indicated that irrigation did not increase production in their farms.

Table 7: Type of irrigation used and reasons for adopting

Variable	Frequency	Percent
Irrigation technology		
Drip system	8	11.9
Furrow system	59	88.1
Reasons		
Easily adopted	31	46.3
Cultivating in downstream of mountains	27	40.3
Efficient in water use	9	13.4

4.2 Results of the binary logit model

The estimated estimation equation shows that explanatory power of estimated factors is satisfactory. The (R^2) meaning that 62.1% of the variation is dependant variable is explained by the influenced factors. Empirical results of the model used are summarized in Table 8 below. Mc Fadden value is 0.515 as shown from the table below; other statistics indicates that the logit model fits well. The Chi-square statistic shows that the model is significant at 5% confidence interval. Likewise, using 50% as the cut-off probability for technology adaptation, the model correctly predicted 82.1% of respondents being able to adopt the technology. Furthermore, four out of seven variables included in the empirical model are significant at 5% level of significance. The variables whose coefficients were statistically insignificance are the main use of water at the household (WATUSE), technology awareness (AWARE) and education level (EDL). The results in Table 8 also suggest that the average income within household (AVINCOM), Knowledge in technology

(KNOW), water problems within households (WATPRO) and access to safe and clean water at households (ACCESS).

Table 8: Parameter estimates of logit model

Variables	Coeff	Std. Error	Sign	Marg. Prob
Main water use at household (WATUSE)	-0.902	0.914	0.323	0.405
Technology awareness (AWARE)	0.422	0.825	0.609	1.52
Average income at hh (AVINCOM)	0.833	0.356	0.019**	2.30
Knowledge on technology (KNOW)	3.515	1.177	0.003**	1.01
Water problems at hh (WATERPRO)	-3.596	1.440	0.012**	0.02
Education level of hh head (EDL)	-0.681	0.702	0.332	0.50
Access to safe and clean water at hh (ACCESS)	2.085	0.887	0.019**	0.12
Number of observations	67			
Adjusted (R2)	0.621			
Cut value	0.5			
% correctly variables	82.1			
% of predictions failure	17.9			

Monthly average income of household has positive influence on the adoption of rainwater storage system and is statistically significant ($p \leq 0.05$ Table 8). The positive sign of the parameter estimated for monthly average incomes shows that the probability of farmers on adaptation of rainwater storage system decreases with average income. This implies that the higher the average the income(s) he becomes intense in adapting technologies to avoid getting water problems. The positive sign of the parameter implies that the monthly average income within households has an

influence on technology adoption and hence its adaptation. Farmers with high average incomes have managed to adapt rainwater storage system and thus solve water problems within their households.

The logit model regression result in Table 8 shows a negative correlation of the variable (water problem at households) with the adaptation of rainwater storage system and is statistically significant ($P \leq 0.05$). This implies that the family with seriously water problems were not able to adopt water storage systems by themselves due to the fact that they are poor and do not have other means for that.

Number of years spends in schooling (education level) was one of the variables examined in this study. Results in Table 8 show that the parameter has negative influence on adaptive adoption of rainwater storage system as it was expected ($P \leq 0.05$). The expectation was that farmers with a substantial level of education will show positive response to technology adoption. The significance of parameter to level of education of the farmer can be attributed to the fact that farmers interviewed had a reasonable level of education, which enabled them to analyze the water situation among their households. The farmer's level of education in technology adoption and adaptation has relation to knowledge about the technology to be adopted.

The parameter estimates for water situation among household was positive and significant at ($P \leq 0.05$). The parameter shows that water situation within households has positive correlation within the adaptation of rainwater storage system. The

significant of the parameter attached to water situation of the farmers can be attributed to the fact that most of farmers interviewed had realized to have water problems within their households. Farmers used to spend most of their time finding for clean water; the adoption of rainwater storage system has reduced time spent and distance by the farmers in search for water. Yet the problem of water situation at households persist to most households, thus those with average income have managed to adapt the technology for the purpose of solving the problem.

4.3 Results of Investment Analysis

Table 9: Results of investment analysis

	NPV (10%)(Tshs)	NPV (90%) (Tshs)	IRR (%)
Constructed tanks	380 247	73 290	52
Charcoal dam	104 343	9827	41

Microsoft excel was used to analyse the investment analysis of constructed tank and charcoal dam for rainwater storage. From Table 9, the NPV for constructed tanks is greater than the NPV for charcoal dams. The data shows that the constructed tanks are more advantageous for the farmers to adapt. Data from Table 9 above indicates that the internal rate of return (IRR) for constructed tanks is higher (52%) than that of charcoal dams 41%. Water stored from the constructed tanks has more use compared to the water from charcoal dams. Water from constructed tanks can be used for

domestic, livestock keeping and gardening. Water from charcoal dams can mainly be used for livestock keeping and some for domestic purposes.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

According to the results obtained from data analysis household size, age of respondents, education level and material status (socio-economic characteristics) show to have close relationship with technology adoption. Furthermore, logit regression showed that adoption has close relationship with technology awareness, knowledge of the technology, water problems at household, level of education for respondents and the level of income

The first specific objective of this study was to determine factors influenced adoption of rainwater storage to farmers. This objective was attained by answering research questions used in questionnaires. The results obtained showed that household's size, education, age of the household and the level of income had influence on the technology adoption. In addition to that, a cross tabulation revealed the adoption to have been influenced by many variables which are economic and social in nature. Economically, adoption of rainwater storage system is associated with the level of income among individuals. Socially, adoption is influenced by households' size, education level and knowledge on the technology. It is hereby concluded that there are strong relationship between household socio-economic characteristic and technological adoption. From the hypothesis one, it was hypothesized that socio factors have no influence on the adoption and adoption of water harvesting technologies. But from the data, it is concluded that the socio factors have influence on the technology adaptation and adoption.

The second objective was to assess the adaptive adoption of rainwater storage system by the farmers. Results of logit regression revealed that knowledge, awareness, water problems at households and income are the factors contributing to the adoption of rainwater storage system by some farmers. These results are supported by the chi-square test, which shows that they are significant at 5% level. The adoption is due to an integrated approach, which not only includes domestic consumption and agriculture, but also takes demand for water from other sectors. The second objective was hypothesized that farmers' perception in the adoption and adoption of rainwater storage system technologies is based on economic gains. As concluded from above, the adoption of rainwater storage system by farmers was due to an integrated approach including domestic, agriculture and other sector. Thus, the second hypothesis showed the economic gain by farmers is one that motivates farmers to adapt the technology for their need

The third objective was to find out the reasons for adoption/adoption of rainwater harvesting with storage system. The results show that water problems for domestic use at the household were the major reason for the adoption of rainwater storage system to farmers. This is due to the fact that the point for people to fetch water is far away from their homes and the price per bucket was not affordable by most farmers. Livestock keeping was another factor for farmers to adapt the technology since most of livestock keepers tend to fight for water for their animals. The reasons are the major motivating factors for someone to decide. Different reasons among farmers were the factors motivated them to adapt the technology according to their needs.

5.2 Recommendations

Based on the key findings, the study has highlighted some important points, which are worth noting with respect to the adoption and adoption of rainwater storage system and enhance its contribution towards household water use. The study makes the following recommendations:

- i. Since farmers' perception in the adoption and adaptation of rainwater storage system technologies is based on socio-economic gains and since the adoption of rainwater storage system has been influenced by factors such as household size, level of income among households, education level, main source of income and farm size. Then for farmers to attain and overcoming their problems at a particular situation, knowledge should be given on the ways of constructing large storage tanks that suits their family demand for a season. This will make the technology intention not to be turned apart and meet the technology recommendation desired.
- ii. Since the adoption of rainwater storage systems by small holders farmers was due to agriculture production, the assessment for adoption have shown the incremental number of diversifications, thus beneficiaries should be given an opportunity to participate and decide their needs rather than being required to accept what is not for their interest. The beneficiaries' participation can make the desired project intended to meet the demand and need of the people at the particular place.
- iii. As the adoption and adaptation of rainwater harvesting and storage system has been motivated by key constraints facing farmers, and since the reasons

for adoption of rainwater storage system have known as lack of enough to access clean and safe water at households, households size, number of livestock kept at households, overcoming long walking distance for collecting water. The project should be replicated in other areas with similar characteristics, as one of the approaches towards poverty reduction and providing access to clean and safe water.

- iv. Since the adoption of rainwater storage system results in a multi-use of water, the effective usage of the system should be maximized through information and education. Raising technology awareness, it's important and the necessities of water quality through education and information, the farmers will be aware of the important of water for the technology introduced around their environment.
- v. As long as it rains, local population will harvest rainwater, hence it would be better to promote and educate instead of neglecting this water source in order to enable use of RWH and storage system. This will enable and motivate to overcome water problems within societies by using locally available materials at their local places. The construction of water storage facilities should be enhanced in areas where access to clean and safe water is a problem to majority of people.
- vi. Other stakeholders to water sector should see that as a challenge in overcoming water problems to societies. They should have come up with another technology that will solve/overcome water problems to societies.

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APPENDICES

Appendix 1: Samples of questionnaires used for data collection

Date of interview.....

Name of respondent.....Village.....

A; HOUSEHOLD CHARACTERISTICS

1. Sex of respondents.....[1} Male [2} Female

2. Age of respondents (years).....

3. For how long have you been schooling?.....years

[1}Others.....(mention)

4. Marital status of respondents.....

{1} Single

{2} Married

{3} Divorced

{4} Widow/Widower

{5} Others..... (mention)

5. Household Composition

Category	Number
Children<14 years	
Youth 15-17 years	
Adult males 18 years and above	
Adult Females 18 years and above	
Total HH members	

6. What is your main occupation?.....

7. What is the average income of the household per months?.....

8. Do you own livestock? [1] Yes [2] No

9. Do you own land? [1]Yes [2] No

10. If yes in above give the number of plots you are owning.....

B: WATER USE AND ACCESSORIES.

11.How do you get water for household use

12. Explain where do you collect water for the family use and the duration you take to the water point.

Water sources	Distance (hrs)	For what purpose

13. Have you adopted the RWH with storage system? [1] Yes [2] No

14. If yes, how much investment have you incurred in the construction of storage facility?.....

15. Do you have knowledge on rainwater storage system? [1] Yes [2] No

16. Which type of storage facility do you have?

[1] Constructed tank [2] Charcoal dam [3] Ndiva {4} Constructed tank and charcoal

17. What is the capacity of your storage facility?.....

18. For how long the water storage has been in operation.....

19. What is your main use of water stored in the storage facility/

[1] Crop production [2] Livestock keeping [3] Domestic use {4} Other
specify

20. What motivated you to use water as mentioned above?.....

.....

21. What can you say about the cleanliness of the water

.....

22. How much do you use and cost incurred

Water Sources	Amount you use (Its)/day	Cost

23. Do you pay water use in your household [1} Yes (2) No

24. If yes, how much do you pay for 20 litres container?.....

25. What can you say concerning water charges you are paying.....

.....

26. What problems are you facing regarding water for home use.....

.....

27. How would you describe the water situation in your household

{1} Very bad {2} Bad {3} Satisfactory {4} Good {5} Excellent

28. What benefits have you obtained in using rainwater storage systems?.....

.....

29. Are there any constraints in using rainwaer storage system? {1} Yes {2} No

30. If yes, which are they?.....

31. What influenced you to adapt the rainwater storage system?

{1} Water problems at hh {2} irrigation purposes {3} Livestock keeping

32. What economic factors have made you to adapt the use of rainwater storage system?.....

33. How do you rate the performance of rainwater storage system in livestock keeping domestic use and crop production?

Livestock keepig	Domestic use	Crop productionm

34. Do you use irrigation technology for crop production ? {1} Yes {2} No

35. If yes above, which irrigation technology do you use to irrigate your products?

{1} Drip technology {2} Furrow Technology

36. Why have you decided to use the technology mentioned above?.....

D: COMMUNITY RELATIONSHIP

37. How do you explain your relationship with neighbors the planning for the establishment of water storage in your area?.....

38. Explain how your neighbors benefited from your adoption in water storage system?.....

39. Explain how you have participated in project activities.....

40. What influence you to participate in project activities.....

.....

41. Are you currently participating in project activities {1} Yes {2} No

42. If yes, explain how.....

.....

43. If no, what make you not to participate.....

.....

44. Explain your participation to the water related meetings.....

.....

F: IMPACT OF WATER STORAGE TECHNOLOGY

45. Explain the impacts attributed by the water scheme to your household in relation to the following

No	Item	Impact
1	Social	
2	Economic	
3	Health	
4	Others.....	

46. What are you comments for achieving sustainability of water and sanitation services under community management in your area.....

THANK YOU FOR YOUR COOPERATION.....

Appendix 2: Summary of the case studies

As the demand for water continues to increase, people are beginning to feel the effects of reduced water availability and challenges of balancing needs for agriculture and other uses. As stipulated in the method for data collection (section 3.1.1), the research was conducted in eight villages in Mankanya ward - Same District. In obtaining more data related to water storage techniques and irrigation

practices, the Chekeleni village in Korogwe District and Moshi Irrigation Zonal Office were used as case studies in supplementing the information on rainwater storage systems used.

1. Chekeleni

Chekeleni Village is located in Mombo in Korogwe District. It is one of the villages in which most people depend on agriculture and livestock keeping as their economic activities. Some farmers at the village have adopted the rainwater storage system for the purpose of increasing agricultural production. It is the place whereby farmers have initiated themselves to adopt rainwater storage for agriculture production during critical periods. Most of the adopters at Chekeleni use the technology for horticultural production.

The adoption of rainwater storage system has enabled some farmers to adapt from the original purpose of adoption. Some have decided to use the storage system as their source for income generation by selling to other people in need. For the agricultural investment, the village is more advantageous due to the fact that water sources are available to overcome water shortages during the dry seasons. The adoption of drip irrigation has enabled farmers to use water efficiently per plant thus making good use of water resource.

2. Moshi Irrigation Zonal Office (MIZO)

This is the place whereby most farmers practice drip irrigation. At this place farmers are monitored by the office for horticultural production and technological

maintenance when damaged. The adoption of rainwater storage system has been motivated for horticultural production. Farmers who are under (MIZO) have access to technological advices and are motivated to grow their products to increase their economic situation. The adoption of rain water storage system and the use of drip irrigation system have enabled farmers to produce more products. MIZO is the place where experts are available thus making the use of rainwater storage and drop irrigation simple and affordable by the farmers.

Appendix 3: Different types of water storage techniques



